Biological and Water Quality Study of the Cuyahoga River

Geauga, Portage, Summit and Cuyahoga Counties, Ohio

Volume 1

August 19, 1994

Ohio EPA Technical Report EAS/1992-12-11

prepared by

State of Ohio Environmental Protection Agency
Division of Surface Water
Ecological Assessment Section
1685 Westbelt Drive
Columbus, Ohio 43228-3809
and
Nonpoint Source Management Section
P.O. Box 163669
1800 WaterMark Drive
Columbus, Ohio 43216-3669
and
Surface Water Section
Northeast District Office
2110 East Aurora Road
Twinsburg, Ohio 44087

TABLE OF CONTENTS

APPENDIX TABLES are located in a separate volume:

Appendices to
Biological and Water Quality Study of
the Cuyahoga River
Geauga, Portage, Summit and Cuyahoga Counties, Ohio
Volume 2
August 19, 1994

Volume 2 is available upon request. (see NOTICE TO USERS, page i for mailing information)

NOTICE TO USERS

Ohio EPA adopted 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, and for the Invertebrate Community Index (ICI), which is based on macroinvertebrates. Criteria for each index are specified for each of Ohio's five ecoregions, and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the chemical and whole effluent toxicity evaluation methods, figure prominently in the assessment of Ohio’s surface water resources.

Several documents support the adoption of the biological criteria by outlining the rationale for using biological information, the specific methods by which the biocriteria were derived and calculated, the field methods by which sampling must be conducted, and the process for evaluating results. These documents are:

Ohio Environmental Protection Agency. 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 & Assessment, 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. Division of Water Quality Monitoring & Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989a. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

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

Ohio Environmental Protection Agency. 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.

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

These documents and this document can be obtained by writing to:

State of Ohio Environmental Protection Agency
Division of Surface Water
Ecological Assessment Section
1685 Westbelt Drive
Columbus, Ohio 43228-3809

ACKNOWLEDGEMENTS

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

Color Plates - Randall Sanders, Dave Stroud, Bob Wysenski (Plate 4, Top Right; Copyright Charles E.Allen. Plate 4, Bottom Right, Bottom Left, Copyright 1989, George Leavens)
Study Area Description - Larry Antosh
Pollutant Loadings - Steve Tuckerman, Ken Frase, Bob Davic (all NEDO)
Pollutant Spills - Jack Freda, Charles Staudt
Ambient Chemical Water and Sediment Quality - Steve Tuckerman, Ken Frase, Bob Davic, David Stroud (all NEDO), John Estenik
Fish Tissue - Steve Tuckerman, John Estenik
Biological Assessment:
Macroinvertebrate Community - Jack Freda, Bob Davic
Fish Community - Randall Sanders, Bob Davic
Data Management - Dennis Mishne, Charles Staudt and Ed Rankin
TSD Coordinator - Jack Freda
Reviewers - Jeff DeShon, Marc Smith, Chris Yoder, and Bob Wysenski

This evaluation and report would not have been possible without the assistance of the study team and numerous full and part time staff in the field and the chemistry analyses provided by the Ohio EPA Division of Environmental Services. The Water Quality Modeling section is also acknowledged for chemical data supplied from throughout the basin and extensive chemical and continuous D.O. data for the lower reaches of the mainstem and navigation channel (in conjunction with NEDO staff) from 1990 and 1991. Dr. Susan Cormier of the United States Environmental Protection Agency is acknowledged for her assistance and analysis of biomarker sampling results. Donna Myers of the United States Geological Survey is acknowledged for her assistance in supplying and evaluating bacteriological sampling data. George Leavens and Charles E. Allen are acknowledged for the use of historical photographic slides of the Cuyahoga River navigation channel. Also, numerous landowners and entities adjacent to the study area are acknowledged for their cooperation in granting Ohio EPA personnel access through their properties.

COLOR PLATES

Biological and Water Quality Survey of the Cuyahoga River and Selected Tributaries (Geauga, Portage, Summit and Cuyahoga Counties, Ohio)

State of Ohio Environmental Protection Agency
Division of Surface Water
P.O. Box 163669
1800 WaterMark Drive
Columbus, Ohio 43216-3669

INTRODUCTION

The 1991 Cuyahoga River mainstem study area extended from upstream of Tare Creek, in Geauga county, to its confluence with Lake Erie (RM 89.5 - 0.0). Biological and water quality sampling was also conducted in selected Cuyahoga River tributaries including; Tare Creek, Fish Creek, Little Cuyahoga River, Furnace Run, Yellow Creek, North Fork Yellow Creek, Brandywine Creek, the Tinkers Creek subbasin (mainstem, Pond Brook, Beaver Meadow Run, Hawthorne Creek), Mill Creek, Big Creek, Morgan Run (water quality sampling only), the old section of river channel near the mouth (water quality and sediment sampling only), and Breakneck Creek and Kingsbury Run (sediment sampling only).

Specific objectives of this monitoring effort were:

1) assess chemical/physical water quality, biological communities, fish tissue, and habitat quality in the study area to determine the magnitude and extent of impacts from point and nonpoint sources of pollution and habitat alteration,

2) evaluate potential impacts associated with major municipal wastewater treatment plants (WWTPs) and industrial discharges within the study area in support of the water quality based effluent limitations (WQBEL) report process,

3) evaluate impacts associated with combined sewer overflows (CSOs), sanitary sewer overflows (SSOs), and urban runoff in the Akron and Cleveland metropolitan areas,

4) assess aquatic life use attainment potential in the study area including the Cuyahoga River navigation channel,

5) determine attainment status of existing and recommended designated uses (aquatic life, recreation, water supply, etc.), and

6) examine trends in chemical water quality and biological condition through time for portions of the Cuyahoga River mainstem, Tinkers Creek, and the Little Cuyahoga River where sufficient historical data is available.

Historical surveys conducted by the Ohio EPA in the Cuyahoga River basin included a basin-wide chemical and biological survey in 1984 (mainstem RM 64.5-0.8 and selected major tributaries), mainstem biological surveys in 1985 (RM 42.6-0.8; fish only), 1986 (RM 43.8-15.6), 1987 (RM

42.8-0.8; chemical and biological) and 1988 (RM 64.5-0.8), and a chemical and biological survey of the Little Cuyahoga River subbasin in 1986. Extensive bacteriological sampling was conducted in 1989-90 between Akron and Cleveland (together with the United States Geological Survey [USGS], City of Akron, Northeast Ohio Regional Sewer District [NEORSD] and National Park Service personnel from the Cuyahoga Valley National Recreation Area [CVNRA]), and by USGS in 1991-93 under peak flow conditions. Fish tissue collections were made in 1989-1992 in the mainstem and outer harbor for the Cuyahoga River Remedial Action Plan (RAP) and biomarker sampling was conducted in the Akron area in 1991 with the United States Environmental Protection Agency (USEPA). Extensive chemical and continuous D.O. monitoring for modeling of the lower mainstem and navigation channel was conducted by the Ohio EPA in 1990-91. In addition, biological and/or water quality data has been collected monthly from the Cuyahoga River National Ambient Water Quality Monitoring Network (NAWQMN) stations at Independence (RM 15.6/14.2), Lower Harvard Ave and West Third Avenue over the past 15 to 21 years.

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

SUMMARY

A biological and water quality study was conducted in the Cuyahoga River basin in 1991 to: 1) determine existing biological, physical habitat and chemical water quality; 2) evaluate impacts from major point source discharges (*i.e.*, Akron WWTP, CSOs, and SSOs; NEORSD Southerly WWTP, CSOs, and SSOs; LTV Steel; eight additional municipal and industrial discharges) and nonpoint sources (*i.e.*, urban runoff, spills, hydromodification, etc.); 3) determine appropriate aquatic life use designations; and, 4) perform trend assessments (*i.e.*, compare 1991 results to earlier data). Standardized methods were used to collect biological, chemical and physical data from the 90-mile segment of the Cuyahoga River mainstem, the Little Cuyahoga River mainstem, Tinkers Creek, and 11 additional tributaries.

Cuyahoga River Mainstem

A summary of aquatic life use attainment status for all biological sampling locations in the 1991 Cuyahoga River mainstem can be found in Table 1. Determination of aquatic life use attainment status is described in the methods section and follows procedures outlined in Ohio EPA (1987b).

Aquatic Life Use Attainment

The 1991 results showed 23.9 percent of the river miles were in FULL attainment of the WWH aquatic life use designation, 20.7 percent miles were in PARTIAL attainment, and 55.4 percent (49.6 miles) were in **NON** attainment (including the undesignated 5.6 mile navigation channel). The distribution of aquatic life use attainment status along with predominant causes and sources in the mainstem is described as follows:

- Biological assemblages were in FULL attainment of WWH biocriteria at the five sites between Hiram Rapids and Kent (RM 75.8 - 54.4). Within this 21.4 mile segment, the highest quality biological assemblages in the study area were found in an approximately ten-mile segment upstream from Lake Rockwell. FULL attainment was attributed to a predominantly rural watershed that resulted in good water quality, diverse physical habitat and minimal point source impacts.

- PARTIAL attainment occurred at two locations downstream from the East Branch and LaDue Reservoirs (RM 89.5 and 80.4) and at two locations downstream from Kent and upstream from Akron at RMs 49.8 and 44.0 (some Akron SSOs were located between RM 49.8 and 44.0). In the upper mainstem, the primary causes of the PARTIAL attainment were low dissolved oxygen, habitat modification, flow alteration, and wetland habitat conditions. The principal sources included bottom releases from City of Akron reservoirs, historical channelization, and natural features. Downstream from Kent, the major negative influences on the mainstem appeared to be the cumulative influences of nutrient enrichment, habitat modification, flow alteration, and thermal impacts. Primary sources included the Fishcreek and Kent WWTPs, instream impoundments, controlled reservoir releases, increased urbanization, and the Ohio Edison-Gorge electric generating station (the Ohio Edison Plant closed in the Fall of 1991).

- **NON** attainment occurred at one site in the upper mainstem downstream from Tare Creek (RM 87.3/87.2) and at all 16 sites in an approximately 43-mile stretch between Akron and Lake Erie (Station RMs 42.8-1.2). **NON** attainment in the upper mainstem resulted from the previously mentioned reservoir releases, wetland habitat influences, and historic habitat modification. Potential point source impacts from the Middlefield area were difficult to distinguish from the pervasive wetland influences and associated low dissolved oxygen levels in lower Tare Creek. Unrestricted livestock access in the upper sections of Tare Creek was also a potential source of impact.

- In the Akron area, initial declines into **NON** attainment were observed downstream from the 36 CSOs and 8 SSOs that discharge to the Cuyahoga, Little Cuyahoga River, Ohio Canal and several small tributaries in Akron. Community performance dropped slightly below biocriteria attainment levels immediately upstream from the Little Cuyahoga River (RM 42.8/42.6). The site was downstream from four Akron CSOs, including two identified as dry weather problem CSOs, and a leaking sanitary sewer in Cuyahoga Falls. More severe **NON** attainment was observed downstream from the Little Cuyahoga River (fish communities in the fair to poor range at RM 38.6) and downstream from the Akron WWTP (fish and macroinvertebrates in the poor to fair ranges at RM 37.2).

- Biological communities in the Akron WWTP mixing zone were in the fair range, but *did not* reflect acutely toxic conditions nor were they substantially different in composition from those found *upstream* from the discharge. This is a distinct change from the responses observed in previous surveys (particularly in 1984-1986) which were decidedly toxic and different from collections observed upstream from the WWTP.

- Between Akron and the NEORSD Southerly WWTP, fish and macroinvertebrate communities gradually improved with increased distance downstream, but the fish remained in the fair to poor ranges. Episodic discharges from CSOs and SSOs associated with the Akron sewer system and continued loading from the Akron WWTP were considered major sources of impact within this segment. Bacteriological surveys in 1989 and 1990 showed fecal coliform levels frequently exceeded the Primary Contact Recreation criterion between Akron and Cleveland following significant rainfall events. The CSO and SSO discharges in Akron were considered the major contributors to the bacterial contamination. In addition, more recent sampling by the United States Geological Survey in 1992 and 1993 showed that storm related secondary process bypasses from the Akron WWTP (discharged after primary treatment and chlorination) can be significant contributors of bacterial contamination. Current treatment processes at Akron are inadequate to properly handle these bypasses. Urban nonpoint source runoff, loading from adjacent watersheds, and numerous pollutant spills reported from the Akron and Cleveland metropolitan areas may have also contributed to **NON** attainment within this stretch.

- This Akron to Cleveland section of the river has shown significant improvement, particularly since 1984. While recovery in fish communities frequently lags behind the macroinvertebrates and some additional improvements might be expected, the 1991 results still reflected the presence of continued chronic water quality impacts. In contrast to previous surveys, biological response signatures at many sites showed a shift in response from the predominantly toxic impacts of the past to more conventional, organic enrichment impact types.

- Blood enzyme analyses (*i.e.*, biomarkers) conducted on white suckers in the Akron area showed increased detoxification activity and probable exposure to high levels of polynuclear aromatic hydrocarbons (PAHs) or halogenated hydrocarbons. These levels were particularly high in the Little Cuyahoga River and generally elevated in the Cuyahoga River downstream from the Akron CSOs and the Kent-Cuyahoga Falls-Akron metropolitan areas. Indicators of contamination in blood plasma and liver samples generally declined downstream from the Akron WWTP.

- Additional declines in biological index values were observed downstream from the NEORSD Southerly WWTP. The mixing zone sampling reflected avoidance and possible toxic responses, perhaps related to effluent chlorination. After the 1991 survey, the WWTP added de-chlorination facilities that may result in improved conditions downstream.

- In the navigation channel, biological index scores declined to the poor and very poor ranges and were significantly below the interim Lake Erie estuary biocriteria. Dissolved oxygen concentrations routinely fell below WWH and LRW criteria during the survey and QHEI scores averaged 33.3, reflecting the severely modified habitat conditions that exist throughout the dredged channel. The combined influences of the permanent and extensive channel modification, CSOs, SSOs, low dissolved oxygen, permitted discharges, and urban nonpoint source contributions result in a 5.5 mile segment of the river that is essentially incapable of supporting a viable, warmwater estuarine community.

- An analysis of historical sediment PAH data from the Cuyahoga basin, Black River and Mahoning River was used to rate PAH induced fish tumorigenic potential in the Cuyahoga River. While results varied considerably from site to site and were dependent on data availability, a number of locations with High tumorigenic potential were identified in the middle and lower sections of the mainstem, (Munroe Falls to the mouth) and in the Little Cuyahoga River in Akron. Ship channel locations were consistently ranked as High. While these ratings should not be construed as showing direct cause and effect, they are an indication of increasing contaminant levels in the river as it flows through the Akron and Cleveland areas. These sections generally coincide with observed declines in biological performance, particularly in fish communities.

- There has been a significant trend of improvement in chemical water quality conditions in the navigation channel over the past four decades, but not for dissolved oxygen. Biological communities have also exhibited some improvement since the initial Ohio EPA biological survey in 1984. However, the resident communities continue to be predominated by relatively small populations of pollution tolerant taxa. Unlike the free-flowing sections of the Cuyahoga River and the more natural Lake Erie estuaries in Ohio, the biological potential of the navigation channel is strongly limited by the permanently modified habitat conditions and periodic low levels of dissolved oxygen. For these reasons, any aquatic life use designation proposed for the navigation channel should reflect the restricted aquatic community potential. Following intensive chemical sampling from 1989 through 1991, an extensive dissolved oxygen modeling analysis of the navigation channel was conducted. These results and a use attainability analysis for the navigation channel are presented in a separate Ohio EPA document (Ohio EPA, 1993)

- Unpermitted pollutant discharges from spills, wild animal kills and NPDES permit violations from point source discharges are potential sources of impact in the Cuyahoga basin. A review of spill information throughout the basin and permit violations from eight of the major municipal WWTPs in the middle Cuyahoga River and Tinkers Creek showed a total of 4,108 incidents from 1980 to 1991. This resulted in an average of 342 incidents per year or nearly one occurrence in the basin per day. Approximately eighty one percent of reported spills and animal kills occurred in the middle and lower sections of the basin (Summit and Cuyahoga counties).

  Over the past decade, WWTP permit violations have shown a declining trend and the most severe pollutant spills generally occurred during earlier reporting periods. However, the review of permit violations did not include any industrial discharges or all municipal discharges, both existing and historical. Therefore, the rate of incidents is considered conservative. The results do suggest a pattern of almost continual environmental insults within the basin that could potentially impact biological and water quality conditions. During 1991, impairment or declines in biological communities most often coincided with areas of increased spill and permit violation incidents.

- The steep sloped, heavily wooded valleys of the Cuyahoga Valley National Recreation Area (CVNRA) between Akron and Cleveland have been identified by two studies as significant contributors of nonpoint source (NPS) sediment runoff to the mainstem (Cuyahoga RAP Stage 1 Report (Draft) 1991; U.S. Army Corps of Engineers, 1981). However, sedimentation was not considered a primary source of biological *impairment* in this study. The severity of mainstem biological impacts (*i.e.*, fish communities in the poor range, high anomalies) coupled with the good to excellent physical habitat quality between Akron and Cleveland, and a lack of observed NPS impacts in adjacent tributaries (*e.g.*, Furnace Run, Yellow Creek) were indications that sedimentation was not a major limiting factor. Based on a statewide analysis of fluvial sediment (Antilla and Tobin 1978) these levels of NPS sediment are a natural consequence of the surficial geology and soils of the area. The good to excellent habitat quality in the mainstem allow these sediment loads to essentially be “assimilated” without the detrimental impacts (*e.g.*, increased substrate embeddedness, siltation, excessive turbidity) usually associated with NPS sediment

Cuyahoga River Mainstem

Cuyahoga River: Impact Types Matrix

Biological community performance in the Cuyahoga River mainstem was evaluated further by examining specific responses of key components of the community data and comparing these with response and stressor indicators. Community performance generally declines as the mainstem flows downstream through Portage, Summit and Cuyahoga counties. A narrative matrix (Figure 1) was constructed summarizing selected environmental stressors (*i.e.,* spills, CSOs/SSOs, and concentrations of urban/industrial land use), exposures (*i.e.,* sediment and fish tissue contamination levels, toxicity), and response indicators (*i.e.,* fish and macroinvertebrate indices, habitat quality). Designated aquatic life use attainment status was also included as part of the matrix. The Cuyahoga River mainstem and the lower sections of the Little Cuyahoga River and Tinkers Creek were evaluated by segment in an upstream to downstream direction. The shaded matrix boxes reflect increasingly poorer biological community performance, lower habitat quality, increases in exposure response indicators (*e.g.,* toxicity, fish tissue contamination), and/or an increase in stressors The shading darkens as the departure from reference widens. While some ratings were necessarily general or based on relative comparisons, they show that observed reductions in response indicators coincide with increased exposure and the increasing presence of external stressors from both point and nonpoint sources.

The greatest declines in the biological community metrics were noted in segments within and downstream from the Little Cuyahoga River; these conditions generally extended downstream into the Cleveland area. The most heavily impacted segments not only contained some biological index scores in the poor or very poor ranges, but also had greater amounts of *reported* spills, CSO and SSO locations, and more concentrated urban/industrial land usage. These segments were also unique for the presence of measured toxicity, either during the 1991 survey or within the past decade. The lowest quality conditions (*i.e.,* the darkest shaded boxes) were found within the navigation channel. While not included in the matrix, it should be noted that the presence of major WWTP discharges and increased volumes of point source effluents along the mainstem also follow a similar increasing pattern from upstream to downstream. Some WWTPs also had, until recently, an extensive history of permit violations and plant bypasses. Except for the extreme upper and lower mainstem, there was no correlation between habitat quality and significant declines in biological community performance.

Cuyahoga River Mainstem

Chemical/Physical Water Quality

A summary of exceedences of water quality criteria listed in the Ohio Water Quality Standards (WQS) in the study area appears in Table 8. Summarized results for each sampling location in the study area appear in Appendix A, Tables 1 and 2.

Water quality and flow conditions in the upper Cuyahoga River were influenced by low stream gradients, extensive wetlands in the Burton area and lower Tare Creek (confluence RM 88.55), and releases from several water supply reservoirs. These factors resulted in D.O. violations at three sites between RM 89.41 and 71.7. Slight increases in phosphorus, suspended and dissolved solids, and ammonia were also observed in this segment. Significant D.O. violations were also noted in the wetland section of lower Tare Creek at RM 1.6. High levels of fecal coliform bacteria were also found at the site and was attributed to runoff from livestock operations and/or the large resident populations of waterfowl. Point source discharges from Middlefield Swiss Cheese (Hans Rothenbuhler & Sons Inc.) and the Middlefield WWTP flow through the wetlands and enter lower Tare Creek downstream from the RM 1.6 site (Middlefield Swiss Cheese) and the Cuyahoga River at RM 88.0 (Middlefield WWTP). Data from the survey was insufficient to separate the effects of these point source discharges from the background water quality conditions in this area.

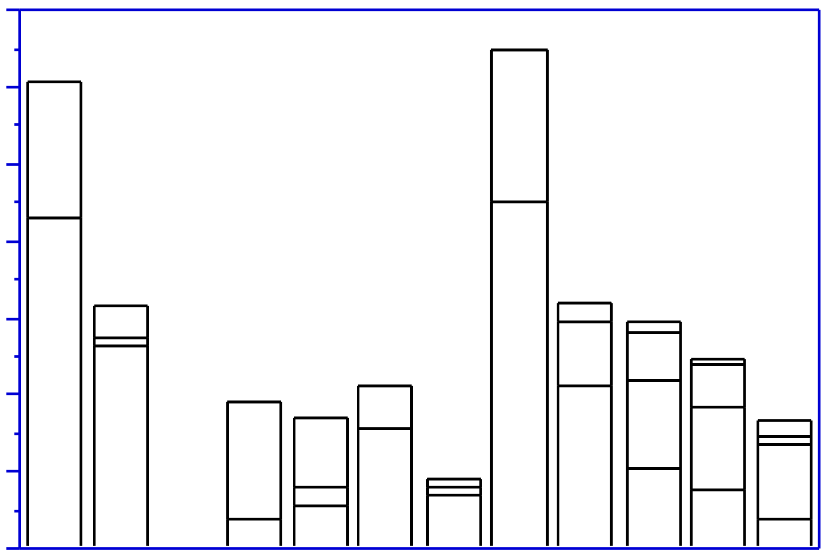


Figure 1. DUMMY PLOT
DUMMY PAGE. INSERT IMPACT MATRIX

Except for the extreme upper portion of the mainstem and the extreme lower reaches in the navigation channel, few water quality exceedences were detected in the mainstem during 1991 sampling. The near lack of chemical water quality criteria violations during critical low flow conditions were a significant departure from past conditions. Historically, low stream flows would represent a worst case water quality scenario in this effluent dominated river. Because of improved point source treatment, high flows have now emerged as the periods of highest impact to water quality. Chemical sampling results obtained during the very dry summer of 1991 did not fully assess the high flow impacts of urban stormwater runoff, CSOs and SSOs, or possible WWTP bypass events on chemical water quality.

Bacteriological sampling of the Cuyahoga River conducted between 1989 and 1993 documented a strong correlation between elevated fecal coliform counts and rainfall events in the Akron and Cleveland areas. The middle and lower portion of the mainstem now routinely meets WWH and primary contact recreation (PCR) criteria during dry weather periods.

Low dissolved oxygen concentrations continue to be problematic in the navigation channel. The channel morphology (deepened to allow for commercial ship traffic) and resultant slow time of travel, is the primary factor effecting D.O. During periods of high stream flow, the chronic dissolved oxygen standard is often met but during low stream flow, concentrations can reach zero. Violations of the acute D.O. standard occur frequently during low flows and have been observed as late as December and January during particularly dry periods. Numerous elevations of total cyanide and occasional exceedences of WWH chronic criteria for copper, iron, lead, zinc and ammonia-N occurred in the navigation channel during 1991. Increases in cyanide, heavy metals, nutrients and turbidity were tied to both point and nonpoint sources including the LTV Steel complex, Zaclon Corp., CSOs, WWTPs and urban runoff in the Cleveland area, and nonpoint sources from upstream watersheds. Visible oil sheens, while not sampled chemically, are not nearly as common in the navigation channel as in previous decades.

Cuyahoga River Mainstem

Biological Community Conditions

Mainstem biological community performance ranged from excellent to very poor during the 1991 survey. Declines in biological communities coincided primarily with presence of increasingly larger municipal point source discharges, an increasing frequency of CSO and SSO discharges, increased urbanization through the Akron and Cleveland metropolitan areas, and an area of extensive channel modification in the navigation channel. Outside of the navigation channel, most industrial discharges have been reduced or eliminated over the past 1-2 decades. However, residual impacts from these sources (e.g., fish tissue contamination, contaminated runoff) may continue to impede the current recovery trends.

Throughout most of the mainstem from Akron to Cleveland, the macroinvertebrate and fish communities responded differently. Most ICI scores attained or marginally attained the WWH criteria while fish communities were in the fair (MIwb) and **poor** (IBI) performance ranges, resulting in **NON** attainment of the WWH aquatic life use. The 1991 results show a continuation of the gradual improvements in community performance and a lessening of impacts since 1984-86, when all three biological indices reflected acutely toxic responses downstream from the Akron WWTP. Indications of continued low-level acute impacts were still evident as late as 1988, which may partly explain the relatively slow pattern of biological recovery during the past decade. In contrast to previous surveys, 1991 results suggested a gradual shift to more conventional, organic enrichment type impacts between Akron and Cleveland. Extensive bacteriological sampling in this section shows that storm related discharges from CSOs, SSOs and secondary bypasses from the Akron WWTP can be significant sources of inadequately treated wastewater to the river. These discharges are most likely related to the impaired but improving biological performance.

Except for the navigation channel, the area of the most severe **NON** attainment (due primarily to the fish community) was found between the NEORSD Southerly WWTP and the Newburg and South Shore (N&SS) railroad bridge (RM 10.5-5.8). The mixing zone results suggested an avoidance response characterized by sharp declines in community densities, MIwb and ICI scores, coupled with increases in toxic tolerant taxa. Community response signatures indicated some form of toxicity within the mixing zone. Fish communities remained impaired throughout this stretch, but macroinvertebrates attained the WWH ICI criterion 0.2 miles downstream from the WWTP and continued to improve gradually with increased distance. Following the 1991 Ohio EPA survey, chlorine was considered a potential cause of the observed impairment. Abdominal gill damage in caddisflies downstream from the WWTP was similar to that described for chlorine impacted streams by Simpson and Bode (1980). De-chlorination facilities were added at NEORSD Southerly in late 1991, after the Ohio EPA field work had been completed.

Overall, the most significant negative influences on biological communities in the free-flowing portions of the mainstem were found downstream from the Little Cuyahoga River (which includes urban runoff, and CSO/SSO discharges in Akron), the Akron WWTP, and the NEORSD Southerly WWTP. Fish community performance initially declined into the poor range downstream from the Little Cuyahoga River and remained in the poor or fair-poor range downstream to the ship channel. At the NEORSD Southerly WWTP mixing zone, both fish and macroinvertebrates reflected some type of avoidance or toxic response. Chlorination was considered a potential source of toxicity associated with the NEORSD Southerly discharge. Also, bioassay testing by NEORSD pointed to yet unidentified compounds associated with chronic toxicity in the receiving stream.

In the navigation channel, biological index scores declined to the poor and very poor ranges and were significantly below interim Lake Erie estuary biocriteria. Both communities were predominated by tolerant varieties and affected by the combined influences of permanent and extensive channel modification, CSOs, SSOs, low dissolved oxygen, permitted discharges, and urban nonpoint source contributions.

Cuyahoga River Mainstem

Historical Trends

The Cuyahoga River has had a very colorful history. For generations it was used as an open sewer. In Cleveland during the 1800s oil refineries and steel mills lined its banks. The effects of increased urbanization and industrialization in the Akron and Cleveland metropolitan areas could be seen in the degraded water quality. Oil and debris continually accumulated along the banks and have caught fire more than once. Water quality studies conducted in the late 1960s described the river "covered with brown oily film" and "large quantities of black heavy oil floating in slicks, sometimes several inches thick[1]. Debris and trash were frequently caught up in these slicks forming an unsightly floating mess. Anaerobic respiration was common as dissolved oxygen

---

[1] Information for much of this section was taken from The Cuyahoga Watershed symposium proceedings, Kent State University, November 1, 1968

concentrations were routinely less than one mg/l and frequently zero. The discharge of artificially heated cooling water increased the water temperature by 10 to 15 degrees (°F). Since stream velocity was negligible in the lower reaches (including the navigation channel) sludge accumulation was rapid and extensive. Except for the most tolerant forms, aquatic life was nonexistent. Only the blue-green algae, *Oscillatoria sp.* grew on submerged structures *above* the water line. The color changed from grey-brown to rusty brown as the river proceeded downstream through Cleveland. This reach (downstream from Lower Harvard Avenue to Center Street) was grossly polluted. In 1968, no fish were collected at 20 sampling stations between Akron and Cleveland[1]. In 1969, oil soaked debris floating in the river caught fire. This incident is widely considered one of the major events that catalyzed the creation of the Environmental Protection Agency in 1970 and the Federal Water Pollution Control Act in 1972.

Since then, significant positive changes in aquatic community composition and response patterns have occurred downstream from Akron. Substantial improvements occurred after 1984 with additional improvements documented between 1988 and 1991. From 1984 to 1988, the Area of Degradation Value (ADV[2]) per river mile between Akron and Independence (RM 42.8-15.6) improved (*i.e.,* the ADV was reduced) 36% for the IBI and 94% for the ICI. Additional incremental improvements were noted between 1988 and 1991 when the ADV/mile exhibited additional declines of 7% and 55%, respectively. The improved community performance correlates well with recent treatment process upgrades at the Akron WWTP, reductions in bypassed loadings, the virtual elimination of acute toxicity (based on bioassay testing) in the Akron WWTP effluent in 1986 (USEPA 1987), and a gradual reduction in heavy metals since the mid-1980s following institution of more stringent pretreatment measures. However, the continued biological impairment observed in the middle mainstem, (including fish index values in the poor range) shows the presence of continued water quality impacts and the need for further reductions in pollutant loadings.

In contrast to the free-flowing portions of the mainstem, ADV statistics from the navigation channel suggest only incremental improvements since 1984. The fish community improved between 1984 and 1987 to the extent that the navigation channel was almost devoid of fish in 1984. There has been little change in the biological index scores since 1987 and the overall biological performance has remained in the poor and very poor ranges. The comparative lack of recovery is particularly noticeable against the more substantial improvements in ADV scores observed upstream. Some additional, although incremental, improvement in biological performance and chemical water quality conditions can be expected in the navigation channel following additional reductions in pollutant loadings (*i.e.,* scheduled closure of the last LTV coking oven, CSO and SSO remediation). However, the highly modified channel morphology and concurrent low D.O. levels are considered the ultimate limiting factors that will preclude full attainment of WWH biological criteria.

Historical trends in community composition between Akron and Cleveland were also evaluated using the Biological Response Signatures developed by Yoder and Rankin (1994). They examined the various biological index metrics and other aggregations of the community data from areas

---

2 The Area of Degradation Value (ADV) is a numerical value calculated for each biological index (IBI, MIwb and ICI) which quantifies the area that each index falls below the applicable biological criterion (see Methods Section). Decreases in ADV scores are an indication of improving biological community performance.

where the predominant impairment causes and sources were well known throughout Ohio. The study was developed from a database of more than twelve hundred samples collected by the Ohio EPA from more than 70 different streams and rivers between 1981 and 1992. The analysis revealed some unique and consistent patterns in the responses of the biological communities that could aid in distinguishing one type of impact from another (*e.g.*, a complex toxic impact linked to multiple industrial and/or municipal sources compared to a conventional organic enrichment impact or the effects of channelization).

For the Cuyahoga River mainstem, the number of sensitive fish species (consists of species designated as highly intolerant and moderately intolerant after Ohio EPA 1987b) was plotted for 1984, 1988 and 1991 (Figure 2). The percentages of tolerant macroinvertebrate taxa were similarly plotted (Figure 3). Besides illustrating significant positive changes in the biological communities over time, the results also suggest changes in the predominant impact types and differences in the rates of recovery between the fish and macroinvertebrates.

For the analysis of sensitive species, the 25th and 75th percentile ranges of four of the more prevalent impact types present in the Cuyahoga Basin study area (Complex Toxic, CSO Toxic, CSO Conventional and Municipal Conventional) are included to illustrate how these have changed through time as well. The severity of biological degradation generally lessens from complex toxic impacted areas to the more conventional enrichment impact types. The Biological Response Signatures revealed a good separation between the very low number of sensitive species associated with complex toxic impacts and the increasingly higher number of sensitive species associated with non-toxic (*i.e.*, conventional) impacts from most CSOs and some municipal WWTP discharges. In 1984, sensitive species were virtually absent downstream from the Akron WWTP and did not exceed values most frequently associated with complex toxic impacts within or downstream from the Little Cuyahoga River. In 1988 the number of sensitive species remained within the ranges typically associated with complex toxic impacts. The values had increased only slightly despite the disappearance of acute toxicity in the Akron WWTP 001 effluent in 1986 (Mount 1987), continued reductions in loadings and bypasses, and other point source upgrades in the Akron to Cleveland corridor. By 1991, sensitive species increased sharply at many locations between Akron and the NEORSD Southerly WWTP and were within the ranges associated with the more conventional CSO and municipal WWTP impact types. Sensitive species were still absent from the NEORSD Southerly mixing zone in 1991 and remained depressed downstream; chlorine was considered the culprit toxicant.

Biological Response Signatures for the percentage of highly tolerant macroinvetebrate taxa, while exhibiting more overlaps between impact types than sensitive fish species, were useful in distinguishing complex toxic impacts from more conventional effects. Median values for each impact type are included in Figure 3. The trend in the macroinvertebrates from 1984 to 1991 contrasted with the response of the fish community by showing more substantial improvements in community performance. The largest changes in the macroinvertebrates occurred between 1984 and 1988 with some additional improvement in the 1991. In 1984, nearly all stations downstream from the Akron WWTP yielded percentages of tolerant taxa above median levels for the complex toxic and CSO/toxic impact types. In 1988, the percentages were well below the complex toxic median and approached the ranges of the conventional CSO and municipal conventional impact types. Elevated percentages were found near the Little Cuyahoga River and Akron WWTP and immediately downstream from Big Creek (CSO and urban impacted) in Cleveland. By 1991, almost all tolerant macroinvertebrate taxa percentages from the Cuyahoga River were within the conventional impact type ranges. Increases in the percentages of tolerant taxa were noted in the

NEORSD Southerly mixing zone, downstream from Big Creek, and continued to be found at high levels in the Little Cuyahoga River near the mouth.

The use of Biological Response Signatures illustrates longitudinal and temporal shifts in both the type of impacts and severity of impacts affecting biological communities in the middle Cuyahoga River. Point source pollution control efforts and other cultural changes in the basin over the past several decades have resulted in a gradual improvement in water resource quality. A shift from a predominantly complex toxic response to a more conventional, organic enrichment response is occurring. By limiting the trend analysis to an examination of biological index scores (*e.g.*, IBI, MIwb, or ICI) the reasons for the trends are not as evident. The 1991 middle Cuyahoga River results suggest a transitional stage in biological recovery from a predominantly complex toxic impact type to one predominated by conventional types. Also, as frequently observed elsewhere, the macro-invertebrates (and chemical) results indicate a more rapid rate of recovery than for fish. However, the recovery process has not been uniformly distributed and the data continues to reveal localized areas of more severe impact associated with more complex and toxic influences. Coupled with the persistent **NON** attainment of the WWH use designation in these segments, continued efforts to reduce pollutant loadings and improve water quality conditions are necessary. In the future, areas of continued severe impact or “hot spots” should become increasingly apparent if the trends observed in some key Biological Response Signatures during the past decade continue.

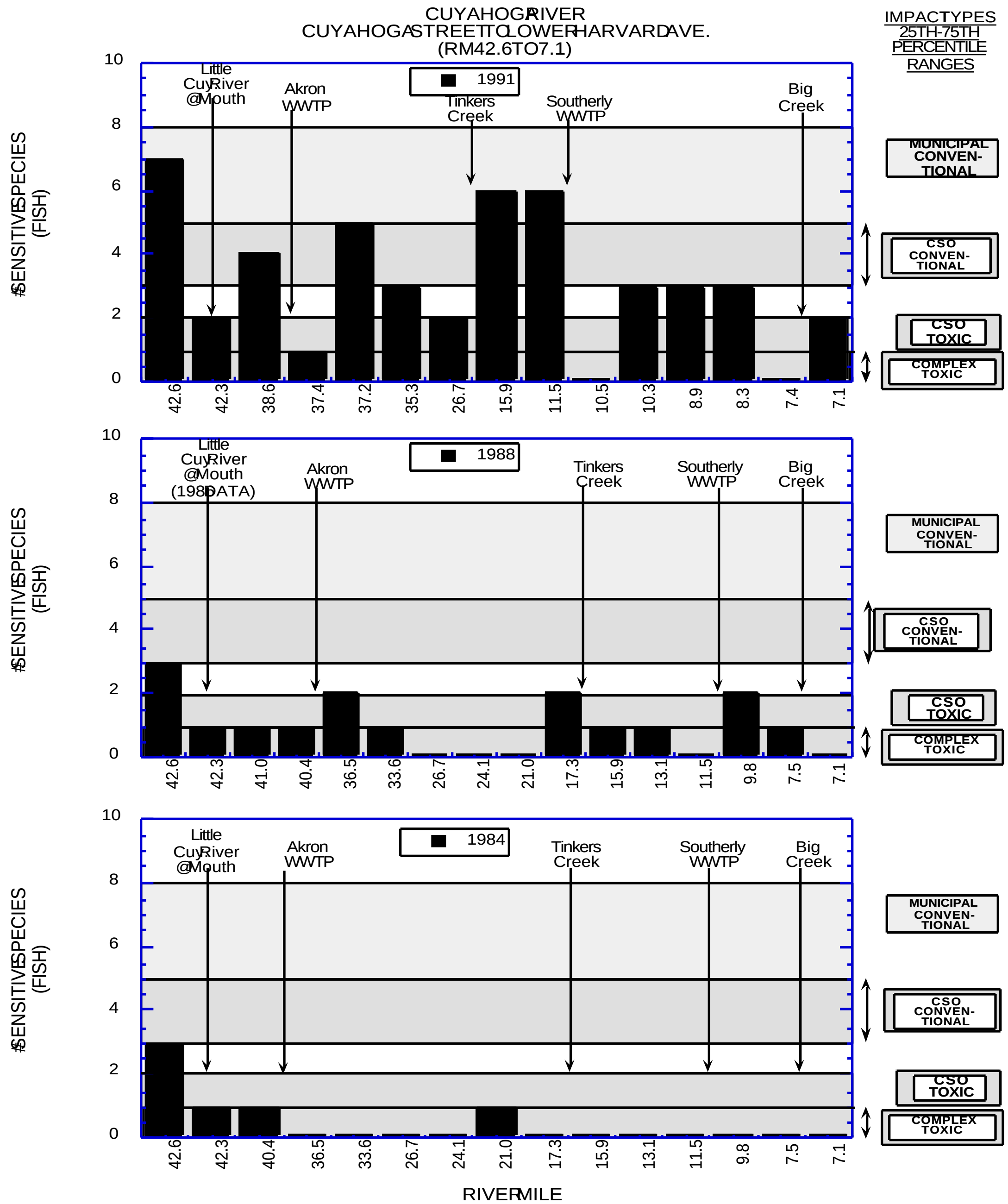


Figure 2. Number of sensitive fish species in the middle Cuyahoga river from sampling stations in 1984, 1988, and 1991. Note: some 1987 stations were included in the 1988 plot where sample coverage was lacking.

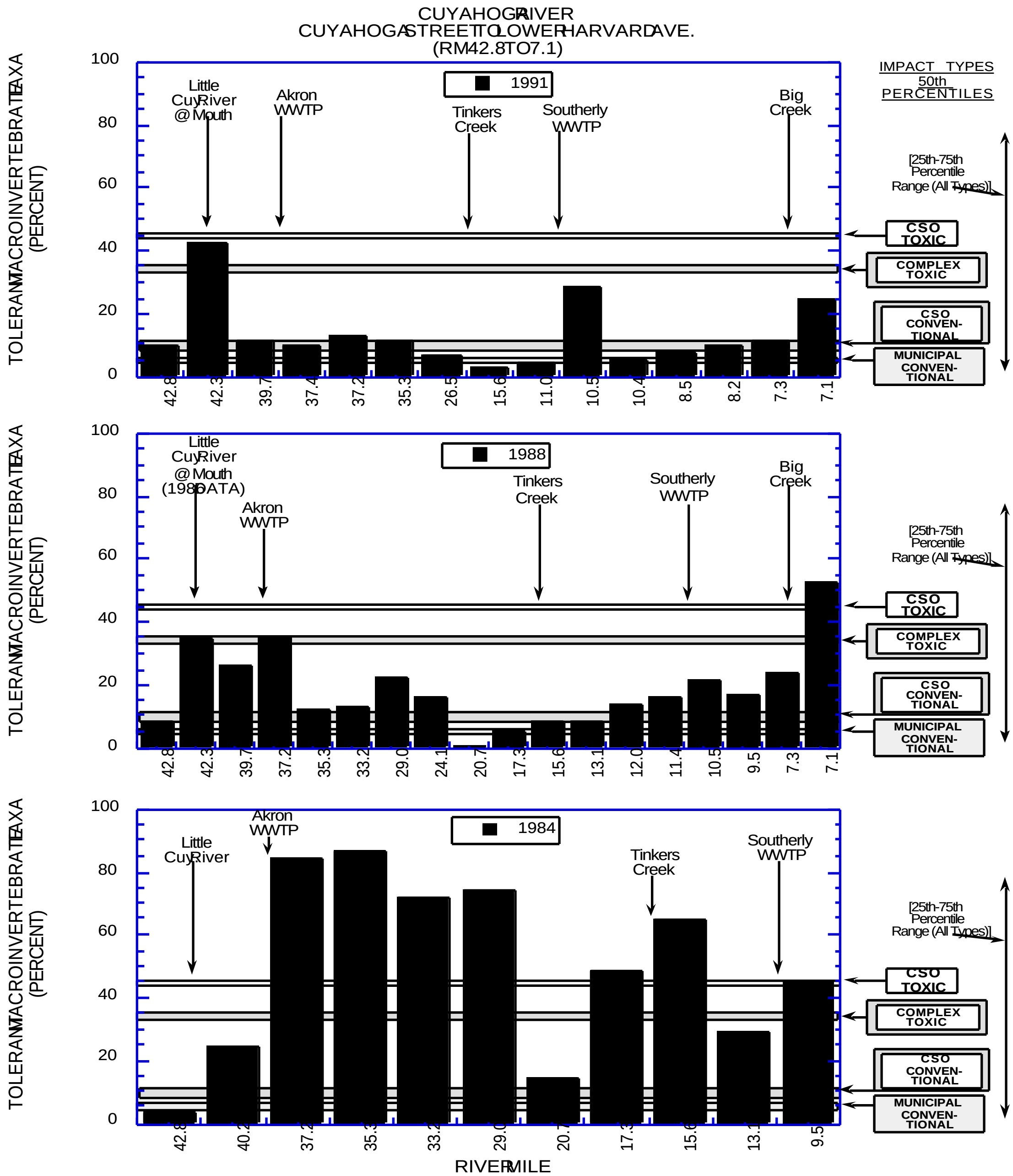


Figure 3. Percentages of tolerant macroinvertebrates at sampling stations in the middle Cuyahoga River in 1984, 1988, and 1991. Note: some 1987 stations were included in the 1988 plot where sample coverage was lacking.

SUMMARY

Cuyahoga River Tributaries

Tare Creek
Biological sampling at RM 3.2 was conducted upstream from an extensive wetland area in the lower reaches of Tare Creek. Community health indices ranged from fair (fish) to exceptional (macroinvertebrates) and were in PARTIAL attainment of WWH criteria. Fish communities reflected a negative response to poor habitat quality resulting from unrestricted livestock access but this did not appear to influence the macroinvertebrate community. Chemical sampling in the wetland area at RM 1.6 detected low dissolved oxygen levels and fecal coliform bacteria exceedences upstream from all known point source discharges. Livestock and possibly large populations of waterfowl in the wetland area were considered potential sources.

Fish Creek
Results of biological sampling at RM 0.4 show Fish Creek was in **NON** attainment of the existing WWH use designation. While biological and habitat quality were not severely degraded, the data suggested stressed communities. Recent channelization immediately upstream from this site was believed to have exerted the greatest influence. Other potential sources of impact included urban runoff from the cities of Kent and Stow, the Norton Co. discharge, and nonpoint source runoff from past and present construction and agricultural activities. Fish Creek has been completely channelized upstream from RM 1.3. Continued maintenance of the channel modification is expected in response to localized flooding problems.

Little Cuyahoga River
A 1986 intensive survey of the Little Cuyahoga River showed severe impacts and toxic conditions associated with industries, CSOs, SSOs and urban runoff sources in Akron. The 1991 results, while indicating a lessening of toxicity, reflected continued impacts from organic wastes and minimal, overall improvements in biological conditions. Biological communities remained in **NON** attainment at four sites between RM 11.0 and 0.3. Akron sewer system overflows and urban runoff continued to be considered major sources of impact. Under dry weather conditions these discharges were not particularly significant and chemical sampling found no exceedences of water quality standards. However, wet weather sampling (i.e., following large storm events) conducted from 1989-93, recognized the Little Cuyahoga River and the Akron sewer system as among the largest sources of fecal coliform bacteria to the Cuyahoga mainstem. During dry weather, septic sediments and sanitary wastes were quite evident in the Little Cuyahoga in Akron, the residuals of past runoff and discharge events.

“Biomarker” sampling of fish blood enzyme levels near the mouth of the Little Cuyahoga River suggested very high exposure to halogenated coplanar aromatic hydrocarbons (a sub-group of PAHs) near the mouth. Fish tissue contamination in the Cuyahoga River also increased sharply downstream from the Little Cuyahoga River confluence. Besides CSOs, SSOs and storm water discharges, the Akron area has also had a long history of pollutant spills during the past decade that may affect biological and water quality conditions. The Little Cuyahoga River is also eroding into the river banks and exposing solid wastes from closed landfills near the confluence with the Cuyahoga River. A phenolic odor was noticeable near the landfills during 1991 fish collections in August.

Most industries in Akron had closed, altered production or tied into the Akron sewer system by

1991. Remaining industrial discharges were primarily storm water runoff and non-contaminated cooling water discharges that, in theory, should not be significant sources of impact. However, the Ohio EPA has occasionally encountered cooling water discharges in other areas of the state that were highly or periodically contaminated and resulted in significant impacts on receiving streams. The Akron industrial discharges should be more closely evaluated in future surveys.

Upstream from Akron at RM 11.0, 1991 biological communities were also in **NON** attainment of the WWH aquatic life use. Macroinvertebrate communities were in the very good range but the condition of the fish communities was poor. The headwaters of the Little Cuyahoga River immediately upstream from RM 11.0 are highly influenced by a series of small impoundments and wetland habitats associated with significant D.O. depletion in the 1986 intensive survey. Continued influences from these habitats and low D.O. may be a major reason for the lack of improvement in this section. However, unknown pollution sources or discharges could not be ruled out.

Yellow Creek
Chemical sampling conducted from 1988 to 1991 in the North Fork of Yellow Creek and Yellow Creek showed no exceedences of chemical water quality criteria. Biological community performance in both the North Fork (RM 0.3) and Yellow Creek below the Village of Ghent (RMs 1.7 and 4.1) was good or very good and indicated FULL attainment of the WWH aquatic life use designation. The collection of several sensitive and intolerant fish species in Yellow Creek suggests the stream could act as an important repopulation epicenter for the mainstem of the Cuyahoga River downstream from the Akron WWTP. Yellow Creek has one of the most diverse fish communities of any tributary stream in the Cuyahoga River basin below Akron. Therefore, it merits a high degree of protection from additional loadings of pollutants above that recommended in the WLA evaluation process. In-stream biological sampling of fish and invertebrate communities should be considered in any future NPDES permits that allow increased loadings of pollutant above 1991 levels.

Furnace Run
The results at RM 0.9 showed good chemical water quality, very good to exceptional community performance and **FULL** attainment of the existing WWH aquatic life use designation. The stream is also important as a potential fish repopulation source and refugia for the more impacted Cuyahoga River mainstem. Furnace Run is designated as a State Resource Waters (SRW) for most of its length. This designation is intended to preclude further water quality and habitat degradation and, along with the recommended aquatic life use, will be the goals that will guide efforts to rehabilitate, restore, and protect water resource quality throughout the watershed. While an upgrade in the aquatic life use designation to EWH was not warranted by the results, there was a strong indication that Furnace Run should receive protection from additional loadings of pollutants via the antidegradation policy.

Brandywine Creek
Both fish and macroinvertebrate data suggested slightly improved performance at RM 0.3 since biological sampling was conducted in 1984 and 1988 (macroinvertebrate sampling only). However, communities continued to show **NON** attainment of WWH biological criteria. Chemical water quality conditions improved considerably between 1990 and 1991 following upgrades at the Hudson WWTP (RM 7.95), but the wasteload allocation predicts that D.O. problems will continue downstream from the discharge. This discharge will be eliminated in 1995-1996 via a tie-in to the NEORSD Cuyahoga Valley Interceptor (CVI). In addition, bacteriological

sampling by USGS in 1991-93 under high flow conditions revealed high levels of fecal coliform bacteria near the mouth of Brandywine Creek, an indication of contamination by sewage.

Tinkers Creek

Tinkers Creek is an effluent dominated stream that receives discharges from at least eight major and minor municipal WWTPs between RM 26.2 and 3.7. The 1991 survey showed significant improvements in water chemistry throughout the Tinkers Creek mainstem and improved macroinvertebrate communities at almost all stations when compared to an earlier, 1984 survey. Improvements in the chemistry and macroinvertebrates were primarily linked to reduced point source loadings following WWTP upgrades, closure and consolidation of many small package plants, and elimination of on-site septic systems. In-stream improvements were most pronounced in the upper and middle sections of the mainstem. Fish communities however, were in a fair to very poor condition at all Tinkers Creek stations and revealed a distinct lack of improvement when compared to the 1984 survey. Overall, biological communities were in **NON** attainment of the WWH use in 28.3 of the 28.8 river miles surveyed and achieved **PARTIAL** attainment only at the farthest upstream site (RM 28.8).

Despite the disparity in the fish and macroinvertebrate results, there was agreement in an overall declining trend in performance from upstream to downstream as the mainstem received additional point source loadings and land use in the basin became increasingly urbanized. Most nutrient and metals concentrations also showed a general increasing trend from upstream to downstream. The area of most severe biological degradation was found at RM 8.5, located immediately downstream from the Richmond Rd. pump station, the Ohio Bulk Transfer Co. garage, and the Richmond Road Mobile Home Park (MHP) WWTP. The landfill garage was responsible for a chronic oily discharge during the summer that appeared to severely impact the biological communities. Oily substrates were also observed at this site during the 1984 Ohio EPA survey. The Richmond Rd. pump station has been associated with numerous overflow events over the past decade. Both the fish and macroinvertebrates remained degraded (fair to very poor ranges) from RM 8.5 to the mouth. This area is subjected to additional WWTP discharges and urban nonpoint sources.

The lack of even partial recovery in the fish community and outright decline in some reaches is in sharp contrast to the improving trends in the macroinvertebrates and water chemistry. One theory is that the presence of several waterfalls in the middle and upper sections could prevent or deter recovery by acting as permanent barriers to upstream migration and recolonization of degraded segments. However, sufficient vestiges of the fish community were present in the upper reaches to enable recovery to WWH levels given sufficient time and environmental conditions. It appears that recovery in the fish has been deterred by other factors such as nonpoint sources, pollutant spills, point sources or undocumented sources that continue to impact these segments. The permanant barriers could influence recovery to the extent that fish recolonization may not occur as rapidly in the upper sections of Tinkers Creek as in comparable, unrestricted stream segments.

Causes of **NON** attainment in the upper part of Tinkers Creek (headwaters to Twinsburg) may be linked to many potential factors including the unusually high levels of suspended solids (high turbidity) observed under low flow conditions, wetland habitats in the headwaters, sediment metals contamination (arsenic) in the headwaters, construction runoff, and continued and/or residual impacts from existing and abandoned point source discharges. In addition, the Tinkers Creek watershed has had an extensive history of both pollutant spills (175) and NPDES permit violations at the five major municipal WWTPs (2,100) from 1978 through 1991. Gas and oil exploration has also increased dramatically in the upper watershed during the same period. The cumulative effects of any number of these factors, while not completely known, may be contributors to the extensive **NON** attainment in Tinkers Creek.

Pond Brook

A change in use designation from WWH to Modified Warmwater Habitat (MWH) was recommended for Pond Brook due to extensive channelization of much of the mainstem and its tributaries. The stream channel is sluggish and flows through numerous wetlands, particularly in the lower 3-4 river miles. QHEI values ranged from 28.0 to 38.0, well below typical WWH potential. Two municipal WWTPs discharge to Pond Brook at RM 3.5 (Aurora Shores) and RM 1.57 (Aurora Westerly), respectively. Biological communities were in **NON** or PARTIAL attainment of MWH at three sampling locations in 1991 between RMs 3.8 and 1.4. Chemical sampling downstream from all point sources at RM 1.4 showed one fecal coliform exceedence and a minimum dissolved oxygen concentration of 3.0 mg/l, an exceedence of the MWH average criteria. However, in August 1989, continuous monitor sampling between RM 1.6 and RM 0.25 showed severe diurnal D.O. depletion with concentrations reaching as low as 0.06 mg/l. Although dissolved oxygen conditions improved at RM 1.4 in 1991, exceedences of criteria continued to be present. Possible reasons for the low concentrations included point source discharges, low dissolved oxygen levels associated with the local wetland drainage, severe physical habitat limitations and a lack of reaeration in Pond Brook.

Since 1984, consolidation of small WWTPs and plant upgrades in the Pond Brook drainage has resulted in substantial reductions in instream ammonia levels and significant improvements in Pond Brook fish communities downstream from the discharges. However, macroinvertebrate sampling in Pond Brook revealed little improvement since 1984. Potential impacts from point sources could not be separated from the influences of severe habitat limitations, sluggish current velocities, and possibly wetland drainage.

Beaver Meadow Run

Biological communities were in the poor ranges and in **NON** attainment of the recommended WWH use designation at RM 0.2. The site was located approximately 0.8 miles downstream from the Solon WWTP and downstream from a leaking sanitary sewer repaired by the end of August 1991. The sewer line was also a suspected source of fecal coliform exceedences found at RM 0.2. Results from 1991 suggested similarly or slightly more degraded conditions than were found in l984.

Hawthorn Run

Biological communities upstream from the Bedford Heights WWTP at RM 0.8 were in the fair ranges (**NON** attainment), despite the presence of good physical habitat conditions. The cause of impairment was unknown but urban runoff was a potential source. Continuous monitors at RM 0.1 detected severe D.O. depression immediately downstream from the WWTP but chemical grab sampling showed no significant water quality problems.

Mill Creek

Biological sampling results showed some improvement in community performance since 1984, but the general condition remained in the poor-fair range. Community performance at the mouth remained well below expectations based on the recommended Warmwater Habitat use designation. Predominant sources of impairment include CSOs and SSOs, urban nonpoint source runoff, spills, unknown dischargers, and leachate from the Harvard Refuse and Warner Hill solid waste landfills. Chemical sampling revealed extremely high fecal coliform counts linked to a blocked sanitary sewer (since remediated) and high levels of ammonia downstream from the landfills.

Big Creek

Biological sampling results showed some improvement in community performance since 1984, but the overall condition remained poor. Community performance at the mouth remained well below expectations based on the recommended Warmwater Habitat use designation. Predominant sources of impairment include combined sewer overflows (CSOs) and SSOs, urban nonpoint source runoff, spills, and unknown dischargers. Chemical sampling indicated no water quality exceedences but an oily sheen was observed on the surface. The discharge was traced to the Research Oil company property near the mouth of Big Creek and was found to contain PCBs. Corrective actions are currently underway.

Major Sources of Pollution and Impacts

The following is a longitudinal (upstream to downstream) summary of major point source discharges in the study area. Summaries include the types of pollutants delivered to the receiving waters and the impacts revealed by the ambient biological and chemical/physical sampling.

Cuyahoga River Mainstem

Kent WWTP (RM 53.9) & Fishcreek WWTP (RM 51.4)

Aquatic life use attainment status in the Cuyahoga River mainstem between Lake Rockwell and the Little Cuyahoga River gradually changed from FULL (RM 54.6/54.2) to PARTIAL (RM 49.8-44.0) to **NON** (RM 42.8-42.6) as the mainstem flowed through the Kent, Cuyahoga Falls, and Akron urban areas. Station RM 49.8 (immediately downstream from the Munroe Falls dam pool) was 4.1 and 1.6 miles downstream from the Kent and Fishcreek WWTPs, respectively. The gradual declines in community indices appeared related to nutrient enrichment, possibly resulting from the WWTP discharges and the increased amount of impounded habitats downstream from Kent. Similar results were found in 1984. No exceedences of water quality criteria were detected in chemical grab samples within this segment. Continuous D.O. monitoring recorded excursions below the WWH criteria immediately upstream from the Ohio Edison dam pool (RM 45.68) and violations of the Limited Resource Waters (LRW) criteria within the Edison dam pool (RM 44.60). The RM 44.6 site was influenced by the Ohio Edison thermal discharge that was eliminated later in 1991. Further monitoring of this segment in closer proximity to the WWTPs (*i.e.*, within the Munroe Falls dam pool) is needed to fully learn the role of each in the predicted D.O. violations and the biological impairment.

Akron WWTP (RM 37.45)

Biological communities in the Cuyahoga River were in **NON** attainment of WWH criteria from Akron to upstream Cleveland (RM 42.8-15.6). Communities remained in **NON** attainment downstream to the confluence with Lake Erie.

As in the previous surveys, the initial impacts in 1991 were observed downstream from the 36 CSOs and 8 SSOs that discharge to the Cuyahoga, Little Cuyahoga River, Ohio Canal and several small tributaries in Akron. All SSOs have been eliminated within the Akron city limits except overflow #5, which will be eliminated by October 1994. During 1994 Akron will issue community discharge permits (CDP) to its customers outside its corporation limits. The CDPs will require elimination of any remaining SSOs in these service areas.

Biological communities in the Akron WWTP mixing zones were in the fair range, but *did not* reflect acutely toxic conditions nor were they substantially different in composition from those found *upstream* from the discharge. This is a distinct change from the responses observed in 1984-1986 that were decidedly toxic and different from that observed upstream from the WWTP. Macroinvertebrates gradually improved from the fair to good to very good ranges between Akron and the south Cleveland suburbs, but the fish community remained in the fair (MIwb) and poor (IBI) ranges for approximately 25 miles downstream from Akron. Biological response signatures suggest a sublethal (chronic) stress downstream from the Akron sewer system (CSOs, SSOs, WWTP) and the Akron urban area.

Chemical sampling during low flow conditions showed steady increases in total lead and total suspended solids concentrations between Akron and Cleveland, but no WQS exceedences were detected. The mainstem now routinely meets all chemical/physical WQS criteria during dry weather, low flow conditions. However, bacteriological surveys conducted from 1989-93 revealed significant and persistently high fecal coliform counts in the Akron to Cleveland segment following heavy rainfall and runoff events. Besides indicating the entry of significant amounts of untreated and partially treated municipal sewage, these precipitation and flow related, episodic events are considered important contributors to **NON** attainment of the WWH aquatic life use in this segment. Given the level of industrial wastewater carried by the Akron sewer system it is likely that toxic pollutants are also involved. Although Akron has made significant improvements in the pretreatment of these industrial discharges to the sewer system, as evidenced by the improvements noted in the mainstem since 1986-88, some problems were still evident. The 1991 results throughout much of the Akron to Cleveland area show shifts in community response from the more toxic impacts of the past to more conventional enrichment type responses. Future mainstem and watershed surveys scheduled for 1996 should better reveal the extent of these improvements.

Since the 1984 Ohio EPA biological and water quality survey, biological communities in the Cuyahoga River between the Akron WWTP and Cleveland have remained in **NON** attainment. The 1984 survey showed acutely toxic conditions, particularly at stations downstream from the Akron WWTP. In contrast, communities have shown an improving trend since 1984. However, indications of acute and chronic stresses were evident as recently as 1988, when MIwb scores in the very poor range were detected in a 3.8 mile section downstream from the Akron WWTP discharge. The 1991 results suggest an easing of the *acute* toxicity formerly associated with the WWTP discharge and further implicate the Akron CSOs, SSOs, and urban runoff (primarily via the Little Cuyahoga River) as increasingly important sources of impact. In addition, more recent bacteriological sampling by the USGS in 1992 and 1993 shows Akron WWTP secondary process bypasses can also be a significant source of contamination under high flow conditions.

NEORSD Southerly WWTP (RM 10.57)
Upstream from the navigation channel, the area of most severe **NON** attainment (based primarily on the fish community) was between the NEORSD Southerly WWTP and the Newburgh & South Shore railroad bridge (RM 10.5-5.8). Fish communities in the NEORSD Southerly mixing zone suggested an avoidance response with sharp declines in density, biomass, and an MIwb score in the very poor range. Macroinvertebrates also exhibited sharp declines in population densities and the ICI (26=fair range) and increased numbers of toxic tolerant taxa. These results suggest some form of toxicity and/or avoidance response within the mixing zone. Fish communities remained impaired throughout this section, but macroinvertebrates improved to meet the WWH ICI criterion

0.2 miles downstream from the WWTP and continued to improve further with increased distance downstream. Chlorine was considered a potential source of the impairment based on the observance of abdominal gill damage in caddisflies downstream from the discharge. This is similar to incidences described in chlorine influenced streams by Simpson and Bode (1980). Since the 1991 survey, de-chlorination has begun at the NEORSD Southerly WWTP.

Two bioassay tests conducted by the Ohio EPA in 1987 found no acute toxicity for fathead minnows, but moderate to severe acute toxicity for *Ceriodaphnia*. There was some daphnid mortality in one mixing zone sample. A review of the effluent samples collected showed high levels (> 10 mg/l) of ammonia-N. These high ammonia-N values were also noted in a March 1989 compliance sampling inspection [CSI] and were believed to be caused by decreased nitrification due to cold air temperature. Process changes at the NEORSD Southerly WWTP came on line in early 1988 that significantly reduced the ammonia-N concentrations in the effluent. Seven chronic bioassay tests of the effluent were conducted in 1989 as part of a toxicity identification evaluation (TIE) to learn if certain heavy metals were contributing to the effluent toxicity problems (DeGraeve 1990). The TIE results pointed to a receiving stream toxicant rather than effluent heavy metals as the source of the chronic toxicity.

American Steel Wire (RM 8.75)
American Steel Wire converted to a water reuse/recycle system in 1991. The system has virtually eliminated the discharge except during extremely wet periods. Biological communities were in **NON** attainment both upstream and downstream from the plant. However, no specific chemical or biological impact could be attributed to the discharge due to the masking effects of the upstream impacts.

Harshaw Chemical (RM 7.1 and 7.3)
The Harshaw Chemical plant process wastewater has been tied into sanitary sewers since 1989. Only non-contact cooling water and storm water run-off are currently discharged from the facility Biological communities were in **NON** attainment both upstream and downstream from the plant. No specific chemical or biological impact could be attributed to the discharge due to the masking effects of the upstream impacts.

LTV Steel East and West Plants (RM 6.74 - 4.70)
LTV Steel is the largest industrial discharger to the mainstem (18 outfalls and 30 monitoring locations) and is a significant source of cyanide, heavy metals, ammonia-N, oil and grease, and TSS in the lower segment of the mainstem. The elimination of production lines, increased wastewater recycling, and treatment upgrades made within the past decade have resulted in a significant reduction of pollutant loadings. However, manufacturing processes and effluent monitoring requirements have been so radically changed in recent years that an *accurate* determination of loading reductions was not possible. Also, use of the river for cooling and process water makes estimates of net loadings such as TSS and metals difficult.

Biological communities were in **NON** attainment of interim criteria for Lake Erie estuaries both upstream and downstream from the LTV steel complex. Potential impacts associated with the discharges were difficult to separate from the low background dissolved oxygen levels and the negative effects of extensive habitat modification in the dredged shipping channel. However, some improvement was noted in fish community indices, particularly the MIwb; index scores increased from the very poor range in 1984 to the poor and lower fair ranges by 1991. This improvement, however slight, is likely due to the lessening of acutely toxic conditions that prevailed in the navigation channel in the early and mid-1980s.

Zaclon (RM 4.6)
Although additional pollution controls have been instituted in recent years, Zalcon remains a major source of zinc discharged to the navigation channel. Elevated concentrations were documented in both sediment and water column samples collected downstream from the discharge. Potential impacts associated with the discharges were difficult to separate from the background low dissolved oxygen levels and the negative effects of the highly modified channel morphology in the dredged navigation channel.

Tinkers Creek Subbasin
Since 1987, bioassay tests have been conducted at the Twinsburg WWTP, Bedford WWTP, Solon WWTP, and Bedford Heights WWTP. Acute toxicity has been observed in the Twinsburg WWTP (*Daphnia* in one of four tests) and the Bedford WWTP (fathead minnows and *Daphnia*, in grab samples only). MBAS (*i.e.*, surfactants) was a suspected source of toxicity at the Bedford WWTP and additional bioassay sampling was conducted by the city of Bedford. The source of toxicity could not be identified.

Streetsboro WWTP (RM 26.2)
The Streetsboro WWTP is a 2.5 million gallon per day (MGD) plant that initiated operations in late 1985. Portage County requested permission to expand design flow at the WWTP to 5.0 MGD in 1992. This regional WWTP consolidated flows from several small package type WWTPs that discharged to tributaries of Tinkers Creek in the Streetsboro area and includes Humphrey Park, Gillie Estates, Arrowhead Estates and Rolling Hills. In 1988, flows from the Summit County Hudson #5 WWTP were diverted to the Streetsboro WWTP as part of an agreement between Summit and Portage Counties. The Summit County #5 plant discharged directly to Tinkers Creek at RM 25.2.

Streetsboro has had good NPDES permit compliance with few violations between 1986 and 1991. Chemical samples collected downstream from the WWTP in 1991 showed much lower ammonia-N and higher nitrate-N levels compared to samples collected downstream from the abandoned, Hudson #5 plant in 1984. No exceedences of chemical water quality criteria were detected in the 1991 survey.

Aurora Shores WWTP (RM 22.51, 3.5)
The Aurora Shores WWTP is a small, 0.25 MGD plant that discharges to Pond Brook at RM 3.5 (based on river miles after rechannelization conducted between 1970 and 1984). Biological monitoring near the WWTP in 1991 was limited to fish collections and qualitative macroinvertebrate collections immediately upstream (RM 3.6/3.8) and downstream (RM 3.4/3.4) from the discharge. Continuous dissolved oxygen (D.O.) monitor sampling was also conducted in 1989 and 1991 along the length of Pond Brook; concentrations below MWH criteria were measured upstream from the WWTP and 0.2-1.5 miles downstream. Additional declines (below LRW criteria) were noted further downstream in a wetland section near the Aurora Westerly discharge. Stream habitats in this section, particularly downstream from the WWTP, have been extensively modified and were of poor quality. The stream also flows through and adjacent to numerous wetlands and is periodically impounded by beaver dams between the WWTP and the confluence with Tinkers Creek. Biological communities were in NON attainment of the recommended Modified Warmwater Habitat (MWH) use designation both immediately upstream and down-stream from the Aurora Shores WWTP discharge. Fish communities improved from

the poor range to the fair range downstream from the WWTP. However, macroinvertebrates declined from fair quality at RM 3.6 to poor quality at RM 3.4. While impacts from the WWTP could not be entirely ruled out, an evaluation of the discharge was confounded by the severely limited habitat conditions (deep, channelized; soft substrates of muck, detritus and silt) at the macroinvertebrate sampling site.

Since 1984, fish communities have improved dramatically immediately downstream from the Aurora Shores WWTP at RM 3.4 with the IBI increasing from 12 (very poor) to 32 (fair) between surveys. One possible cause is reduction of toxic levels of ammonia with the removal of the Geauga Lake WWTP discharge, which was tied into the new Aurora Westerly WWTP. In contrast, macroinvertebrates were largely unchanged (poor in both 1984 and 1991), an indication of an overriding habitat influence on the macroinvertebrates.

Aurora Westerly WWTP (RM 22.51, 1.57, 0.45)
The Aurora Westerly WWTP is a 1.4 MGD plant that initiated operations in May 1989 and replaced four smaller WWTPs in the area (Geauga Lake, Walden, Aurora Acres and Four Seasons). It discharges to an unnamed tributary that enters Pond Brook at RM 1.57. This section of the stream is pooled, extensively channelized and receives drainage from wetlands, Aurora Pond, and small lakes. During the late summer of 1991, flows at the site appeared stagnant and the surface was covered with duckweed. Chemical monitoring below the Aurora Westerly WWTP tributary in 1991 revealed one fecal coliform exceedence and a dissolved oxygen concentration below the MWH average D.O. criterion of 4.0 mg/l. Continuous monitor data from August of 1989 revealed severe D.O. depletion immediately upstream and downstream from the Aurora Westerly WWTP (RM 1.58-1.41). Concentrations as low as 0.06 mg/l were detected and all samples were below the minimum average MWH criterion of 4 mg/l. Continuous monitors from 1991 showed improved D.O. conditions but concentrations below MWH criteria were still noted upstream and downstream from the WWTP tributary. Continuous D.O. monitoring in the Aurora Westerly tributary showed improved minimum D.O. levels from 1989 (minimum of 1.91 mg/l) to 1991 (minimum of 4.19).

Biological communities at Pond Brook RM 1.4 were in PARTIAL attainment of the recommended MWH aquatic life use designation. The lack of full attainment resulted from the fair condition of the macroinvertebrate community (ICI=16). The severe habitat limitations, lack of current, and potential wetland influences at RM 1.4 tended to mask potential impacts associated with the WWTP.

Twinsburg WWTP (RM 15.65)
The Twinsburg WWTP is a 3.4 MGD plant expanded from 2.2 MGD in late 1988. Twinsburg is currently planning an expansion to 4.45 MGD. Biological communities were in **NON** attainment of WWH throughout most of Tinkers Creek (RM 28.3 - 0.1). Because of the impairment upstream, additional biological impacts downstream from the WWTP appeared slight. An increase in the MIwb suggested a potential organic enrichment effect. Compliance sampling inspection (CSI) monitoring in 1990 indicated elevated effluent concentrations of Cu, COD, $cBOD_5$ and acute toxicity to *Ceriodaphnia* in one of four bioassays conducted since 1989.

Solon Central WWTP (RM 10.62, 0.97)
The Solon Central WWTP is a 3.6 MGD plant under Director's Findings & Orders for non-compliance with mercury limitations (since February 1989) and frequent exceedences of design capacity (30-35% of the time). A facility expansion to 5.8 MGD is being planned. The Solon

Central plant discharges to Beaver Meadow Run and is among the larger contributors of point source loadings to the Tinkers Creek subbasin. Bioassay testing conducted three times since 1990 has failed to show acute toxicity associated with the discharge. However, high concentrations of zinc and some low level concentrations of organics were detected during CSI monitoring in April and August of 1991, respectively. Last upgraded in 1980, loadings of oil & grease, zinc, $cBOD_5$, TSS, phosphorus and ammonia-N have gradually increased, particularly over the last five years. Lead and copper loadings have gradually decreased during this period. Biological communities in Beaver Meadow Run, 0.8 miles downstream from the discharge, were in the poor range and indicated **NON** attainment of the recommended WWH use designation. Some impairment may have been related to a leaking sewer line upstream from the WWTP; the line was repaired by mid-summer of 1991. Tinkers Creek biological communities were in **NON** attainment of WWH both upstream and downstream from Beaver Meadow Run. Slight declines in all index values were observed downstream from the confluence. Although chemical samples collected downstream met the WQS, an obvious peak in ammonia-N concentrations was observed downstream from Beaver Meadow Run.

Bedford Heights WWTP (RM 7.83, 0.12, 0.02)
The Bedford Heights WWTP is a 7.5 MGD plant that discharges to an unnamed tributary of Hawthorn Creek. The WWTP was upgraded between 1984 and 1985, resulting in significant reductions in ammonia-N loadings since the mid 1980s. However, the plant was placed under Director's F&Os (Findings and Orders) in 1989-90 for non-compliance with copper limitations and lab quality control problems. Sampling in Hawthorn Creek upstream from the WWTP indicated only fair quality biological communities despite habitat conditions capable of supporting the WWH use designation. Tinkers Creek biological communities were in **NON** attainment of WWH both upstream and downstream from Hawthorn Creek. Impacts from the Bedford Heights WWTP could not be separated from the already degraded conditions downstream from the Ohio Bulk Transfer Co. garage, the Richmond Rd. pump station, and Richmond Rd. mobile home park. However, the Bedford Heights discharge may have contributed to the lack of full recovery observed in the lower seven miles of Tinkers Creek.

Bedford WWTP (RM 3.72, 1.5)
The Bedford WWTP is a 3.2 MGD plant that discharges to Wood Creek, a tributary of Tinkers Creek. Wood Creek is designated a Limited Resource Water (LRW). Last upgraded in 1987, loading trends suggest only small changes since 1984. Biological communities were in the fair to poor range throughout the lower section of Tinkers Creek, both upstream and downstream from Wood Creek. The influence of the Bedford WWTP could not be separated from the already degraded mainstem conditions, but the discharge likely contributed to the lack of full recovery in the lower section of Tinkers Creek.

CONCLUSIONS

Upper Cuyahoga River Mainstem

- In the upper Cuyahoga mainstem upstream from Lake Rockwell (RMs 89.5 to 64.2), biological sampling identified 14.6 miles of FULL WWH attainment, 7.6 miles of PARTIAL attainment and 3.1 miles downstream from Tare Creek in **NON** attainment. **NON** and PARTIAL attainment was found in segments influenced by reservoir releases, sluggish, swampy habitats and the lingering effect of past channelization activities. Chemical, biological and physical habitat conditions improved with increased distance downstream from these areas. The highest quality biological communities in the Cuyahoga River basin study area were found in the lower reaches of this segment. Future development pressures in the upper Cuyahoga River watershed are expected to be high following the recent completion of a major highway extension and a planned turnpike exit. Without proper safeguards and adherence to riparian habitat protection principles, future development will pose a significant threat to the high quality biological and water quality conditions.

- The upper Cuyahoga River was in substantial compliance with chemical water quality criteria except for dissolved oxygen, iron, and fecal coliform bacteria. Mainstem D.O. violations of minimum WWH criteria were noted at RM 89.41, 87.26 and 71.7. Probable causes include bottom releases from the Akron water supply reservoirs, naturally low D.O. levels common to the extensive wetland areas, and oxygen demanding sources discharged by municipal point sources. Nonpoint source contributions resulting from unrestricted livestock access to streams is believed to be an additional factor to the D.O. and fecal coliform bacteria violations in the Tare Creek watershed.

- Fifty percent of the samples collected exceeded the 1.0 mg/l criteria for total iron. These exceedences are the result of natural background conditions that is a common occurrence throughout Ohio.

- One sample from the upper Cuyahoga River downstream from Tare Creek exceeded the fecal coliform bacteria criterion for the Primary Contact Recreation use.

Middle Cuyahoga River Mainstem

- From Lake Rockwell to the Little Cuyahoga River (RMs 54.6 to 42.6), aquatic life use attainment gradually changed from FULL to PARTIAL to **NON**. Upstream to downstream declines coincided with the combined influences of several pollution sources. These included WWTP discharges in Kent and Stow (Fishcreek WWTP), impoundments, increased urbanization, the Ohio Edison Gorge Power Plant thermal discharge (eliminated in fall, 1991), and CSOs and SSOs in the Cuyahoga Falls and Akron areas. The river also cuts into an abandoned landfill area located in the lower reaches of the Little Cuyahoga River and along the mainstem upstream from the confluence (RM 39.9-43.6).

- **NON** attainment of the WWH aquatic life use persisted throughout the 40-mile length of the Cuyahoga River between the Little Cuyahoga River and the mouth (RM 39.7 to 0.0). From Akron to the navigation channel (RM 39.7 to 5.8), differential responses between macroinvertebrate and fish communities were observed. Most ICI scores attained or marginally attained the WWH criterion (*i.e.*, good performance) while fish community performance was primarily fair or poor based on the MIwb and IBI criteria, respectively. However, there has been a continued, gradual improvement in community performance since 1984, when a severe toxic response was indicated downstream from the Akron WWTP.

- Overall, the most significant negative influences on biological communities in the middle Cuyahoga River mainstem were the Akron metropolitan area (CSOs, SSOs and urban runoff), the Akron WWTP, and the NEORSD Southerly WWTP.

- The middle Cuyahoga River from RM 57.4 to 7.4 was in substantial compliance with chemical water quality criteria throughout the 1991 survey. Except for iron, no chemical exceedences of acute or chronic criteria were detected in chemical grab samples. The middle and lower portion of the mainstem now routinely meets WWH and primary contact recreation (PCR) criteria during dry weather periods.

- Bacteriological sampling conducted by the U.S. Park Service, Ohio EPA, the City of Akron, NEORSD and USGS in 1989-93 documented a strong correlation between elevated fecal coliform counts and rainfall events in the Akron and Cleveland areas. Major sources included CSOs and SSOs in the Akron and Cleveland areas and bypasses of the secondary process wastewater at the Akron WWTP.

- Fish communities in the NEORSD Southerly mixing zone suggested an avoidance response with sharp declines in density, biomass, and an MIwb score in the very poor range. Macroinvertebrates also exhibited sharp declines in population densities, a decline in the ICI to the fair range and increased numbers of toxic tolerant taxa. The results suggested some form of toxicity and/or avoidance response within the mixing zone. Chlorine was considered a potential toxicant.

- D.O. violations were noted in the Ohio Edison dam pool based on continuous monitoring data. The electric generating station recently ceased operation, eliminating the large thermal load discharged to this segment. Upstream contributors of oxygen demanding substances that also may have contributed to the D.O. problems include the Cuyahoga Falls SSOs and pump station overflows.

Lower Cuyahoga River Mainstem

- The Cuyahoga River Navigation Channel, (River Mile 5.4 to 0.0) frequently failed to meet the D.O. criterion for the prevention of nuisance conditions due to a combination of channel morphology, point source loadings, CSOs/SSOs, and urban nonpoint source contributions. All other chemical parameters met the WWH criteria during 1991.

- Historical chemical sampling suggests only slight improvement in Navigation Channel D.O. concentrations at West Third Street (RM 3.26) over the past 10-20 years. However, concentrations of nutrients and heavy metal parameters have exhibited substantial declines during this period, primarily in response to reductions in point source loadings. Future additional reductions in ammonia-N and cyanide concentrations are expected after all LTV Steel coking operations ceased in January 1993.

- Given the reductions in historical point source loadings, the major contributor of metals and inorganic compound loadings for this reach of the Cuyahoga River is now primarily from urban nonpoint sources. However, the major contributors of nitrogen and phosphorus loadings remain the point sources (Cuyahoga RAP, 1992).

- CSO/SSO discharges are a major source of sediment oxygen demand (SOD) which contributes significantly to the oxygen deficit in the Navigation Channel.

- The morphology of the Navigation Channel is the primary limiting factor influencing D.O. in this segment. The shape and size of the channel contribute to a greatly extended residence time for pollutants entering the channel.

- Biological communities in the Navigation Channel were in poor or very poor ranges in 1991. However, trends in some biological indices suggest small, but detectable improvements since 1984. The severe habitat limitations of the modified channel coupled with the low background dissolved oxygen levels are considered the major limiting influences to further improvements and will preclude attainment of the WWH aquatic life use in the foreseeable future.

Little Cuyahoga River

- **NON** attainment of the WWH aquatic life use was evident in the Little Cuyahoga River from near Mogadore to the mouth (RM 11.0-0.3). Although the fish community consistently performed in the poor to fair ranges, macroinvertebrate community performance ranged from very good upstream from Akron, to poor and fair downstream from the Akron urban area and the Ohio Canal. Chemical water quality criteria were generally met but there was obvious evidence of water quality problems at most sampling locations. Extensive anoxic sediments were observed along the stream banks and in the stream channel in Akron downstream from the Akron CSOs and SSOs. Large amounts of landfill debris were also observed near RM 0.5 where the river channel has intruded into the closed Cascade Valley Landfill. Akron is currently eliminating SSOs and has remediated portions of the closed landfill. Ohio EPA has requested further remediation at the landfills (see Plate 7).

- The apparent lack of correspondence between the severity of the biological impairment and the near absence of chemical water quality exceedences illustrates the episodic nature of the impacts to the Little Cuyahoga River mainstem. Besides CSOs, SSOs and urban runoff, other potential sources include pollutant spills and undocumented releases from small industries authorized only to discharge non-contact cooling water to the upper mainstem and tributaries.

Tinkers Creek Subbasin

- The 1991 water chemistry data collected during low flow conditions in the mainstem revealed no exceedences of chronic water quality criteria for heavy metals and ammonia-N. Concentrations were significantly lower in 1991 than were found during the 1984 Ohio EPA survey, especially for copper and ammonia-N.

- Macroinvertebrate community performance in Tinkers Creek ranged from exceptional at RM 25.5 to poor at RM 8.3 and generally declined from upstream to downstream as point source discharges increased. In the lower 8.3 miles, community performance ranged from fair to poor and failed to attain the WWH ICI criterion. A persistent oily discharge from the Ohio Bulk Transfer Co. garage (RM 8.5) appeared primarily responsible for the most severe impairment observed in this stretch.

- Longitudinally, fish community performance in Tinkers Creek ranged from fair to very poor despite generally good physical habitat quality (mean QHEI = 72.6) and water quality. IBI scores in the headwaters declined from 30 (fair) at RM 28.8 to 21 (poor) at RM 25.0. MIwb values ranged from a low of 4.5 (very poor) at RM 10.5 to 6.9 (fair) at RM 0.2. The mean relative number of fish increased markedly at RM 14.3 and suggested an upstream source(s) of nutrient or organic enrichment. Non-attainment of the WWH MIwb and IBI criteria appeared the result of multiple influences including nonpoint source runoff (primarily construction activities), spills, pollutant loadings from point sources, and potentially from undocumented sources.

- Tinkers Creek at the mouth (RM 0.2) supported similar, but less diverse fish assemblages than found in the Cuyahoga River downstream from the confluence (RM 15.9). Although both communities reflected fair to poor quality, MIwb and IBI scores were higher in the Cuyahoga River.

- Water quality conditions as measured by grab sampling have improved significantly in Tinkers Creek since 1984. Macroinvertebrate communities also improved at all locations except RM 8.3, downstream from the Ohio Bulk Transfer Co. garage. Other downstream sites improved over 1984, but were still below WWH expectations. Changes in the water chemistry and macroinvertebrates appeared strongly correlated with improvements in wastewater treatment via point source upgrades and elimination of discharges.

- Similar improvement in the fish communities has not been observed since 1984. This was apparently the result of multiple influences including nonpoint source runoff (primarily construction activities), spills, pollutant loadings from point sources, and potentially from undocumented sources. The poor performance and lack of attainment in the lower reaches of the creek show the need for additional loadings reductions in the future. The fair performance observed at the headwaters site (RM 28.8; IBI = 30) may be due to the wetland like stream habitat conditions; however, departures below this level of performance noted at downstream sites indicate influences beyond habitat alone.

- The lack of recovery commensurate with the macroinvertebrates and water column chemistry may also be the result of natural geological features that prevent upstream reinvasion from the lower reaches and the Cuyahoga River mainstem. However, enough vestiges of a WWH fish community exist in the middle and upper reaches to rule this out as a major reason for the lack of recovery and sometimes outright declines. Future monitoring scheduled for the mid-1990s should shed more light on this situation.

RECOMMENDATIONS

Status of Aquatic Life Uses

- several streams evaluated during this study were originally designated for aquatic life uses in the 1978 Ohio WQS. The techniques used then did not include standardized approaches to the collection of instream biological data or numerical biological criteria. Therefore, because this study represents a first use of this type of biological data to evaluate and establish aquatic life use designations in several stream segments in the study area, several revisions are recommended. While some changes may appear to constitute "downgrades" (*i.e.,* EWH to WWH, WWH to MWH, etc.) or "upgrades" (*i.e.,* LWH to WWH, WWH to EWH, etc.), any changes should not be construed as such because this constitutes the first use of an objective and robust use evaluation system and database. Ohio EPA is under obligation by a 1981 public notice to review and evaluate all aquatic life use designations outside the WWH use before basing any permitting actions on the existing, unverified use designations. Thus, some of the following aquatic life use recommendations were a fulfillment of that obligation.

- The following Cuyahoga River basin segments were surveyed in 1991 and are recommended to retain their current WWH aquatic life use designations. The designations apply to the entire length of the waterbody unless otherwise noted.

  1) *Cuyahoga River Mainstem* - headwaters to navigation channel (RM 5.6).
  2) *Tare Creek*: The existing WWH use designation is considered appropriate for Tare Creek based on PARTIAL attainment of the WWH use in the headwaters (RM 3.2/3.1). However, the lower 1-2 miles of the stream are bordered by extensive wetlands. Water quality sampling in this segment (upstream from all point sources) documented D.O. concentrations

consistently below the WWH criteria and, at times, LRW. For these reasons, the lower reaches of the stream may qualify for exemptions to the WWH D.O. criteria under Section 3745-1-01(G)(1) of the Ohio WQS. Site-specific criteria could be calculated for this section on an as-needed basis.

3) *Fish Creek* (RM 1.3 - 0.0)
4) *Little Cuyahoga River*
5) *Yellow Creek*
6) *North Fork Yellow Creek*
7) *Brandywine Creek*
8) *Furnace Run*
9) *Tinkers Creek mainstem*

- Changes in use designation status are recommended for the following tributaries:

1) *Fish Creek* (Headwaters - RM 1.3; WWH Existing/MWH Recommended): An additional habitat evaluation was conducted in 1992 at RM 1.3 and revealed a QHEI of 43 and a strong predominance of high influence modified habitat attributes. Recent, extensive channel modifications had taken place throughout the mainstem between RM 1.3 and the headwaters. Continued maintenance of the channel for flood control purposes performed under the Ohio Drainage Law (ORC 6131) and low stream gradient result in no potential for recovery to WWH. Therefore, the MWH use designation is recommended.

2) *Pond Brook* (WWH Existing/MWH Recommended): The 1991 survey results and a reanalysis of 1984 survey data showed a failure to attain the WWH use and a strong predominance of high influence modified habitat attributes based on QHEI scoring. The existing WWH designation should be changed to MWH due to extensive channelization and ongoing maintenance done under the Ohio Drainage Law (ORC 6131).

3) *Beaver Meadow Run* (Undesignated/WWH Recommended): Biological sampling in 1991 and a reanalysis of 1984 data showed a lack of WWH attainment, primarily related to point source impacts from the Solon Central WWTP. QHEI scores showed a clear predominance of warmwater habitat attributes, making WWH the appropriate use designation.

4) *Hawthorn Creek* (Undesignated/WWH Recommended): Biological sampling in 1991 was conducted upstream from all known point source discharges. Although both fish and macroinvertebrates were in the fair range (**NON** attainment of the WWH use), the QHEI of 80.5 showed a clear predominance of good quality physical habitat attributes, making WWH the appropriate aquatic life use.

5) *Mill Creek* (RM 12.2 - 0.0; LWH Existing/WWH Recommended): Biological sampling in 1991 at the mouth and reanalysis of the 1984 results showed a failure to attain the WWH use, due primarily to impacts from SSOs and other sources. QHEI scoring showed a predominance of good quality physical habitat attributes at all sites except the most upstream location where a localized disturbance near a landfill adversely affected habitat quality. Although 1991 biological communities were in the poor range, this represented an improvement over the extreme degradation observed in 1984. CSO/SSO and other abatement efforts are continuing in the subbasin and appear to result in positive biological responses. Since the LWH designation is being phased out as streams are reevaluated, WWH is considered the appropriate aquatic use based on the presence of good quality

physical habitat attributes.

6) *Big Creek* (RM 4.4 - 0.0; LWH Existing/WWH Recommended): Biological sampling in 1991 at the mouth and reanalysis of 1984 results showed failure to attain WWH criteria, due primarily to impacts from CSOs/SSOs. Recalculated QHEI scores based on 1984 data showed a predominance of warmwater attributes. Although 1991 biological communities were in the poor range, improvement over the 1984 results was evident. CSO abatement efforts are continuing in the subbasin and, as in Mill Creek, have resulted in positive biological responses. Since the LWH designation is being phased out as streams are reevaluated, WWH is considered the appropriate use based on habitat potential.

7) *Cuyahoga River Navigation Channel* (RM 5.5 - 0.0; Undesignated/LRW Recommended): The navigation channel is a highly altered and artificial aquatic environment and is incapable of meeting either the WWH chemical or biological criteria prescribed by the WQS. The extensive and permanent channel modification has created conditions under which the retention time of water entering the channel is greatly increased thus decreasing turnover time. Add to this the negative effects of point sources, CSOs, SSOs, and urban nonpoint source contributions, even under permitted conditions, and the result is a 5.6 mile segment of the river that is incapable of meeting the WWH use. D.O. concentrations in the navigation channel routinely fall below the WWH criteria and periodically below LRW criteria. Biological index scores were significantly below the interim Lake Erie estuary criteria performing in the poor and very poor ranges. QHEI scores averaged 33 and reflected the submarginal habitat conditions that exist throughout most of the navigation channel. For these reasons, the LRW aquatic life use designation was recommended. From 1989 through 1991, an extensive water quality modeling analysis of the navigation channel was conducted following intensive chemical monitoring. Dissolved oxygen modeling for the channel concluded that even without point source discharged loading, minimum D.O. criteria for the WWH use could not be met. Detailed results from this survey and a use attainability analysis for the ship channel are presented in a separate document (Ohio EPA 1993).

Status of Non-Aquatic Life Uses

- No changes are recommended to the existing non-aquatic life use designations currently in the Ohio WQS. These uses include agricultural and industrial water supply, primary and secondary contact recreation, public water supply and State Resource Water (SRW). For a complete description of each designation, refer to OAC Chapter 3745-1-26.

Other Recommendations

General

- Ohio EPA needs to develop a comprehensive strategy for deciding about WWTP expansions in the Cuyahoga basin. Developmental pressures in the basin have and will continue to increase which will put pressure on existing WWTPs to expand flows and service areas. Considerations should go beyond effluent loading and water quality concerns to include interceptor sewer alignments, construction site impacts, and riparian/stream habitat concerns. This type of planning could have state wide utility.

Upper Cuyahoga River

- Ohio EPA should work with the city of Akron water department to evaluate Akron's reservoir release and well pumping practices. Issues for consideration should include modification of operations to reduce extremes in mainstem flows resulting from East Branch and LaDue Reservoir releases, splash plates and other reaeration mechanisms to increase oxygen levels in reservoir bottom releases. These are relatively low cost measures that could result in significant benefits to mainstem biological communities and water quality conditions. Monitoring of the D.O. profile in the upper Cuyahoga river should be conducted following the implementation of an improved reservoir release management strategy.

- Akron should be encouraged to continue the instream monitoring program of their water supply. The Akron water quality data collected in 1991 compared favorably to the data collected by Ohio EPA. Beyond the current program, the city should add chemical monitoring sites immediately upstream and downstream from the East Branch and LaDue reservoirs. At a minimum, parameters should include D.O., ammonia-N, and total phosphorus.

- Unrestricted livestock access in the Tare Creek watershed is suspected of having negative impacts on fish communities, physical habitat quality, and possibly water quality conditions. Restricting direct livestock access to streams via fencing and reestablishing riparian buffer zones (not grass filter strips) is recommended. The Upper Cuyahoga River Water Task Force (UCRWTF) is encouraged to work with local landowners in these efforts.

- More detailed investigations should be conducted to learn the cause of increases in fish anomalies and sharp increases in macroinvertebrate densities at Hiram Rapids (RM 75.8) and the comparatively low D.O. levels found at Pioneer Trail Rd. (71.7).

Middle and Lower Cuyahoga River

- SSO and CSO abatement strategies in the Akron and Cleveland metropolitan areas should be emphasized along with feedback monitoring to evaluate the effectiveness of the controls.

- Efforts should be made to further reduce storm-related bypasses from the Akron WWTP.

- Strategies for habitat preservation and restoration should be developed throughout the basin. These programs could result in the following major benefits: improved instream habitat that will lead to improved biological community performance, improved water quality and assimilative capacity, an improved ability to assimilate nonpoint source sediment, and stabilized stream banks.

- The city of Akron should continue remediation efforts at the closed Cascade Valley Park landfill, located next to the Little Cuyahoga River and Cuyahoga River mainstem near Cuyahoga Street. Remediation of other solid waste facilities within the basin such as the landfills in Garfield Heights along Mill Creek should also continue. Demolition sites such as the Kurtz Brothers and Gnatovich landfills near the NEORSD Southerly WWTP and other excavation activities that are currently not regulated by the Ohio EPA need to be addressed when regulatory tools are available.

- Additional studies should be performed to evaluate the impacts of dams and other hydromodifications to the water resources within the basin. These impacts include aesthetics, water quantity and water quality degradation, and habitat loss and fish migration barriers. Consideration should be given to removing dams that no longer serve a useful purpose and pose a risk of biological impairment.

- Follow-up investigations should be performed to confirm if the observed impacts associated with the NEORSD Southerly WWTP were due to chlorine toxicity. A toxic impact was suggested by the toxic response signature of the macroinvertebrates (Simpson and Bode 1980) and the very poor condition of the fish community.

- Occasional high levels of arsenic were found in sediments in some areas of the Cuyahoga River basin that could not be attributed to known anthropogenic sources. A paper by Mastoff et. al. (1982) on naturally occurring arsenic in northeast Ohio would suggest that wetland areas might provide the type of setting where the reduction of ferric hydroxides would foster the release of arsenic and iron into the water. Considering these observations, additional studies of wetland sediments in N.E. Ohio should be conducted to learn if arsenic is naturally higher in these areas. As a matter of procedure, parameter coverage in North East Ohio should routinely include this metal in environmental water quality and sediment metals samples to document background concentrations or the presence of a potential problem.

- Determining compliance with an LRW use designation for the Cuyahoga River Navigation Channel is dependent in part upon the flow measured at the Independence gage. Funding priorities need to ensure the continued operation of the Independence gage or other reliable flow measurement given the importance of the information for detecting compliance with the proposed water quality standards.

- The self-monitoring regimes currently in use at the Akron WWTP and LTV Steel result in inaccurate loading values. Sampling for Akron and LTV monthly operating reports (MORs) should be redesigned to provide more accurate loadings data.

- Run-off controls on material storage piles next to the river are needed, particularly at reclamation facilities along Bradley Road in Cleveland and throughout the navigation channel.

- Evaluations of tumorigenic potential in fish associated with sediment PAHs in the Cuyahoga River revealed several areas that lacked sediment data or require additional evaluation. These areas include:

  1) East Branch Reservoir (RM 91.07) and Bridge Creek (Cuyahoga River confluence at RM 83.2).

  2) The Cuyahoga River segment from U.S. Route 422 (RM 76.51) to the Munroe Falls dam (RM 50.0). This segment appears to have very low sediment PAH tumorigenic potential. However, two (2) WWTPs and the Kent urban area are located upstream. It is likely that high sediment PAH tumorigenic potential extends upstream from the dam. Lake Rockwell (RM 57.7) and the Kent dam pool (RM 54.8) should be evaluated for sediment PAH contamination because of their potential to act as sediment sinks.

  3) The Cuyahoga River downstream between Old Portage Trail (RM 40.3) and RM 37.97 (upstream. Akron WWTP [RM 37.45]) has not been analyzed for PAHs.

  4) The Cuyahoga River upstream and downstream from the Station Road Dam (RM 20.8). The dam pool should be evaluated because of its potential to act as a sediment sink.

5) The amount of sediment PAH data close to the NEORSD Southerly discharge (RM 10.5) and in the southern Cleveland area between Tinkers Creek and the diversion canal (RM 16.4-8.4) is small. Additional sampling sites would help fill these "gaps."

5) Mill Creek and Big Creek in the Cleveland metropolitan area receive point source discharges and polluted runoff from many sources. They have not been evaluated for sediment PAHs.

Tributaries

- Several high quality tributaries enter the Cuyahoga River between Akron and Cleveland and will serve an important function as biological repopulation epicenters and refugia for the Cuyahoga River mainstem communities. Yellow Creek and Furnace Run are the most notable. Future considerations for projects that would expand existing point source discharges, site new discharges, or contribute to nonpoint and habitat impacts in these tributaries should employ a most conservative approach. Furnace Run is designated as a State Resource Water (SRW) for most of its length. This designation is intended to preclude any further water quality and habitat degradation and, along with the recommended aquatic life uses, will be the basis for setting goals to restore and protect the watershed. Although the Yellow Creek SRW designation is limited to the section near the mouth where it enters CVNRA property, its value as a repopulation epicenter should be considered in the NPDES process.

- Chlorine toxicity during base flow conditions during the summer months should be limited by requiring all point source dischargers to de-chlorinate before discharge. This dechlorination policy should be applied to *all* dischargers that employ chlorine disinfection.

- In the North Fork of Yellow Creek, the erosion of clay sediment from a drainage ditch located immediately above the Summit County #42 WWTP should be addressed by stormwater regulations or local codes that may exist to control nonpoint source runoff.

- No additional loadings of pollutants should be permitted in the Mill Creek and Big Creek watersheds in Cleveland. A more comprehensive survey of both subbasins is needed to specifically identify problem areas and sources of impact.

Future Monitoring Needs

Cuyahoga River Mainstem

- Follow-up sampling is needed to re-evaluate NEORSD Southerly WWTP impacts following installation of dechlorination in late 1991.

- Additional sampling is needed to evaluate potential bottom release impacts from Lake LaDue, East Branch reservoir and Lake Rockwell, and to verify model predictions of D.O. violations in the Munroe Falls dam pool.

- The analysis of tumorigenic potential in fish suggests that there may be a correlation between PAH sediment contamination and impaired biological performance that cannot be explained by water column chemistry results alone. Additional PAH sediment sampling and documentation of fish tumor incidences would better guide remediation measures (*e.g.*, source identification and elimination) and perhaps better explain the PARTIAL and **NON** attainment of the fish communities. These efforts should be the focus of the Cuyahoga RAP biotic impairments subcommittee.

- Navigation channel studies should be conducted to evaluate expected water quality improvements resulting from the elimination of the last LTV coke oven wastewater discharge in January 1993. Fish migration patterns should also be studied to evaluate the current function of the navigation channel and provide baseline information.

Tinkers Creek Subbasin

- Periodic fish community sampling should be conducted in the upper mainstem and previously unsampled tributaries to track any evidence of recovery and repopulation epicenters.

- The population status of greenside darters in the lower four river miles should be monitored closely. Because greenside darters were not reported in the Tinkers Creek subbasin before 1955, their attempt to recolonize the lower four river miles can be used to document the effects of both water quantity and water quality from upstream WWTPs and other sources.

- Follow-up biological sampling should also be conducted downstream from RM 10.3 to more specifically locate potential impacts from point sources. Specifically, sampling stations should be located upstream and downstream and within the mixing zones of Hawthorn Run (Bedford Heights WWTP impacts) and Wood Creek (Bedford WWTP impacts).

- The effects of the high nitrate concentrations on nutrient dynamics and stream fish communities need to be investigated. It is possible that elevated nitrates may be acting to limit the biological potential of fish communities in Tinkers Creek. If nitrates are found to have a deleterious effect the feasibility and economic impact of nitrate removal at WWTPs should then be investigated.

- Additional sediment samples for arsenic and iron should be collected from the headwater stations to characterize background levels and locate potential sources.

- Nonpoint sources of suspended solids should be identified and best management land use and/or construction practices should be developed for the Tinkers Creek subbasin. Additional investigations should be conducted to learn the source of the elevated ambient levels of suspended solids.

Yellow Creek Subbasin

- Biological monitoring should be conducted in Yellow Creek downstream from the village of Ghent to assess impacts from any increased loadings of point source pollutants that may be requested. All requests for additional loadings to the Yellow Creek watershed should be evaluated to determine the assimilation capacity of the stream system using wasteload allocation modelling procedures as specified by the Ohio EPA. Biological monitoring should be considered as a condition of any future NPDES permits granted in the Yellow Creek subbasin. Yellow Creek is an important fish repopulation epicenter for the mainstem of the Cuyahoga River within the Cuyahoga Valley National Recreation Area.

Mill Creek and Big Creek Subbasins

- Continued monitoring at the mouths of each tributary are needed to document potential improvements following continued CSO/SSO remediation and implementation efforts.

Brandywine Creek

- Future monitoring should be conducted after the Hudson WWTP discharge is eliminated by the Cuyahoga Valley Interceptor in 1995-96.

Table 1. Aquatic life use attainment status for the Warmwater Habitat (WWH) use designation in Cuyahoga River and tributaries based on data collected from June to September 1991. Attainment status is based on the biocriteria for the Erie/Ontario Lake Plain ecoregion of Ohio (OAC 3745-1-07, Table 7-17).

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Attainment Status[c]	Comment
Cuyahoga River						
	Erie/Ontario Lake Plain - WWH Use Designation (Existing)					
89.4/89.5	34[ns]	6.4*	22*	47.0	PARTIAL	Ust. Tare Creek (wetland)
87.2/87.3	31*	7.9*	20*	47.0	**NON**	Dst. Tare Creek (wetland)
80.5/80.4	44	9.0	24*	63.0	PARTIAL	Dst. Ladue Res.(wetland)
75.8/75.8	38	8.7	40	70.5	FULL	Winchell Rd.
71.7/71.7	50	10.1	46	79.0	FULL	Pioneer Trail Rd.
67.5/67.6	51	8.9	48	66.0	FULL	Infirmary Rd.
64.5/64.2	44	8.8	54	83.0	FULL	Ust. Lake Rockwell
>[d]*Lake Rockwell*						
54.6/54.4	40	8.8	G	72.5	FULL	Kent urban area
49.8/49.8	35*	8.7	32[ns]	74.0	PARTIAL	Dst Kent/Fishcreek WWTPs
44.0/44.0	29*	6.9*	36	84.0	PARTIAL	Dst. Ohio Edison (gorge)
42.6/42.8	33*	8.1*	28*	86.0	**NON**	Ust. L. Cuyahoga River
>*Little Cuyahoga River*						
38.6/39.7	25*	6.9*	32[ns]	76.5	**NON**	Dst. L. Cuyahoga River
37.4/37.4	29	7.0	28	NA	NA	Akron WWTP Mix Zone
37.2/37.2	24*	6.9*	26*	79.5	**NON**	Dst. Akron WWTP
35.3/35.3	21*	6.5*	32[ns]	81.0	**NON**	Ira Road
26.7/26.5	22*	7.0*	36	73.0	**NON**	Boston Mills
>*Tinkers Creek*						
15.9/15.6	24*	7.3*	42	73.0	**NON**	Dst. Tinkers Cr. (NAMS)
11.5/11.0	19*	6.6*	42	71.5	**NON**	Ust. Southerly WWTP
10.5/10.5	20	3.9	26	NA	NA	Southerly Mix Zone
10.3/10.4	18*	6.1*	36	69.0	**NON**	Dst. Southerly WWTP
8.9/8.5	19*	5.8*	34	75.5	**NON**	Ust. Amer. Steel Wire
8.3/8.2	17*	5.9*	32[ns]	72.5	**NON**	Ust Bradley Rd. Smelters
7.4/7.3	20*	6.3*	34	63.0	**NON**	Ust. Big Creek
7.1/7.1	21*	6.9*	34	73.5	**NON**	Dst. Big Creek
	Interim Lake Erie Estuary Criteria [e] - WWH Use Designation (Existing)					
5.8/5.8E	17*	5.0*	26	55.5	**NON**	Ust. N&SS RR Bridge
Cuyahoga River Navigation Channel						
	Interim Lake Erie Estuary Criteria [e] - LRW Use Designation (Recommended)					
5.0/5.0W	21*	5.2*	10*	27.0	**NON**	Dst. LTV Steel
3.3/3.3E	19*	5.4*	6*	25.0	**NON**	Center Street
1.4/1.2W	20*	5.4*	8*	48.0	**NON**	Sixth Street

Table 1. (continued).

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Attainment Status[c]	Comment
Tare Creek						
	Erie/Ontario Lake Plain - WWH Use Designation (Existing)					
3.2/3.1	28*	NA	58	39.5	PARTIAL	Ambient; ust. wetland
Fish Creek						
	Erie/Ontario Lake Plain - WWH Use Designation (Existing)					
0.4/0.4	32*	NA	F*	70.5	**NON**	Channelized upstream
Little Cuyahoga River						
	Erie/Ontario Lake Plain - WWH Use Designation (Existing)					
11.0/11.0	27*	5.8*	44	65.0	**NON**	Dst. lakes, wetlands
-- /3.8	--	--	P*	64.0	**(NON)**	Akron CSOs
2.2/ --	26*	5.9*	--	64.0	**(NON)**	Akron CSOs
0.3/0.3	22*	6.0*	16*	75.0	**NON**	Dst. Ohio Canal
Yellow Creek						
	Erie/Ontario Lake Plain - WWH Use Designation (Existing)					
4.1/4.1	36	NA	VG	64.5	FULL	Ust. WWTP
1.7/1.7	38	NA	VG	76.5	FULL	Dst. WWTP
North Fork Yellow Creek						
	Erie/Ontario Lake Plain - WWH Use Designation (Existing)					
0.3/0.3	42	NA	VG	69.5	FULL	
Brandywine Creek						
	Erie/Ontario Lake Plain - WWH Use Designation (Existing)					
0.4/0.3	30*	NA	F*	72.0	**NON**	Near mouth
Furnace Run						
	Erie/Ontario Lake Plain - WWH Use Designation (Existing)					
0.9/0.9	46	NA	E	73.0	FULL	
Tinkers Creek						
	Erie/Ontario Lake Plain - WWH Use Designation (Existing)					
28.8/28.8	30*	NA	48	67.0	PARTIAL	Regional Reference Site
28.3 / --	22*	NA	--	--	**(NON)**	Wetland
25.0/25.0	21*	NA	54	77.5	**NON**	Dst. Streetsboro WWTP
21.9/22.1	18*	4.8*	40	62.0	**NON**	Dst. Pond Brook
14.3/14.3	22*	6.4*	40	73.5	**NON**	Dst. Twinsburg WWTP
11.2/11.2	19*	4.7*	38	79.0	**NON**	Dst. Glenwillow LF
10.5/10.3	17*	4.5*	32[ns]	73.5	**NON**	Dst.Solon (BM Run)
8.5/8.5	17*	5.0*	12*	74.0	**NON**	Dst. Inland Rec. LF
7.2/7.4	21*	5.0*	28*	82.5	**NON**	Dst. Hawthorne Cr.
2.2/2.4	17*	5.7*	F*	60.5	**NON**	Dst.Deer Lick Run&Wood Cr.
0.2/0.1	21*	6.9*	28*	76.5	**NON**	@ mouth

Table 1. (continued).

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Attainment Status[c]	Comment
Pond Brook						
Erie/Ontario Lake Plain - MWH Use Designation (Recommended)						
3.6/3.8	22*/22*	NA	F*/F	28.0	**NON**	Ust. Aurora Shores WWTP
3.4/3.4	32*/32	NA	P*/P*	33.5	**NON**	Dst. Aurora Shores WWTP
1.4/1.4	30*/30	NA	16*/16*	38.0	PARTIAL	Channelized
Beaver Meadow Run						
Erie/Ontario Lake Plain - WWH Use Designation (Recommended)						
0.2/0.2	18*	NA	P*	80.0	**NON**	Dst. Solon WWTP
Hawthorne Creek						
Erie/Ontario Lake Plain - WWH Use Designation (Recommended)						
0.8/0.8	28*	NA	F*	80.5	**NON**	Ambient
Mill Creek						
Erie/Ontario Lake Plain - WWH Use Designation (Recommended)						
0.2/0.2	24*	NA	P*	71.0	**NON**	CSOs, urban
Big Creek						
Erie/Ontario Lake Plain - WWH Use Designation (Recommended)						
0.2/0.1	22*	NA	P*	72.0	**NON**	CSOs, urban

* - significant departure from interim biocriteria; poor and very poor results are underlined.
ns - nonsignificant departure from interim biocriteria for WWH or EWH (4 IBI or ICI units; 0.5 MIwb units).
a - Narrative evaluation used in lieu of ICI (E=Excellent, VG=Very Good, G=good, F=Fair; P=Poor).
b - Qualitative Habitat Evaluation Index (QHEI) values based on the new version (Rankin 1989).
c - Attainment status based on one organism group is parenthetically expressed.
d - > denotes entry of major tributaries or presence of large physical structures (e.g.,dams) as the receiving stream flows from upstream to downstream.
e - For Lake Erie estuaries, Interim WWH criteria of MIwb=7.5 (boat); IBI=32 (boat) and ICI=22 are applied.
f - Modified Warmwater Habitat for channel modified areas.

Ecoregion Biocriteria: Erie-Ontario Lake Plain (EOLP)

INDEX - Site Type	WWH[e]	EWH	MWH[f]
IBI - Headwaters	40	50	24
IBI - Wading	38	50	24
IBI - Boat	40	48	24
Mod. Iwb - Wading	7.9	9.4	6.2
Mod. Iwb - Boat	8.7	9.6	5.8
ICI	34	46	22

STUDY AREA

Cuyahoga River Basin

The Cuyahoga River basin (Figure 4) drains 813 square miles and includes 1,220 stream miles spanning parts of Geauga, Portage, Summit and Cuyahoga counties, emptying into Lake Erie at Cleveland. As the river enters the lake, the harbor breakwall and the predominantly easterly littoral drift usually direct about 80 percent of the flow to the east, inside the breakwall. The general characteristics of streams in the study area are presented in Table 2.

The basin contains parts of three major physiographic provinces: the glaciated Allegheny Plateau, the till plains, and the lake plains. Most of the basin occurs in the glaciated Allegheny Plateau, and owes its topographic and hydrologic features to a complex glacial history. A small portion of the basin in southwest Cuyahoga County lies within the till plains, a relatively flat area more characteristic of north central and northwestern Ohio. The Cuyahoga River basin also cuts through the narrow border of the nearly level lake plains that surround Lake Erie and represents the ancient bottom of the predecessors to Lake Erie.

The Cuyahoga basin is situated within the Erie/Ontario Lake Plain (EOLP) ecoregion, a glacial plain that lies between the unglaciated Western Allegheny Plateau (WAP) ecoregion to the southeast and the relatively flat Eastern Corn Belt Plains (ECBP) ecoregion to the west and southwest. The EOLP ecoregion is characterized by glacial formations that can have a significant local relief of up to 300 feet and exhibits a mosaic of cropland, pasture, woodland, and urban areas. Soils are mainly derived from glacial till and lacustrine deposits and tend to be light colored, acidic, and moderately to highly erodible. Many glacial features characteristic of the EOLP ecoregion are found in the Cuyahoga River basin. The northern and eastern boundaries of this v-shaped watershed are largely defined by the terminal moraines left by two fingers of glacial ice. The retreating glaciers then buried the ancient river valleys with glacial outwash. The headwaters originate in northeastern Geauga County and flow southwest to Akron through relatively hilly knob and kettle topography. The river generally follows the course of the buried valleys, but does traverse a ridge of erosion resistant sandstone, resulting in the falls and cascades of Cuyahoga Falls. The river turns sharply to the northwest at the confluence with the Little Cuyahoga River just north of Akron, then winds through outwash terraces, till plains, and till ridges before reaching the flat lake plain of the Cleveland area.

Land use patterns vary greatly from the upper basin that is primarily agricultural, to the lower basin which is among the most densely populated and industrialized urban areas in the state. Agriculture is the predominant land use in the upper basin, and while less prevalent in the middle basin, the soils are highly erodible and can result in significant sedimentation and nutrient loadings. Resource extraction and hydromodification are localized throughout the basin. The waters of the heavily populated areas of the middle and lower basin are influenced by urban and construction site runoff, combined/sanitary sewer overflows, and land disposal.

Part of the Cuyahoga River is a designated State Scenic River and several stream segments within the basin have been designated as State Resource Waters. The Cuyahoga River, from the Ohio Edison Dam to the mouth and the nearshore area two miles west to ten miles east of the mouth has been identified as an Area of Concern by the International Joint Commission.

Tinkers Creek Subbasin

Tinkers Creek is the largest tributary of the Cuyahoga River and drains portions of Portage, Geauga, Summit and Cuyahoga counties (Figure 5). Tinkers Creek has a drainage area of 96.4 square miles and a total length of about 30 miles and enters the Cuyahoga River at RM 16.36. The watershed lies on a glaciated plateau. Soils are mostly silt loam and clayey silt loam. Wetland swamps, bogs and fens are common in the upper watershed. Flows in the lower section of the creek are highly influenced by the discharge of treated wastewater from upstream WWTPs; in 1991 the combined effluent had a median discharge of 11.623 mgd or 17,983 cubic feet per second (cfs).

Other Tributaries

Additional Cuyahoga River tributaries where water, sediment or biological sampling was conducted in 1991 included Tare Creek (confluence RM 88.55), Breakneck Creek (RM 56.82), Fish Creek (RM 52.12), the Little Cuyahoga River (RM 42.27), Yellow Creek and North Fork Yellow Creek (RM 32.7), Brandywine Creek (RM 24.2), Furnace Run (RM 33.1), Mill Creek (RM 11.5), Big Creek (RM 7.2), Kingsbury Run (RM 4.15) and the old Cuyahoga river channel (RM 0.4) in the estuary near the confluence with Lake Erie. Table 3 lists sampling locations and sampling types for all stations in the 1991 survey.

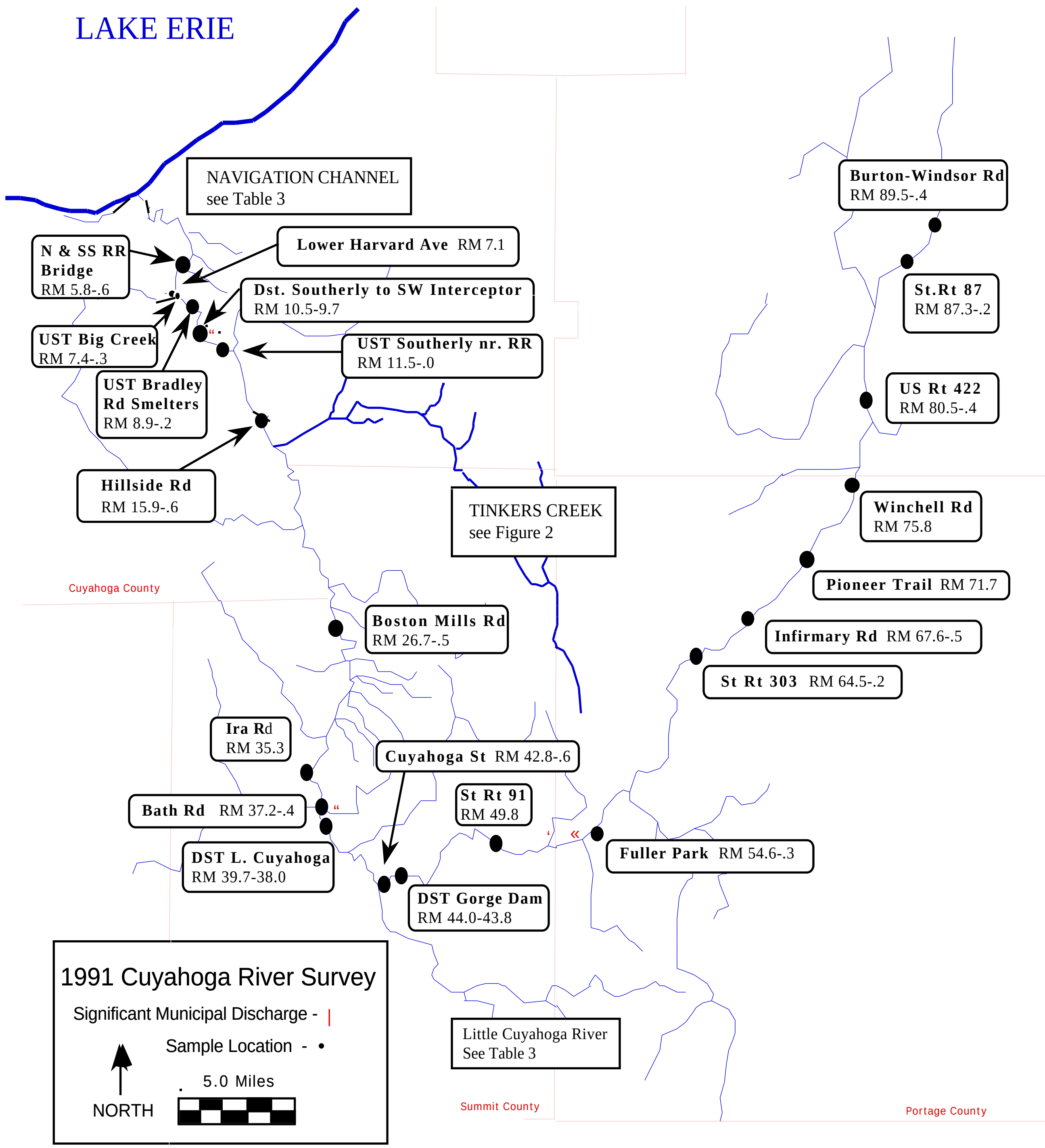


Figure 4. Sampling locations in the Cuyahoga River basin study area. Physical/chemical, benthic macroinvertebrate and fish were sampled at each location. Additional sampling sites are listed in Table 3.

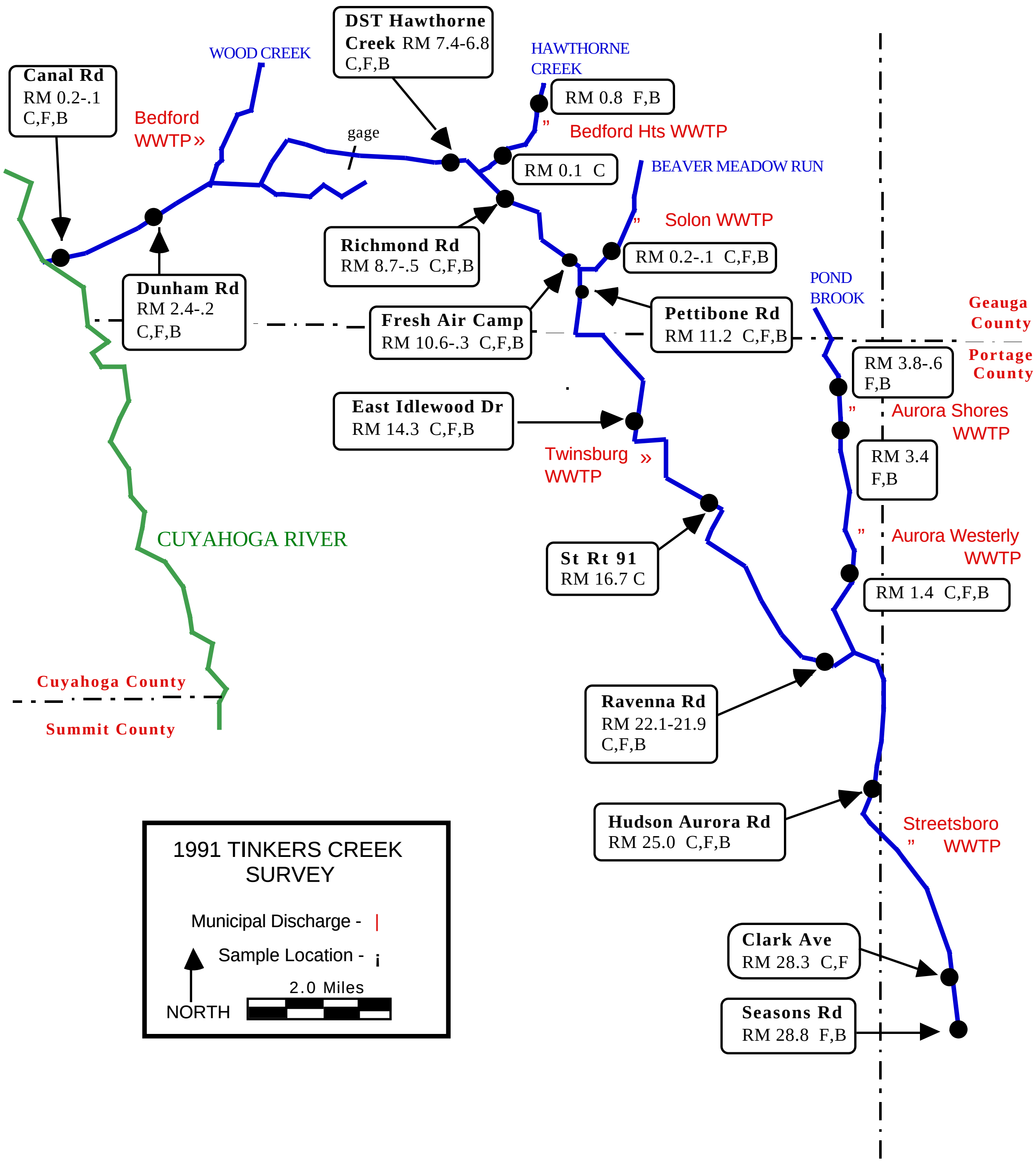


Figure 5. Locations of chemical and biological sampling stations in the Tinkers Creek basin study area, 1991. Each station included physical/chemical (C), benthic macroinvertebrate (B), and fish (F) sampling unless otherwise indicated. Additional sampling locations are listed in Table 3.

Table 2. Stream characteristics and significant identified pollution sources in the Cuyahoga River basin study area.

Stream Name	Length (Miles)	Avg. Gradient (Feet/Mile)	Drain. Area (Square Miles)	Nonpoint Source Pollution Categories	Point Sources Evaluated
Cuyahoga River (mainstem)	100.1	7.1	813.3	Resource extraction, hydromodification, urban runoff, land disposal, in place pollutants, agriculture	Municipal WWTPs: Mantua, Burton, Kent, Fishcreek, Akron, NEORSD-Southerly, Middlefield (unnamed trib) Industrials: Harshaw Chem, American Steel & Wire, LTV Steel, Zaclon CSO/SSO: Cuyahoga Falls, Akron, Cleveland/NEORSD
Tare Creek	8.0	22.5	12.2	Agriculture	Hans Rothenbuhler & Sons
W. Branch Cuy. R.	19.2	12.5	39.9	Agriculture run-off	--
Little Cuyahoga R.	23.8	20.6	86.3	Agriculture, urban run-off, hydromodification, in-place pollutants	Akron CSOs/SSOs
Yellow Creek	16.7	44.3	40.6	Agriculture, urban run-off, Resource Extraction, on-site septic systems Land disposal	Robinwood Hills WWTP
North Fork Yel. Cr.	6.4	54.2	9.8	--	
Brandywine Creek	11.5	35.6	26.2	Agriculture, urban run-off, Hydromodification	CSO
Tinkers Creek (subbasin)	33.0	15.4	112.9	Agriculture,urban runoff, Hydromodification, Land disposal, In place pollutants, construction site runoff	MunicipalWWTPs: CSO,Aurora Westerly, Aurora Shores, Streetsboro, Solon, Twinsburg, Bedford, Bedford Heights Industrials: Zircoa
Mill Creek	12.2	53.5	18.14	Urban runoff, land disposal	CSO/SSO
Big Creek	12.0	23.4	38.65	Urban runoff,	CSO/SSO, Ford Motor Co., Gen. Motors
Burke Branch	6.7	58.8	4.41	In-place pollutants, land disposal	LTV Steel
Morgan Run	4.8	73	2.05	Urban-industrial runoff,	LTV Steel, CSO/SSO
Kingsbury Run	9.5	53.2	8.53	Urban runoff, Hydromod-ification, in place-pollutants	CSO/SSO

METHODS

All chemical, physical, and biological field, laboratory, data processing, and data analysis methods and procedures follow 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 ll-llI (Ohio Environmental Protection Agency 1987, 1989b, 1989c), and The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989) for aquatic habitat assessment. A list of all 1991 sampling locations in the 1991 survey is presented in Table 3.

Attainment/non-attainment of aquatic life uses is determined by using biological criteria codified in Ohio Administrative Code (OAC) 3745-1-07, Table 7-17. The biological community performance measures used include the Index of Biotic Integrity (IBI) and the Modified Index of well-being (MIwb), both of which are based on fish community characteristics, and the Invertebrate Community Index (ICI) which is based on macroinvertebrate community characteristics. IBI and ICI are multi-metric indices patterned after an original IBI described by Karr (1981) and Fausch et al. (1984). The MIwb is a measure of fish community abundance and diversity using numbers and weight information; it is a modification of the original Index of well-Being applied to fish community information from the Wabash River (Gammon 1976, Gammon *et. al.* 1981).

Performance expectations for the basic aquatic life uses (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 1988). 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 an aquatic life use is FULL if all three indices (or those available) meet the applicable criteria, PARTIAL if at least one index does not attain and performance does not fall below the fair category, and **NON** if all indices either fail to attain or any index shows poor or very poor performance.

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989). Various attributes of the available habitat are scored based on their overall importance to the establishment of viable, diverse aquatic faunas. Evaluations of type and quality of substrate, amount of instream cover, channel morphology, extent of riparian canopy, pool and riffle development and quality, and stream gradient are among the metrics used to determine the QHEI score which generally ranges from 20 to 100. The QHEI is used to evaluate the characteristics of a stream segment, not just the characteristics of a single sampling site. As such, individual sites may have much 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 shown that values higher than 60 are generally conducive to the establishment of warmwater faunas while scores greater than 75-80 often typify habitat conditions that could support exceptional faunas.

During this survey, macroinvertebrates were sampled using modified Hester/Dendy multiple-plate artificial substrate samplers supplemented with a qualitative assessment of the available natural substrates. Exceptions included tributary sites in the Tinkers Creek subbasin, Fish Creek, the Yellow Creek subbasin, Brandywine Creek, Furnace Run, Mill Creek, Big Creek and two locations in the Cuyahoga River (RM 54.4) and Tinkers Creek (RM 2.4), where the artificial substrate samplers were lost and qualitative samples only were collected.

Fish were sampled with pulsed D.C. electrofishing gear using the wading method (150 meter zones) or boat method (500 meter zones). Cuyahoga River, Tinkers Creek and Little Cuyahoga River stations were sampled two or three times. Exceptions were the Cuyahoga River at RM 89.4 and Tinkers Creek at RMs 28.8 and 28.3, which were sampled only once. All other tributary locations were electrofished once using the wading method.

An Area of Degradation Value (ADV; Rankin and Yoder 1991) was calculated for the study area based on the longitudinal performance of the biological communities. The ADV portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, and ICI) departs from the stream criterion or the upstream level of performance (Figure 6). The magnitude of impact refers to the vertical departure of each index below the criterion. The total ADV is the area beneath the ecoregional criterion when the results for each index are plotted against river miles. This is also expressed as ADV/mile to normalize comparisons between segments and other areas. To generate the ADV, ICI values were assigned based on the narrative evaluation for sites that lacked valid quantitative data due to loss or disturbance or the artificial substrates.

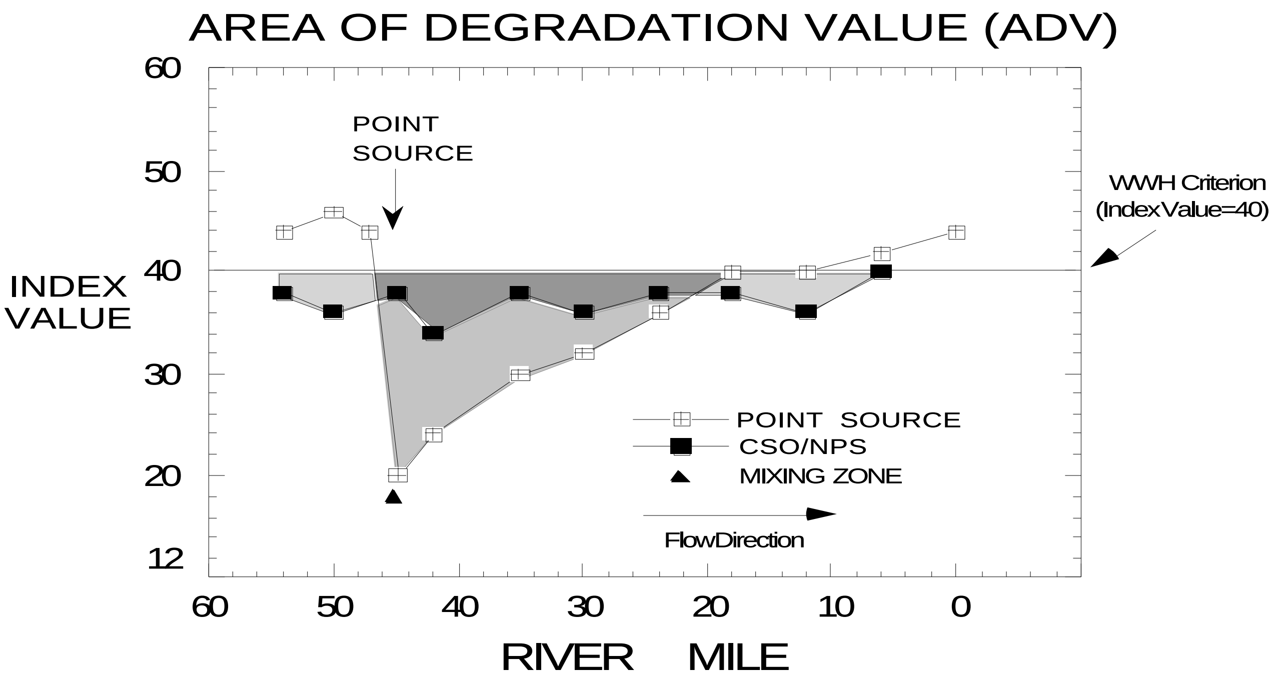


Figure 6. Graphic illustration of the Area of Degradation Value (ADV) based on the ecoregion biocriterion (WWH in this example). The index value trend line indicated by the unfilled boxes and solid shading (area of departure) represents a typical response to a point source impact (mixing zone appears 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.

Table 3. Sampling locations (effluent sample - E, water chemistry - C, sediment chemistry - S, macroinvertebrates (benthos) - B, fish - F, fish tissue - FT, continuous monitor - D) in the Cuyahoga River study area, 1991. With the exception of effluent locations, river miles are rounded to tenths.

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 min. Quad. Map
Cuyahoga River				
89.5	B	41 29 14 / 81 06 23	CR 14	Middlefield
89.4	C,F,D	41 29 10 / 81 06 26	CR 14	Middlefield
87.3	C,B,D	41 27 54 / 81 07 37	SR 87	Burton
87.2	F	41 27 52 / 81 07 42	SR 87	Burton
80.5	C,F,S	41 23 12 / 81 09 28	US 422	Burton
80.4	B	41 23 07 / 81 09 27	US 422	Burton
75.8	C,F,B,D	41 20 28 / 81 10 01	Winchell Rd.	Mantua
72.6	C (1X)	41 18 37 / 81 11 42	SR 82	Mantua
71.7	C,F,B	41 18 02 / 81 12 11	Dst. Pioneer Trail Rd.	Mantua
69.8	D	41 16 53 / 81 13 15	Ust. Mantua WWTP	Mantua
69.1	D	41 16 38 / 81 13 38	Dst. Mantua WWTP	Mantua
67.6	B,D	41 16 09 / 81 14 45	Infirmary Rd.	Mantua
67.5	C,F,D	41 16 06 / 81 14 49	Infirmary Rd.	Mantua
64.5	F	41 14 59 / 81 16 51	SR 303	Kent
64.3	C,S,D	41 42 42 / 81 17 11	SR 303	Kent
64.2	B	41 14 36 / 81 17 28	SR 303	Kent
54.6	F	41 09 00 / 81 21 53	Fred Fuller Park	Kent
54.4	B	41 09 00 / 81 21 57	Fred Fuller Park	Kent
54.3	C	41 08 58 / 81 22 03	Fred Fuller Park	Kent
52.6	C (1X)	41 08 16 / 81 23 26	Middlebury Rd.	Kent
49.8	C,F,B,S	41 08 32 / 81 26 21	SR 91	Hudson
45.7	D	41 07 27 / 81 29 04	Ust. Edison pool	Akron East
44.6	D	41 07 21 / 81 29 50	Ohio Edison pool	Akron East
44.5	D	41 07 25 / 81 29 56	Dst. Ohio Edison dam	Akron East
44.0	F, B	41 07 22 / 81 30 28	Edison Gorge	Akron West
43.8	C,S	41 07 24 / 81 30 39	Edison Gorge	Akron West
42.8	B	41 07 01 / 81 31 22	Cuyahoga St.	Akron West
42.6	C,F,S,D	41 07 01 / 81 31 30	Cuyahoga St.	Akron West
39.7	B	41 08 19/ 81 33 10	Dst. L. Cuyahoga R.	Peninsula
38.6	F	41 08 39 / 81 33 53	Dst. L. Cuyahoga R.	Peninsula
38.0	C,S,D	41 09 10 / 81 34 05	Dst. L. Cuyahoga R.	Peninsula
37.45	E	41 09 33 / 81 34 22	Akron WWTP 001	Peninsula
37.4	F, B	41 09 36 / 81 34 23	Akron WWTP mix zone	Peninsula
37.2	C,F,B,D	41 09 44 / 81 34 28	Bath Rd.	Peninsula
35.3	C,F,B,S,D	41 10 33 / 81 35 02	Ira Rd.	Peninsula
26.7	F	41 15 46 / 81 33 37	Boston Mills Rd	Northfield
26.5	C,B,S,D	41 15 47 / 81 33 37	Boston Mills Rd	Northfield
20.8	C (1X)	41 07 01 / 81 32 30	SR 82	Northfield

Table 3. (continued).

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 min. Quad. Map
Cuyahoga River (continued)				
15.9	F	41 22 15 / 81 36 53	Hillside Rd.	Northfield
15.6	C,B,D	41 22 44 / 81 36 53	Hillside Rd.	Northfield
13.2	C,D	41 23 43 / 81 37 48	Independence Gage	Cleveland South
11.5	F	41 25 04 / 81 38 30	Ust. Southerly WWTP	Cleveland South
11.0	C,B,S	41 25 04 / 81 38 50	Ust. Southerly WWTP	Cleveland South
10.57/0.2	E	41 25 08 / 81 38 55	Southerly WWTP 001	Cleveland South
10.57/0.1	E	41 25 13 / 81 39 07	Southerly eff. channel	Cleveland South
10.5 (N Bank)	C,F,B	41 25 10 / 81 39 22	Southerly mix zone	Cleveland South
10.5 (S Bank)	B	41 25 10 / 81 39 18	Opposite Mix zone	Cleveland South
10.4	B	41 25 16 / 81 39 27	Dst. Southerly WWTP	Cleveland South
10.3	F	41 25 16 / 81 39 33	Dst. Southerly WWTP	Cleveland South
9.7	C,S	41 25 37 / 81 39 57	@ SW Interceptor	Cleveland South
8.9	F	41 26 04 / 81 40 07	Ust. American Steel	Cleveland South
8.5	B	41 26 20 / 81 40 09	Ust. American Steel	Cleveland South
8.3	C,F,S	41 26 22 / 81 40 15	Ust. Bradley Rd. Smelters	Cleveland South
8.2	B	41 26 19 / 81 40 16	Ust. Bradley Rd. Smelters	Cleveland South
7.4	F,S	41 26 42 / 81 41 58	Ust. Big Creek	Cleveland South
7.3	C,B	41 26 42 / 81 41 03	Ust. Big Creek	Cleveland South
7.1	C,F,B,S,D	41 26 51 / 81 41 00	Dst. Big Creek	Cleveland South
6.74	E	41 27 06 / 81 40 52	LTV East 002	Cleveland South
6.1	S	41 27 48 / 81 40 52	Ust. LTV West 022	Cleveland South
6.0	E	41 27 46 / 81 40 53	LTV West 022	Cleveland South
5.9	C (1X)	41 27 48 / 81 40 50	LTV Footbridge	Cleveland South
5.84	E	41 27 54 / 81 40 45	LTV West 024	Cleveland South
5.8	F, B	41 27 50 / 81 40 47	Ust. Shipping Channel	Cleveland South
5.6	C,S,D	41 27 53 / 81 40 37	@ LTV 802 intake	Cleveland South
5.5	S	41 27 54 / 81 40 26	Ust. LTV East 005	Cleveland South
5.39	E	41 27 55 / 81 40 23	LTV East 005	Cleveland South
5.3	S	41 27 59 / 81 40 19	Dst. LTV East 005	Cleveland South
5.07	E	41 28 13 / 81 40 10	LTV West 027	Cleveland South
5.0	C,F,B,S,D	41 28 16 / 81 40 10	Clark Ave.	Cleveland South
4.91	E	41 28 24 / 81 40 12	LTV East 014	Cleveland South
4.70	E	41 28 30 / 81 40 16	LTV East 017	Cleveland South
4.5	S	41 28 39 / 81 40 03	@ Zaclon 004	Cleveland South
4.3	S	41 28 43 / 81 40 26	Ust. Kingsbury Run	Cleveland South
4.1	C,S,D	41 28 57 / 81 40 35	Dst. Kingsbury Run	Cleveland South
3.3	C,F,B,S,D	41 29 17 / 81 41 07	West 3rd. St.	Cleveland South
2.8	S	41 28 57 / 81 40 35	Dst. Walworth Run	Cleveland South
1.9	C,S,D	41 29 41 / 81 41 54	Carter Rd (twin RR bridge)	Cleveland South
1.4	F	41 29 26 / 81 42 18	Columbus Ave.	Cleveland South
1.2	B	41 29 26 / 81 42 17	Columbus Ave.	Cleveland South

Table 3. (continued).

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 min. Quad. Map
Cuyahoga River (continued)				
0.9	C,S,D	41 29 40 / 81 42 12	Center Street	Cleveland South
0.8	S	41 29 35 / 81 42 14	Near Center St.	Cleveland South
0.0	C,S	41 30 09 / 81 42 43	@ mouth	Cleveland South
Tare Creek				
3.2	F	41 30 07 / 81 04 13	CR 14	East Claridon
3.1	B	41 30 04 / 81 04 13	CR 14	East Claridon
1.6	C	41 29 09 / 81 04 57	SR 608	Middlefield
Breakneck Creek				
14.7	S	41 05 12 / 81 18 04	Homestead Ave.	Suffield
6.9	S	41 08 25 / 81 16 14	Summit Rd.	Kent
Fish Creek				
0.4	F,B	41 08 44 / 81 23 51	River Rd.	Hudson
Little Cuyahoga River				
11.0	C,F,B,S	41 03 17 / 81 24 01	Gilchrist Rd.	Akron East
3.8	B	41 05 15 / 81 29 27	North St.	Akron West
2.2	F	41 05 31 / 81 30 54	Main St.	Akron West
2.1	C,S	41 05 33 / 81 31 01	Main St.	Akron West
0.3	C,F, B,S	41 06 53 / 81 31 39	Dst. Ohio Canal	Akron West
Yellow Creek				
5.7 (1988)	C	41 09 41 / 81 38 10	Granger-Shaw Rd	West Richfield
4.1	C,F,B	41 09 26 / 81 37 50	Yellow Cr. Rd.	West Richfield
1.7	C,F,B	41 09 36 / 81 36 00	Dst Waterfall	Peninsula
0.1 (1988)	B	41 09 38 / 81 34 31	Riverview Rd.	Peninsula
North Fork Yellow Creek				
0.3	C,F,B	41 09 42 / 81 38 17	Ust. WWTP #42	West Richfield
0.1	C	41 09 33 / 81 38 18	Dst. WWTP #42	West Richfield
Furnace Run				
0.9	C	41 12 12 / 81 34 59	Riverview Rd.	Peninsula
0.4	F	41 12 05 / 81 34 33	Everett Rd.	Peninsula
0.3	B	41 12 05 / 81 34 25	Everett Rd.	Peninsula
Brandywine Creek				
9.0	C	41 14 57 / 81 27 09	West Prospect Rd.	Hudson
8.0	C	41 15 12 / 81 28 22	Ust. Hudson WWTP	Twinsburg
7.9	C	41 15 12 / 81 28 24	Dst. Hudson WWTP	Twinsburg
7.0	C	41 15 37 / 81 29 21	Hines Hill Rd.	Twinsburg
5.2	C	41 16 59 / 81 30 17	Twinsburg Rd.	Twinsburg
0.2	C,F,B	41 17 08 / 81 33 46	Old Box Co. Rd.	Northfield
Tinkers Creek				
28.8	F,B,D	41 12 53 / 81 22 22	Seasons Rd.	Kent
28.3	C,F,S	41 12 58 / 81 22 23	Clark Rd.	Kent
25.0	C,F,B,D	41 15 43 / 81 23 39	Hudson-Aurora Rd.	Twinsburg

Table 3. (continued).

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 min. Quad. Map
Tinkers Creek (continued)				
22.1	C,B	41 17 07 / 81 24 22	Ravenna Rd.	Twinsburg
21.9	F	41 17 08 / 81 24 34	Ravenna Rd.	Twinsburg
16.7	C	41 19 06 / 81 26 06	SR. 91	Twinsburg
15.7	D	41 19 26 / 81 26 57	Ust. Twinsburg WWTP	Twinsburg
14.8	D	41 19 45 / 81 27 13	Dst. Twinsburg WWTP	Twinsburg
14.3	C,F,B,S	41 19 59 / 81 27 28	East Idlewood Dr.	Twinsburg
13.4	D	41 20 24 / 81 27 16	Glenwood Dr.	Twinsburg
11.2	C,F,B,S,D	41 21 26 / 81 28 20	Pettibone Rd.	Twinsburg
10.6	C	41 21 46 / 81 28 16	Fresh Air Camp	Twinsburg
10.5	F,D	41 21 50 / 81 28 19	Fresh Air Camp	Twinsburg
10.3	B	41 21 52 / 81 28 14	Fresh Air Camp	Twinsburg
8.7	C,S	41 22 36 / 81 29 24	Richmond Rd.	Shaker Heights
8.5	F,B,D	41 22 36 / 81 29 35	Dst. Richmond Rd.	Chagrin Falls
7.4	B	41 23 00 / 81 30 27	I-271	Shaker Heights
7.2	F,D	41 23 01 / 81 30 42	I-271	Shaker Heights
6.8	C	41 23 02 / 81 30 40	Dst. Hawthorn Creek	Shaker Heights
3.6	S	41 22 25 / 81 34 47	Dst. Deer Lick Run	Shaker Heights
2.2	C,D	41 22 25 / 81 34 47	Dunham Rd.	Northfield
2.4	B	41 22 30 / 81 34 31	Ust. Dunham Rd.	Northfield
2.2	F	41 22 26 / 81 34 45	Ust. Dunham Rd.	Northfield
0.2	F	41 21 57 / 81 36 26	Canal Rd.	Northfield
0.1	C,B,S	41 21 53 / 81 36 33	Canal Rd.	Northfield
Pond Brook				
3.8	B	41 20 12 / 81 24 10	Ust. A. Shores WWTP	Twinsburg
3.6	F	41 29 26 / 81 42 18	Ust. A. Shores WWTP	Twinsburg
3.4	B,F,D	41 19 51 / 81 24 10	Dst. A. Shores WWTP	Twinsburg
3.0	D	41 19 36 / 81 24 07	Dst. A. Shores WWTP	Twinsburg
1.6	D	41 18 27 / 81 23 58	Ust. Aurora Westerly	Twinsburg
1.4	C,F,B	41 18 18 / 81 23 59	SR 82 (Dst. A. Westerly)	Twinsburg
0.3	D	41 17 33 / 81 24 02	Near mouth	Twinsburg
Aurora Westerly WWTP Trib.				
0.1	D	NA	@ mouth	Twinsburg
Beaver Meadow Run				
2.8	D	NA	Aurora Rd.	Chagrin Falls
1.0	D	NA	Dst. Solon Rd.	Chagrin Falls
0.2	F,B	41 21 40 / 81 28 09	Cochran Rd.	Chagrin Falls
0.1	C,S	41 21 40 / 81 28 12	Cochran Rd.	Chagrin Falls
Hawthorn Creek				
0.8	F	41 23 00 / 81 29 21	Richmond Rd.	Chagrin Falls
0.2	S,D	41 23 04 / 81 29 26	Ust. Bed. Hts. WWTP Trib.	Shaker Heights

Table 3. (continued).

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 min. Quad. Map
Hawthorn Creek (continued)				
0.1	C,D	41 23 05 / 81 29 29	Dst. Bed. Hts. WWTP Trib.	Shaker Heights
Mill Creek				
2.9	S,C	41 26 41 / 81 37 30	Ust. Landfills	Cleveland South
1.6	C	41 26 11 / 81 38 12	Dst. Harvard Refuse L.F.	Cleveland South
0.7	S	41 25 26 / 81 38 16	Dst. Landfills	Cleveland South
0.5	C	41 25 16 / 81 38 10	Ust. Unnamed Trib.	Cleveland South
0.2	S	41 25 09 / 81 38 13	Near Canal Rd.	Cleveland South
0.1	C,S,F,B	41 25 06 / 81 38 16	Canal Rd.	Cleveland South
Unnamed Trib. to Mill Creek				
0.1	C	41 25 15 / 81 38 08	At mouth	Cleveland South
Big Creek				
0.2	C,F,B,S	41 26 45 / 81 41 13	Jennings Rd.	Cleveland South
Kingsbury Run				
0.1	C,S	41 28 53 / 81 40 30	At Mouth	Cleveland South
Cuyahoga R. / Old River Channel (RM 0.4)				
0.8	S	41 29 30 / 81 43 04	Near Dry Dock/ Akzo	Cleveland South

RESULTS AND DISCUSSION

Pollutant Loadings and Compliance History: 1980 - 1991

Cuyahoga River Basin

- Many municipal and industrial point source discharges and waste water collection systems have undergone significant changes due to upgrades, improvements, wastewater consolidation and closures over the past decade. Table 4 presents a summary of wastewater pollution control changes and improvements throughout the watershed.

Upper Cuyahoga River (Headwaters to Lake Rockwell)

- Total pollutant loading from municipal point source dischargers for conventional parameters (*i.e.,* TSS, BOD, phosphorus) has declined since 1980 for each WWTP in the upper basin (Figures 7-8). However, the Mantua WWTP loading for ammonia-N has increased since 1989 and were similar to the loadings discharged in 1980.

- Industrial loading reductions have occurred at Burton Rubber (not presented) and the Hans Rothenbuhler & Sons (Middlefield Cheese) plants in the Tare Creek subbasin. A survey of the upper Cuyahoga watershed for phosphorus was conducted in 1985-88 by the E.B. Long consulting firm. The report concluded Middlefield Cheese was a major source of phosphorus in this segment. Loadings of TSS and phosphorus have been considerably reduced at this facility following treatment upgrades in 1990. The report also concluded that point source phosphorus controls that were under implementation in 1990 should have resulted in an approximate 40% reduction in loadings to the Lake Rockwell water supply reservoir. Even with the improvements and reduced loadings, Middlefield Cheese discharges the largest TSS and phosphorus loadings to this segment of the Cuyahoga River.

Middle Cuyahoga River (Lake Rockwell to Big Creek)

- Loadings and discharge volumes for major municipal point source discharges at Kent, Fishcreek, Akron and Southerly were evaluated for trends over the past decade (Figures 9-14). Loadings for conventional parameters (*i.e.,* TSS, BOD, $NH\text{-}N_3$, etc.) have declined for all WWTPs in the middle Cuyahoga River segment except the Summit County Fishcreek WWTP. Conversely, discharge volumes have shown increasing trends at each WWTP except Akron.

- Loadings and discharge volumes from the Fish Creek WWTP (Figures 9-10) have increased due to development within the service area and subsequently increased wastewater flows to the WWTP. Fishcreek is a relatively new WWTP (constructed in 1980) and treatment efficiency has remained high. Preliminary work is in progress to determine if this facility can expand to meet the increasing development pressures in this region. This segment of the river also receives effluent from the Kent WWTP. Upgrades of the Kent WWTP in 1985 and 1986 resulted in significant declines in both annual and third quarter ammonia-N loadings (Figure 10). Currently, the Kent and Fishcreek WWTPs contribute to unverified model predictions of dissolved oxygen WQS violations in the Munroe Falls Dam Pool. Continuous monitoring of D.O. is needed to verify these projections for this section.

- Bypasses of untreated wastewater at the Akron (Figure 11) and NEORSD Southerly WWTPs have been virtually eliminated. However, bypasses of chlorinated wastewater following primary treatment continue to occur frequently at the Akron WWTP. NPDES monitoring has been inadequate to accurately quantify these bypassed loadings. The bypassed secondary flow is estimated and only quarterly monitoring of $cBOD_5$, TSS and heavy metals is conducted before mixing with the final plant effluent. Final effluent samples can be collected during periods when no bypasses are occurring. Thus, the accuracy of estimates of the total loading of contaminants to the river is questionable. Ohio EPA is currently drafting a revised permit for the Akron WWTP that will address these monitoring and accuracy concerns.

- Using the existing data, loadings of ammonia-N, TSS, and metals from the Akron WWTP show a definite decreasing trend between 1980 and the present (Figures 12-13). However, heavy metals loads were highest during the mid to late 1980s. Institution of additional pretreatment requirements by Akron following enforcement measures by the Ohio EPA and construction improvements in 1989 has resulted in reductions in metals loadings since then. Loadings for $cBOD_5$ have declined since 1980 but not to the significant degree observed in other parameters.

- CSOs and SSOs in the Akron and Cuyahoga Falls area discharge significant amounts of untreated wastewater to the Cuyahoga River via the Ohio Canal, the Little Cuyahoga River, several smaller tributaries, and by direct discharge to the mainstem. Most of the overflow events occur within the Little Cuyahoga River subbasin. There had been no significant CSO remediation efforts in Akron before the 1991 survey. However, plans are currently being developed to address CSO problems in the service area. The city has been more aggressive in SSO identification and remediation. Bulkheading of SSOs was initiated in 1988 and all SSOs, except overflow #5, are scheduled for elimination by 1994. Overflow at #5 will occur only following a ten-year rain event.

- The construction and connection of the NEORSD Southwest Interceptor to the NEORSD Southerly WWTP has eliminated many smaller WWTPs that caused localized water quality problems. The city of Cleveland has also eliminated several chronic SSO and pump station overflows since 1984, the NEORSD has assumed control of other pump stations and has aggressively investigated and repaired leaks and breaks within the sewer system. These actions have contributed to the increased discharge volumes from NEORSD Southerly over the past decade (Figure 9). Also, a series of treatment plant upgrades (Table 4) have resulted in significant reductions in pollutant loadings (Figure 14).

Lower Cuyahoga River (Big Creek to Mouth)

- Reductions of industrial pollutant loadings to the Cuyahoga River have occurred primarily due to improved treatment facilities, process water recycling, tie-ins to sanitary sewers, production cutbacks, and plant closings. Better management of the facilities and awareness of environmental concerns has also contributed to improved wastewater treatment.

- LTV and Zaclon are the largest remaining industrial dischargers to the river and both have upgraded wastewater treatment. NPDES monitoring has been inadequate to completely monitor loading from LTV. The use of internal monitoring stations, calculated flows and changes in LTV processes and effluent monitoring requirements has made an accurate determination of pollutant loads very difficult. The use of the river for cooling water makes an accurate estimate of net loadings for parameters such as TSS even more problematic. For the above reasons, loadings trends were not plotted for inclusion in this report. However, installation of recycle systems in the 1980s and closure of blast furnaces C4 (1979), C3 (1986), and C2 (12/1990) and coke plants #1 (12/1990) and #2 (12/1992) have significantly decreased pollutant loadings. Since 1993, there are no longer any operating coke plants in the Cuyahoga River basin.

- Zaclon loadings have fluctuated since 1984 (Figure 15). NPDES permit monitoring requirements also changed from analysis of dissolved metals to total metals.

- Englehard/Harshaw has had most of its process wastewater tied into the sanitary sewers in 1989. Since the fall of 1993, all process wastewater from Harshaw has been diverted to sanitary sewers. Storm water, groundwater and non-contact cooling water are the only remaining discharges.

- The City of Cleveland eliminated several chronic SSO and pump station overflows in 1988. The city and the NEORSD also reached agreement on the NEORSD assuming control of pump stations where ownership of the stations was unclear. NEORSD and Ohio EPA have worked to eliminate more than a dozen broken sanitary sewers or illegal tie-ins to storm sewers in the Big Creek watershed since 1989. There are approximately 72 CSOs that discharge to the Cuyahoga River Basin in the NEORSD service area. At least 35 of these discharged at least once during dry weather to the Lower Cuyahoga River or tributaries in the Cleveland Metropolitan area in 1990. An average 1.45 billion gallons per year of combined sewer flow enters the Cuyahoga River based upon discharge estimates from 1973 and 1980 reports. However, these amounts have probably been reduced following the recent controls and sewer remediation instituted by NEORSD. The Cuyahoga RAP Stage One Report lists the major contributors of pollutants to the Cuyahoga River from Akron to Lake Erie. These sources include atmospheric deposition, urban/construction site storm water run-off, industrial stockpiles, suburban and metropolitan areas, and streets and highways as.

Table 4. Wastewater treatment plant improvements, closures or regionalization and wastewater collection system improvements in the Cuyahoga River basin, 1979 to 1991.

Facility/Area	Date	Type of Improvement
		Municipal Entities
Cuyahoga River		
Bolingbrook	1988	Upgraded
Red Fox	1988	Upgraded
Mantua	1988	Upgraded
Kent	1986	Upgraded
Akron WWTP	1984	Sludge processing improvements and new belt filter press.
	1984	Double primary capacity (to 150 MGD); enhanced settling, phosphorus removal.
	1985	Digester renovations.
	1986	Addition of six new final clarifiers and renovation of some existing equipment.
	1986	Primary tank renovations.
	1987	Sludge composting facility.
	1988	Re-piping of secondary bypasses to receive chlorination. Construction of new discharge structure.
	1989	Headworks improvement to prevent raw bypasses and new fine screens.
Sharon-Seven Hills	1985	Closed or wastewater diverted to a regional facility.
Nagy #7	1987	Closed or wastewater diverted to a regional facility.
Hawthorne State Hospital	1987	Closed or wastewater diverted to a regional facility.
Northfield	1987	Closed or wastewater diverted to a regional facility.
Greenwood Village #23	1986	Closed or wastewater diverted to a regional facility
Brecksville	1985	Closed or wastewater diverted to a regional facility
Valleview Area	1990	Initial sewer lines installed in industrial area
Garfield Heights	1991	Initial sewer lines installed in industrial area
NEORSD -Southerly	1974	Incinerator modification
	1979	Installation of centrifuges and gravity thickeners, ash lagoons, primary sludge degritting facilities, sludge storage facilities, and solids handling facilities.
	1981	Installation of primary treatment facilities, new headworks, second stage treatment facilities, effluent filters and chlorine facilities.
	1987	Installation of first stage treatment facilities
	1988	First stage final settling rehabilitation completed
	1989	Odor control improvements
	1991	Boiler and vacuum filter improvements; Installation of disinfection and dechlorination facilities (late 1991).
Tare Creek		
Middlefield	1991	Upgraded

Table 4. (continued).

Facility/Area	Date	Type of Improvement
Eckert Ditch		
County Home	1988	Upgraded
Breakneck Creek		
West Park	1987	Closed or wastewater diverted to a regional facility.
Village Estates	1990	Closed or wastewater diverted to a regional facility.
Franklin Hills	1988	Upgraded
Brandywine Creek		
Macedonia #9	1988	Closed or wastewater diverted to regional facility
Macedonia #15	1988	Closed or wastewater diverted to regional facility
Hudson Village facility in	1988	Upgraded-Wastewater will be diverted to a regional 1995
Mud Brook		
Hudson #6	1987	Closed or wastewater diverted to a regional facility.
Furnace Run		
Briarwood	1990	Closed or wastewater diverted to a regional facility.
Pine Valley Nursing Home	1991	Closed or wastewater diverted to a regional facility.
Chippewa Creek		
Bramblewood	1990	Closed or wastewater diverted to a regional facility.
Vineyard Apts.	1987	Closed or wastewater diverted to a regional facility.
Seneca Club Apts.	1987	Closed or wastewater diverted to a regional facility.
Broadview Heights	1986	Closed or wastewater diverted to a regional facility
Avery Meadows	1990	Closed or wastewater diverted to a regional facility.
Tollis Parkway Apts	1990	Closed or wastewater diverted to a regional facility.
Wallings Rd School	1990	Closed or wastewater diverted to a regional facility.
Royalton Heights	1990	Closed or wastewater diverted to a regional facility.
Tinkers Creek Subbasin		
Four Seasons (Aurora)	1979	Closed or wastewater diverted to a regional facility.
Solon	1980	Upgraded
Bedford Heights	1984	Upgraded
Humphrey Park	1985	Closed or wastewater diverted to a regional facility.
Walton Hills	1985	Closed or wastewater diverted to a regional facility.
Gillie Estates	1986	Closed or wastewater diverted to a regional facility.
Rolling Hills Estates	1986	Closed or wastewater diverted to a regional facility.
Arrowhead	1986	Closed or wastewater diverted to a regional facility.
Streetsboro	1986	New Plant
Bedford	1987	Upgraded
Geauga Lake	1988	Closed or wastewater diverted to a regional facility.
Aurora Westerly	1988	New Plant
Summit Co Hudson #5	1988	Closed or wastewater diverted to a regional facility.

Table 4. (continued).

Facility/Area	Date	Type of Improvement
***Tinkers Creek** (continued)*		
Waldon	1988	Closed or wastewater diverted to a regional facility.
Aurora Acres	1988	Closed or wastewater diverted to a regional facility.
Twinsburg	1989	Upgraded
Strathmore	1990	Closed or wastewater diverted to a regional facility.
Hub Parkway	1990	Closed or wastewater diverted to a regional facility.
Roseland Estates	1991	Closed or wastewater diverted to a regional facility.
Mill Creek		
Maple Heights	1985	Closed or wastewater diverted to a regional facility.
Unknown		
St. Sava's	1990	Closed or wastewater diverted to a regional facility.
Furhmeyer Rd. Plant	1990	Closed or wastewater diverted to a regional facility.
Independence	1990	Closed or wastewater diverted to a regional facility.
Hawthorne Den	1990	Closed or wastewater diverted to a regional facility.
		Industrial Entities
Cuyahoga River		
Burton Rubber	NA	
Elco	NA	Closed or wastewater diverted to a regional facility.
Wabash Alloys	NA	Closed or wastewater diverted to a regional facility.
Harshaw	NA	Partially Abandoned
Norandex	NA	Closed or wastewater diverted to a regional facility.
Great Lakes Etching	NA	Closed or wastewater diverted to a regional facility.
American Steel and Wire	NA	Converted to water recycle system
Tare Creek		
Hans Rothenbuhler & Sons (Middlefield Swiss Cheese)	1990	Upgraded
Little Cuyahoga River		
Gen. Corp	NA	Closed or wastewater diverted to regional facility
Goodyear Tire and Rubber	NA	Closed or wastewater diverted to regional facility
RCA Rubber Co.	NA	Closed or wastewater diverted to regional facility
GenCorp Research	NA	Closed or wastewater diverted to regional facility
Mud Brook		
Alside	NA	Closed or wastewater diverted to a regional facility.
Tinkers Creek subbasin		
Bedford Anodizing	NA	Closed or wastewater diverted to a regional facility.
Hukill	NA	Partially abandoned
Ferro	NA	Closed or wastewater diverted to a regional facility.
SK Wellman	NA	Closed or wastewater diverted to a regional facility.
American Steel Drum	NA	Closed or wastewater diverted to a regional facility.

Table 4. (continued)

Facility/Area	Date	Type of Improvement
Mill Creek		
Aluminum Smelting and Refining	NA	Closed or wastewater diverted to regional facility.
Akron - Weathervane Lane	1989	Improved electrical system to prevent overflows.
Wastewater Collection System Improvements		
Akron - Shullo Drive	1988	Sewer reconstruction
Akron Melbourne	1988	Sewer reconstruction
Akron - Schocalog Rd.	1988	Sewer reconstruction/upsizing
Cuyahoga Falls - Babb Run	1991	Sewer reconstruction
Cuyahoga Falls - Gorge Pk	1988	Sewer reconstruction
Cuyahoga Falls - Gorge Pk	1990/91	Sewer re-lining
Cuyahoga Falls - Gorge Pk	1990	Sewer re-lining
NEORSD	1990	SWI accepts first flows
NEORSD	1989	Cuy. Valley Interceptor complete

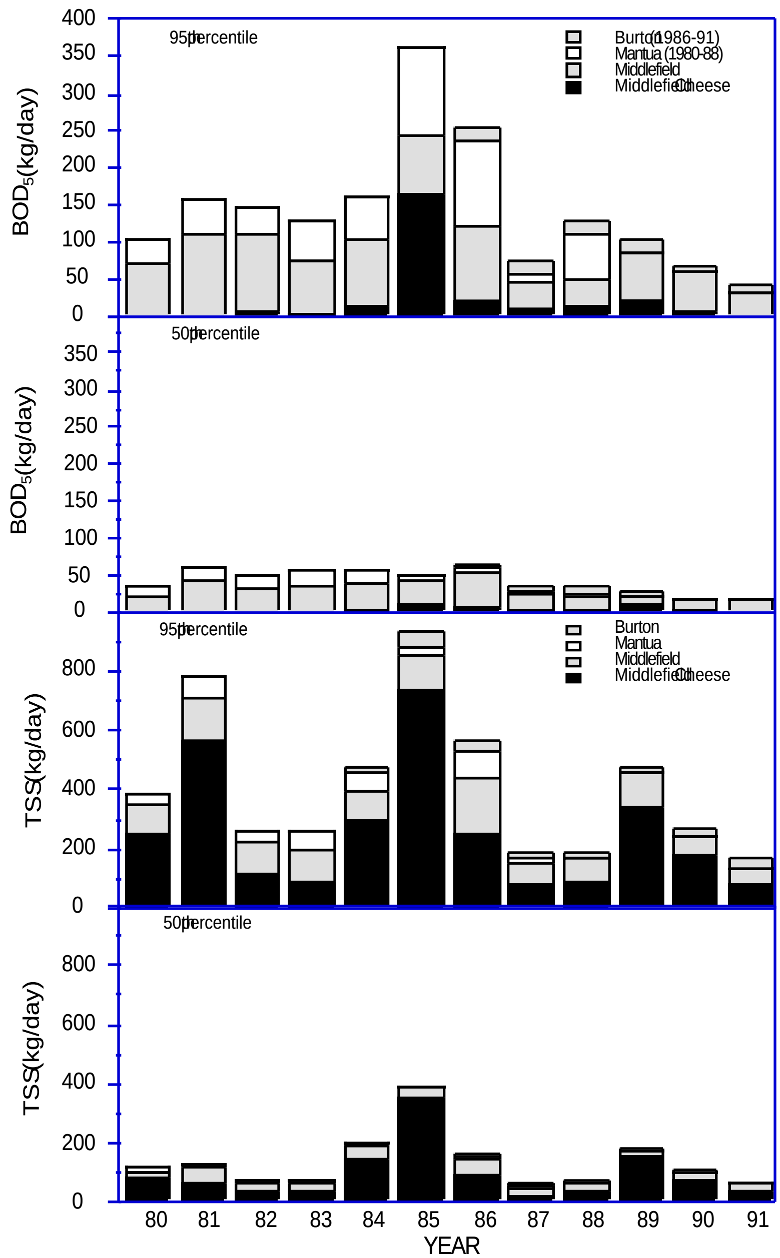


Figure 7. Annual loadings (kg/day) of total suspended solids (TSS), and five day biochemical oxygen demand (BOD_5) at the Burton, Middlefield, Hans Rothenbuhler & Sons (Middlefield Cheese), and Mantua WWTPs in the upper Cuyahoga River basin study area, 1980-1991.

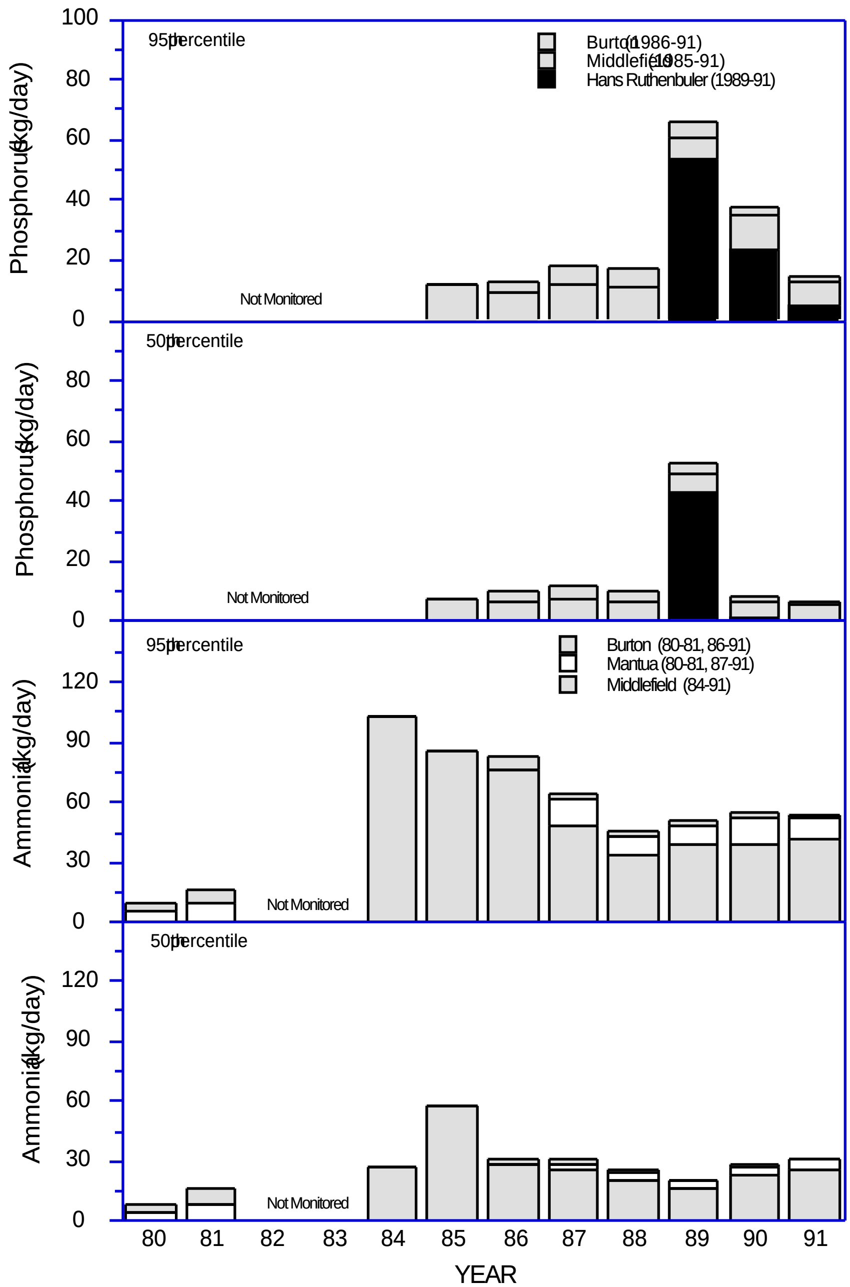


Figure 8. Annual loadings (kg/day) of phosphorus (Total P), and ammonia (NH_3-N) at the Burton, Middlefield, Hans Ruthenbuler Cheese and Mantua WWTPs in the upper Cuyahoga River basin study area, 1980-1991.

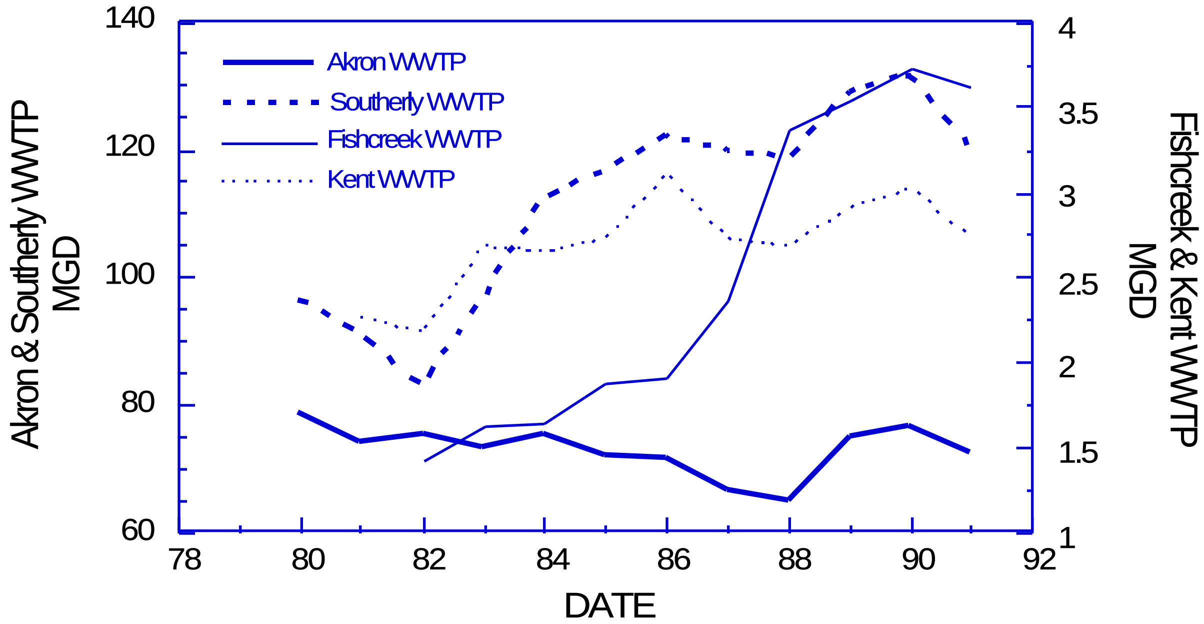


Figure 9. Average annual discharges in millions of gallons per day (MGD) at four major municipal WWTPs on the Cuyagoga River, 1980-91.

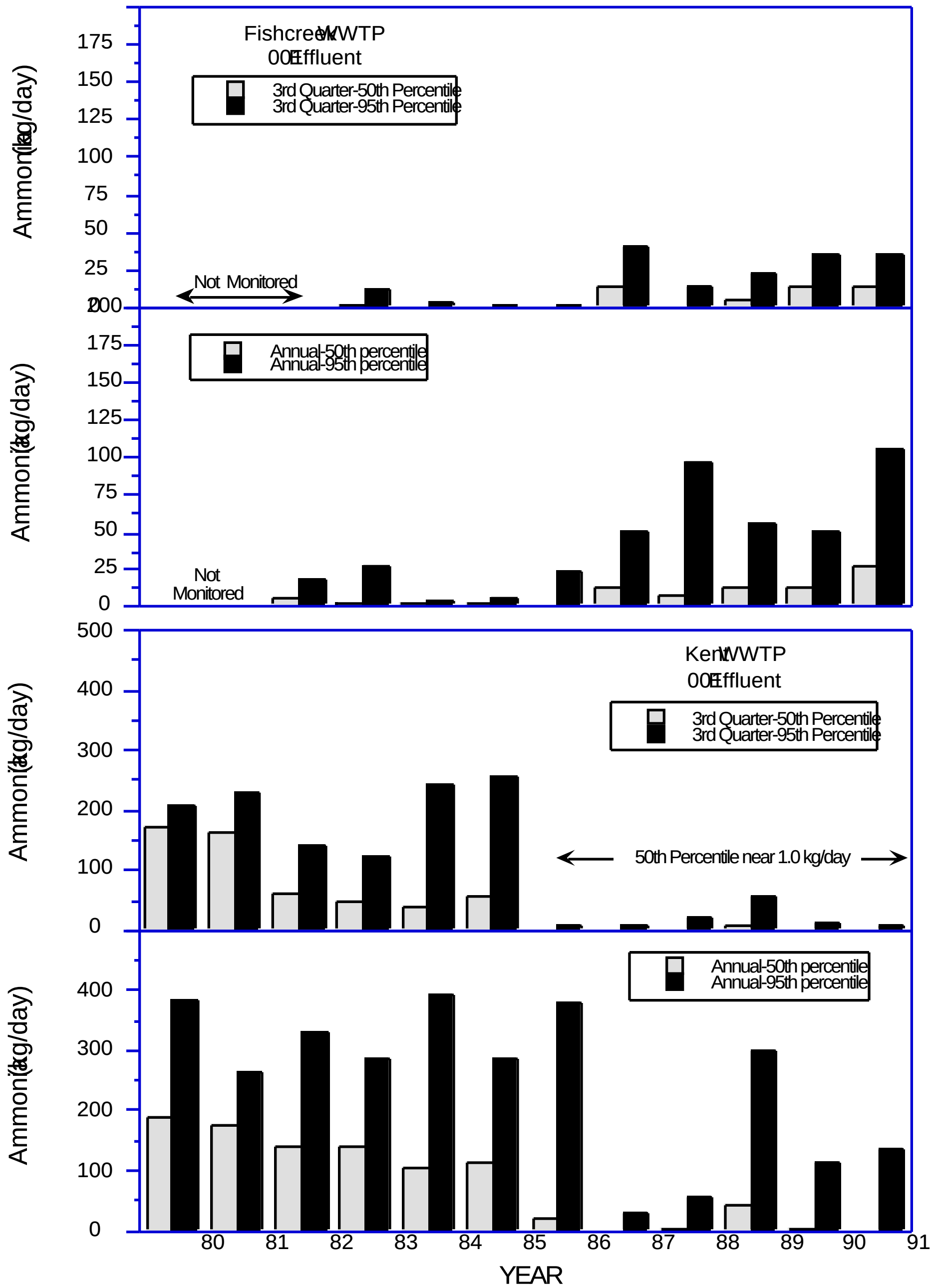


Figure 10. Annual and 3rd quarter (July through September) loadings (kg/day) of ammonia at the Fishcreek (upper) and Kent (lower) WWTPs in the Cuyahoga River study area, 1980-1991.

Figure 11. Akron WWTP discharges of raw (untreated), secondary (discharged after primary treatment) and total wastewater bypasses in billions of gallons/year from 1980-91. Total bypasses are reported as the sum of the raw and secondary discharges. Data do not include CSO's, dry weather overflows or secondary bypasses that were chlorinated.

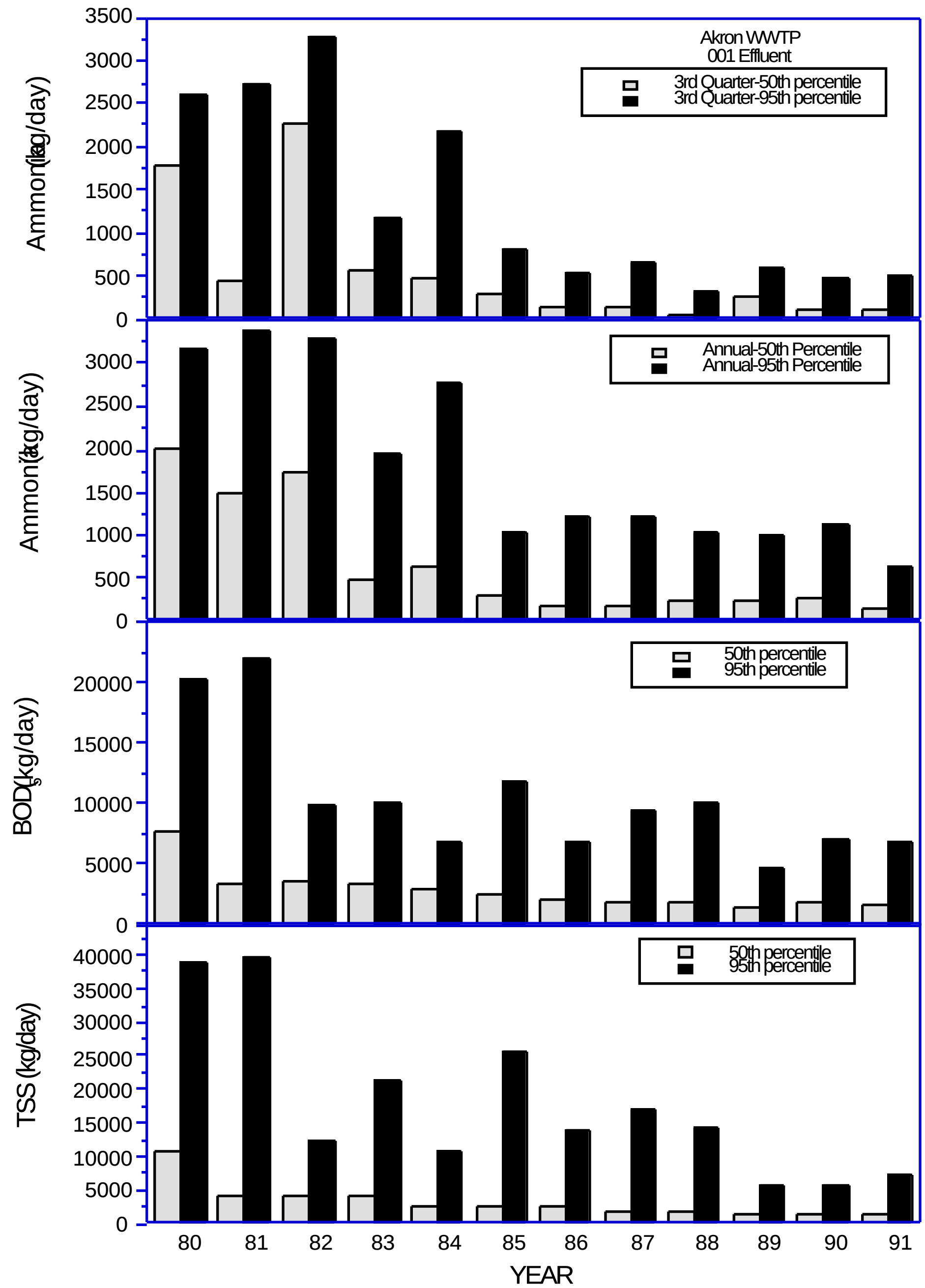


Figure 12. Annual and third quarter loadings (kg/day) of ammonia; annual loadings of total suspended solids (TSS), and five day biochemical oxygen demand (BOD_5) at the Akron WWTP, 1980-1991.

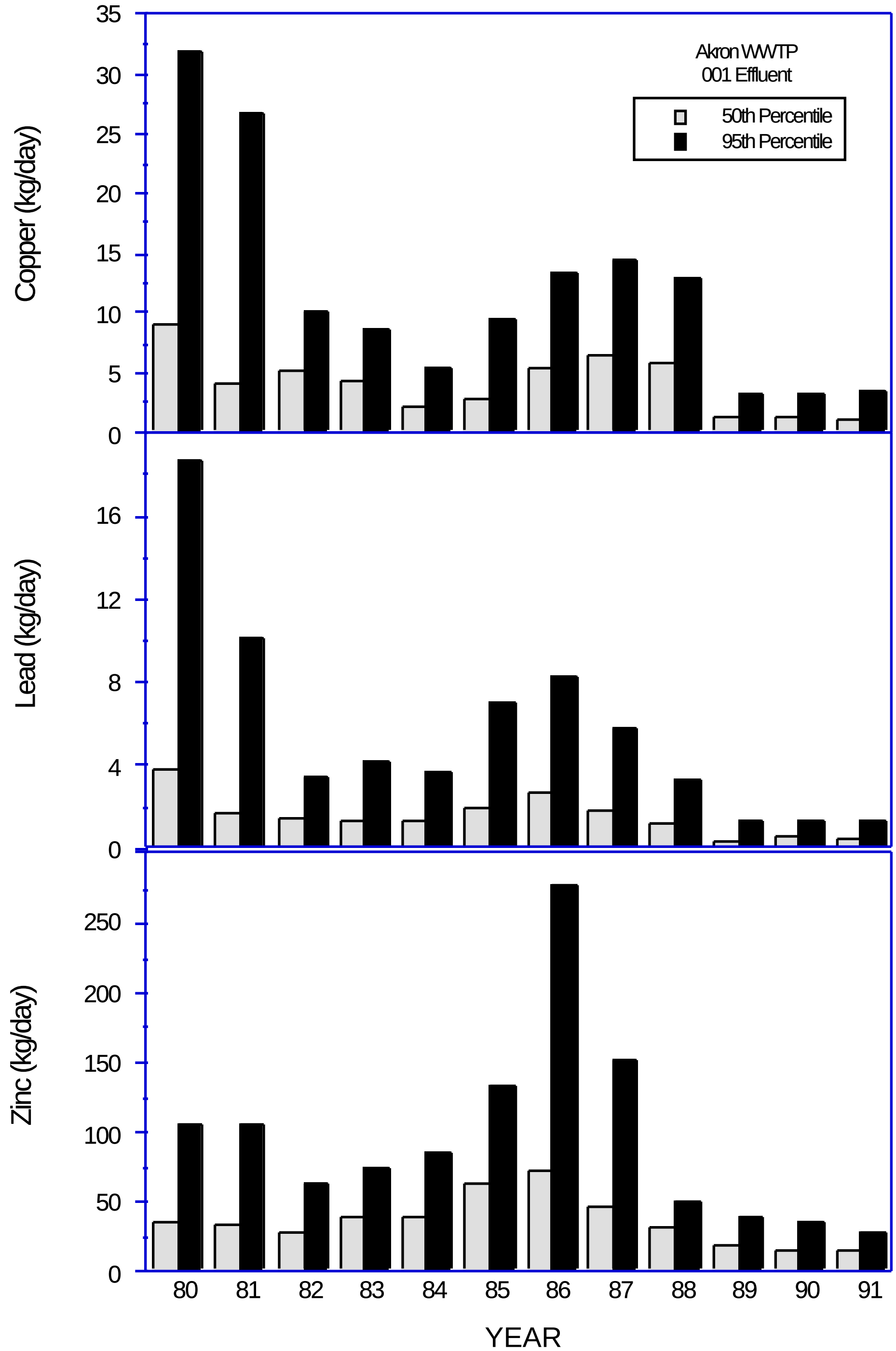


Figure 13. Annual loadings (kg/day) of copper, lead, and zinc at the Akron WWTP, 1980-1991.

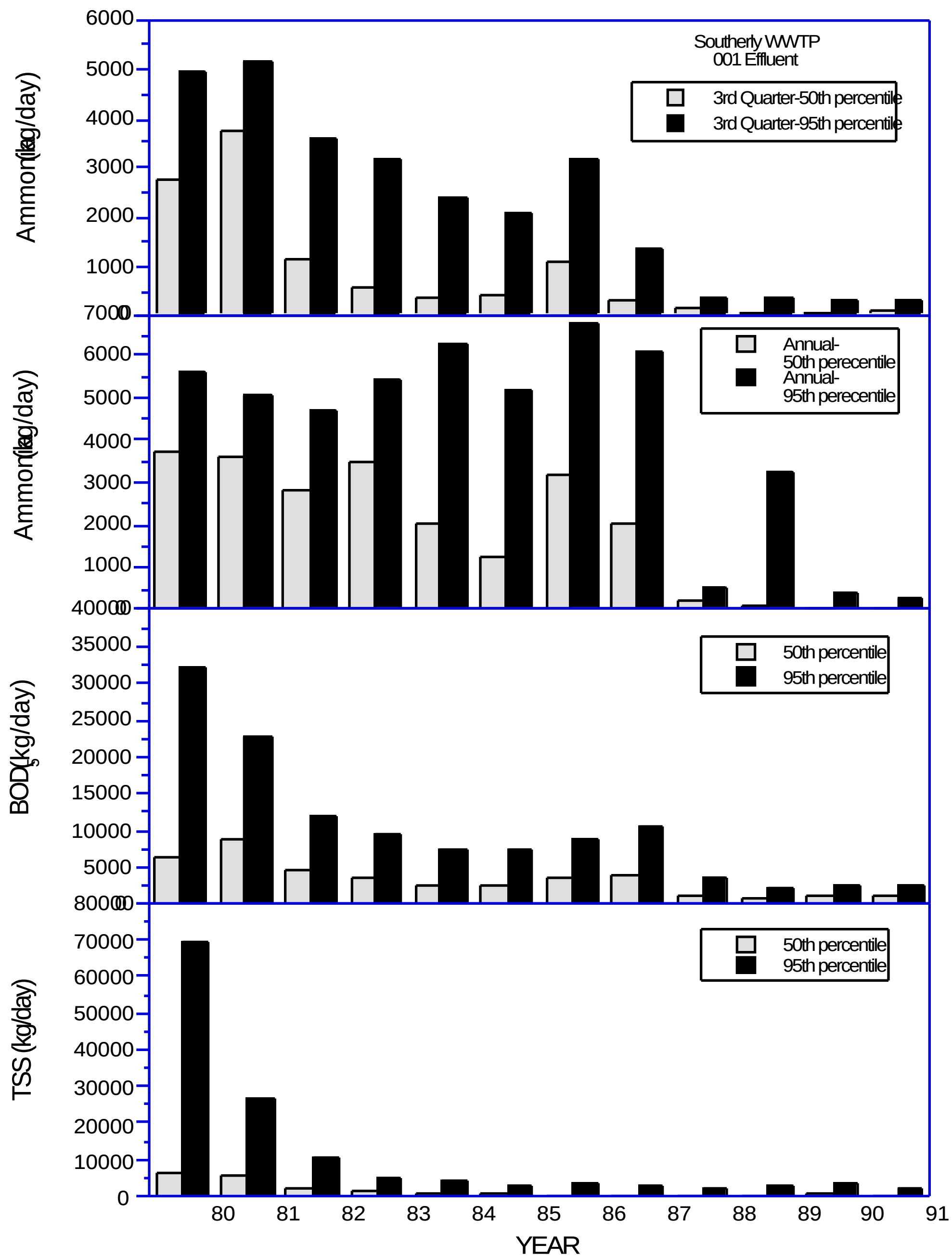


Figure 14. Annual loadings (kg/day) of ammonia, total suspended solids (TSS), and five day biochemical oxygen demand (BOD_5) and third quarter ammonia at the NEORSD Southerly WWTP (RM 10.57) in the Cuyahoga River study area, 1980-1991.

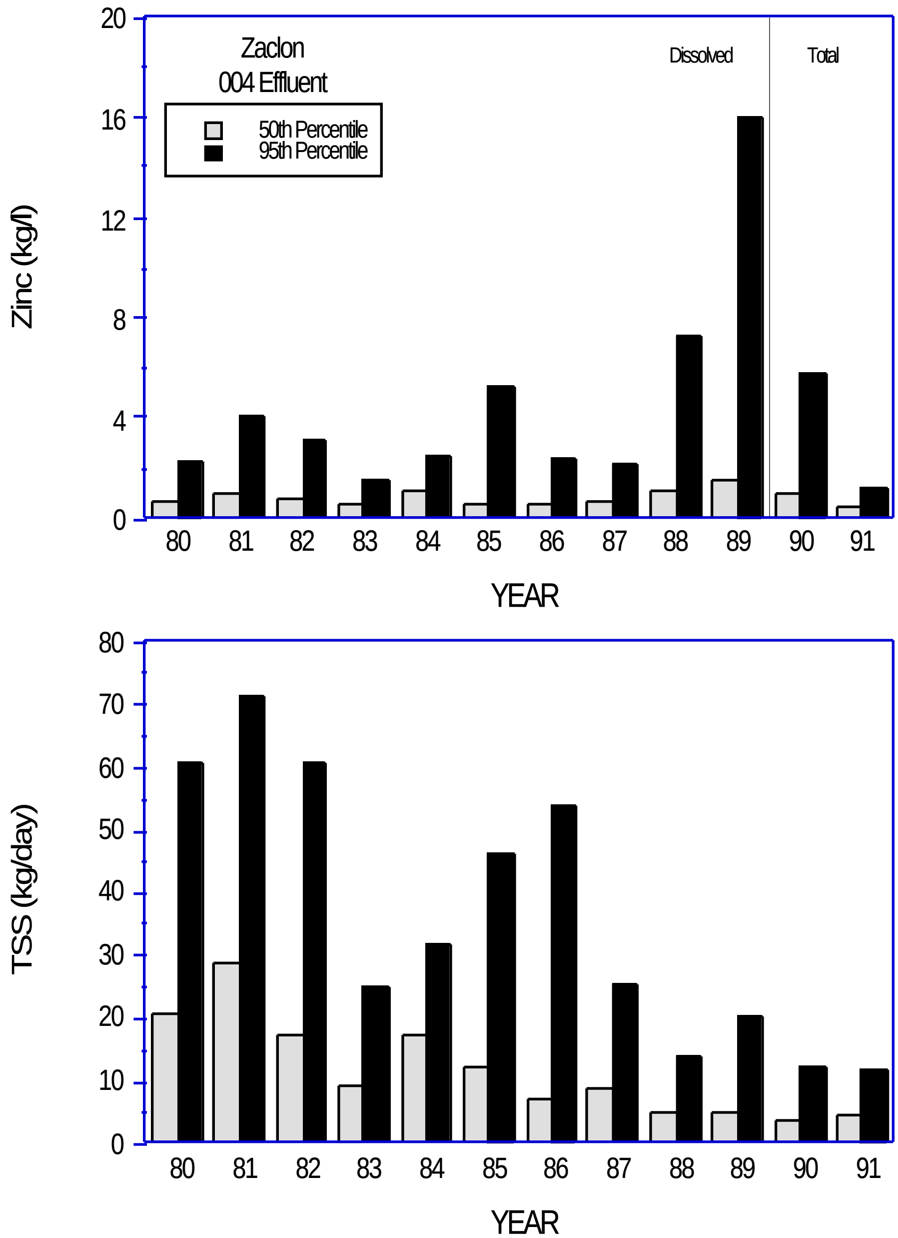


Figure 15. Annual mean loadings (kg/day) of zinc (Zn) and total suspended solids (TSS) from the Zaclon Inc. 004 discharge (RM 4.6), 1980-1991.

Nonpoint Source Loadings - Cuyahoga River Mainstem

- Nonpoint sources are major contributors of pollutant loading to the Cuyahoga River. Table 5 lists the selected pollutants carried by the Cuyahoga River in kilograms per year. These estimates include contributions from both point and nonpoint sources and the amount removed by maintenance dredging of the navigation channel. Although nonpoint source loadings are based on estimates and model predictions, and therefore are not precise, they do suggest the relative size of the nonpoint source contributions compared to point source loadings. Estimates of CSO and SSO loadings are being developed via the Cuyahoga River RAP process.

Table 5. Point and nonpoint source pollutant loadings in the Cuyahoga River basin Area of Concern (RM 100.1 - 0.0). Data are from the Cuyahoga River RAP Stage One Report, June 1992.

	Point Sources[a]	Nonpoint Sources	Contaminants Removed by Dredging (kg/yr)
Copper	8,263 (13%)	54,000 (87%)	24,000
Lead	6,962 (6%)	115,000 (94%)	38,000
Zinc	60,160 (28%)	151,000 (72%)	87,000
Total Suspended Solids	3,148,301 (1%)	359,996,000 (99%)	
TKN	3,603,753 (74%)	1,789,000 (26%)	504,000
Total Nitrogen		1,409,000	
Phosphorus	299,060 (53%)	263,000 (47%)	890,000

[a] Does not include CSO and SSO loadings.

NPDES Compliance History - Cuyahoga River Mainstem

- NPDES compliance history was reviewed for dischargers in the middle Cuyahoga River from 1980 through 1991. The Kent, Summit County Fishcreek, Akron and NEORSD Southerly WWTP's have all occasionally violated their NPDES effluent discharge permit limits (Figure 16). During the 11-year period, Akron had the most violations with 368 and NEORSD Southerly the least with 51.

- The Kent WWTP had 63 violations of the effluent limits of their NPDES permit in the 132 months between 1980 and 1991. Those violations included oil and grease (22), lead (9), mercury (8), ammonia-N (6), TSS (6), pH (5), total residual chlorine (3), fecal coliform bacteria (1), cyanide (1), nickel (1) and phosphorus (1). Most violations for oil and grease (the most frequently exceeded parameters) occurred during construction in 1984. Three of the six ammonia violations occurred in 1989 and eight of the nine lead violations were in 1990. The other violations were scattered throughout the ten-year period.

- The Summit County Fishcreek WWTP had 153 violations of NPDES permit effluent limits in 96 months between 1983 and 1991. Violations included BOD (37), phosphorus (32), ammonia-N (18), copper (16), pH (14), total residual chlorine (12), TSS (8), cadmium (6), fecal coliform bacteria (5), mercury (4), dissolved oxygen (1), and zinc (1). Violations for the most frequently exceeded parameters (BOD, phosphorus and ammonia-N) mostly occurred during start-up or because of broken shafts on RBCs (Rotating Biological Contactors) at the WWTP. Eleven (11) of the 16 copper violations occurred in 1987.

- The Akron WWTP had 368 violations of NPDES permit effluent limits in 132 months between 1980 and 1991. The violations included TSS (67), phosphorus (64), copper (57), total residual chlorine (35), fecal coliform bacteria (35), BOD (34), phenols (33), cadmium (18), zinc (11), dissolved oxygen (4), ammonia-N (4), pH (3), mercury (2), and oil and grease (1). Thirty (30) of the 33 phenol violations have occurred since 1988.

- The NEORSD Southerly WWTP had 51 violations of the NPDES permit effluent limits in 132 months between 1980 and 1991. The violations included TSS (17), BOD (15), phosphorus (11), ammonia-N (3), pH (3), lead (1), and phenolics (1). Forty-three (43) of the 51 violations occurred in 1980 and 1981.

- The graph of the WWTP violations shows a general decrease of violations since 1987. NPDES permit limitations have generally become more restrictive as water quality based limitations have been developed. The more stringent permit limits and a decline in the number of violations suggest improving effluent quality. An effluent limit violation does not necessarily result in an exceedence of water quality standards in the receiving stream and NPDES violation history should not be used to directly assess specific violations of water quality standards. However, the likelihood of ambient impairment increases with increased violations. The data can be used as an indication of the operation and maintenance of the point sources and their ultimate effect on the water resource.

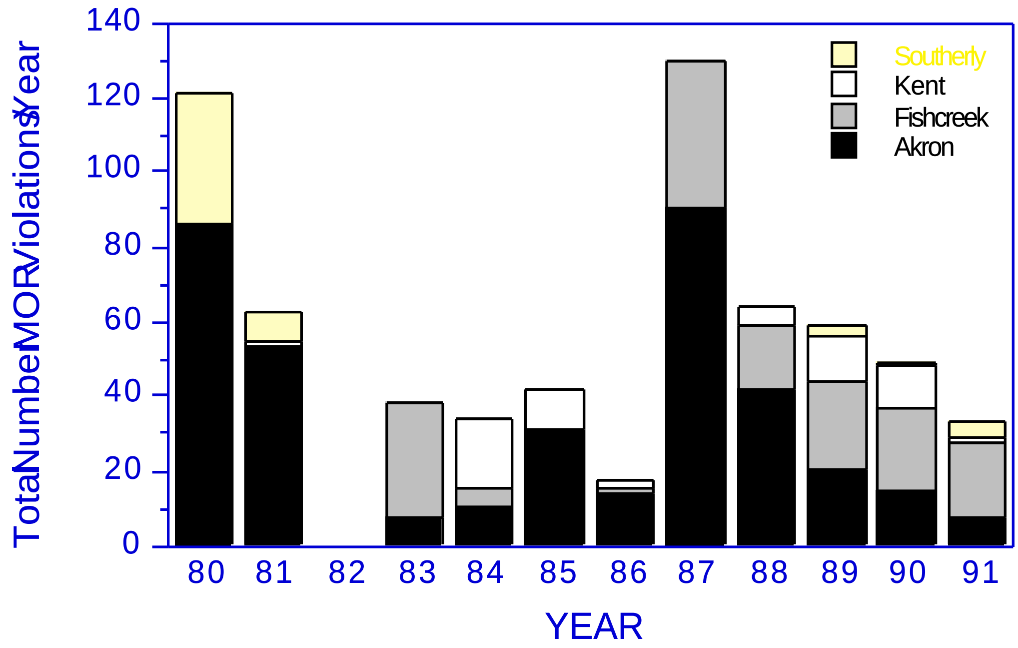


Figure 16. Total numbers of monthly operating report (MOR) violations per year at the Kent, Fishcreek, Akron and NEORSD Southerly WWTPs, 1980-91.

Tinkers Creek Subbasin- River Mile 28.8 to 0.0

- Significant upgrades to wastewater treatment facilities has occurred in the upper Tinkers Creek subbasin (above RM 8.7) since 1984. In the Streetsboro and Hudson areas, the Gillie Estates WWTP, Arrowhead Estates WWTP, Rolling Hills WWTP, and Summit County Hudson #5 WWTP were tied-in to the Streetsboro Regional WWTP in 1985. In the Pond Brook subbasin, the Geauga Lake WWTP, Aurora Acres WWTP, and Waldon WWTP tied-in to the Portage County regional Aurora Westerly WWTP in 1989. Plant improvements and the elimination of bypasses were completed in August 1988 at the city of Twinsburg WWTP. The Roseland Estates WWTP tied-in to the NEORSD sanitary sewer system in October 1991, following the field survey. This WWTP formerly discharged to an unnamed tributary that entered Tinkers Creek downstream from the Twinsburg WWTP discharge.

- In the Deer Lick Run subbasin, the Walton Hills WWTP tied-in to the NEORSD Cuyahoga Valley Interceptor (CVI) sewer in 1984 and the Bedford Anodizing Company process waste was tied-in in 1985. The S.K. Wellman Company closed in September 1990 and ceased all discharges while the Hukill Chemical Company connected all stormwater runoff to the regional sanitary sewer. Taken together, these actions have resulted in a complete elimination of process water discharges to Deer Lick Run.

- Average loadings of BOD, TSS, total phosphorus, ammonia-N, oil and grease (not plotted), and heavy metals from the WWTP's in the Tinkers Creek subbasin showed either similar or slightly lower values in 1991 as compared to 1984 (Figures 17-20). The only exceptions to these trends were higher loadings of phosphorus from the Twinsburg WWTP and higher ammonia-N from the Solon WWTP.

- Wastewater dischargers to Pond Brook include the Aurora Shores WWTP at RM 3.5 (0.25 MGD) and the Aurora Westerly WWTP at RM 1.57 (1.2 MGD). Loadings trends for ammonia-N, total suspended solids, $cBOD_5$ and flow from the plants are found in Figure 21. The Aurora Shores discharges remained relatively stable from 1985 to 1991 except for some increases in TSS and $cBOD_5$ during the late 1980s. At Aurora Westerly, discharge flows and loadings of TSS and $cBOD_5$ show an almost consistent increasing trend since the plant began discharging in 1988. Third quarter ammonia loads at Westerly in 1989 were much higher than normal as the plant was coming on line. These levels dropped substantially during 1990 and 1991.

NPDES Compliance History - Tinkers Creek Subbasin

- A review of the NPDES compliance records for five of the major municipal dischargers (Streetsboro, Bedford, Bedford Heights, Solon and Twinsburg WWTPs) showed that all have occasionally violated permit limits between 1980 and 1991 (Figure 22). A total of 1272 NPDES permit violations were recorded over the 132-month period. However, 67 percent of these violations occurred during 1980 - 1983. It is important to note that permit limits for some heavy metals (*e.g.*, copper, cadmium) were modified in 1991 due to revisions of the water quality criteria. These revisions generally resulted in less stringent effluent limits for some metals after 1991. This was especially important for review of the Twinsburg WWTP compliance record that has shown elevated copper in effluent samples. For these reasons only monthly operating report (MOR) values that violated the 1991 permit limits were listed as violations.

- While there was no clear pattern of non-compliance with any specific parameter at individual entities, there has been a significant reduction in the total number of violations over time. This trend suggests that the treatment efficiency of the Tinkers Creek dischargers have improved since the early 1980s.

- Since 1987, occasional violations have been reported for a wide range of parameters, from BOD, TSS and total phosphorus, to more toxic parameters such as ammonia-N, heavy metals and cyanide. Thus, a high probability remains that one or more of the Tinkers Creek dischargers will record a violation in a given month (minimum number of 24 violations in 1991). These episodes are symptomatic of the multiple, cumulative stresses identified along the length of Tinkers Creek and correlate with the chronic non-attainment reflected by the aquatic communities. These stresses include many reports of spills or unauthorized pollutant discharges, increased urban runoff, a sewer line break in Beaver Meadow Run, pump station overflows, effluent toxicity (based on bioassay testing), landfills, construction site runoff, and increasingly larger inputs of point source effluent from upstream to downstream.

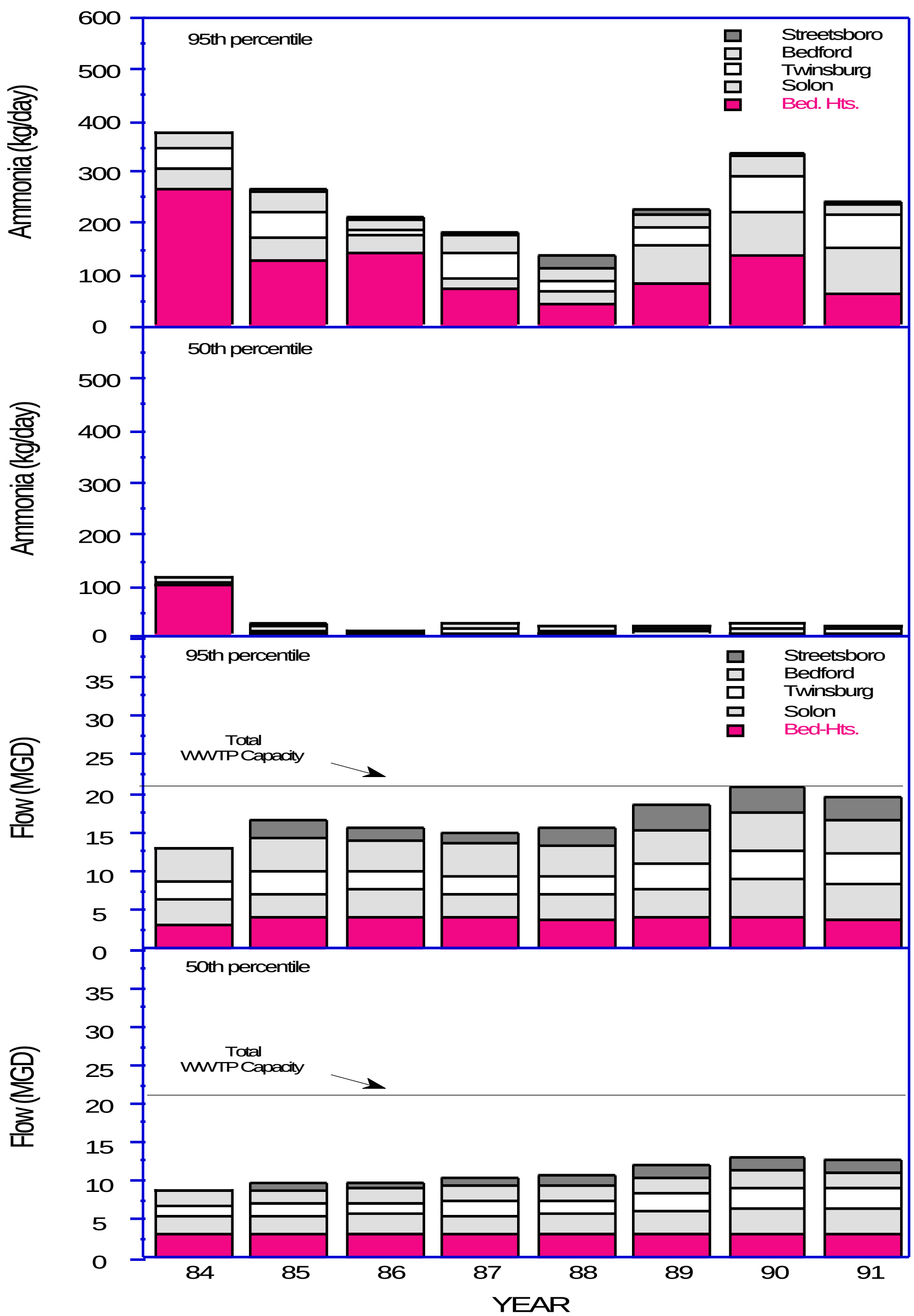


Figure 17. Annual loadings of ammonia-N (kg/day) and annual discharge volumes (MGD) at five WWTPs in the Tinkers Creek basin, 1984-1991.

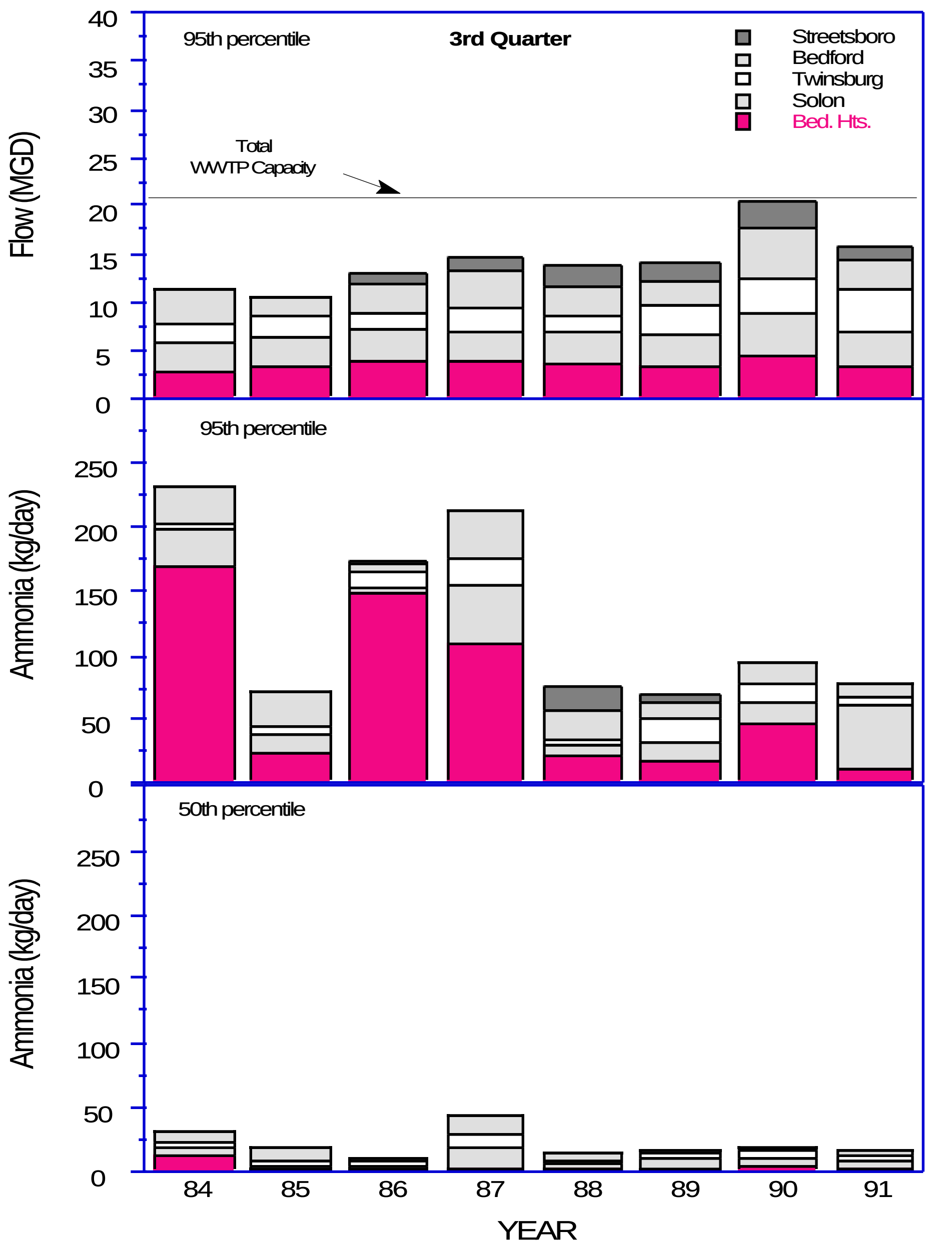


Figure 18. Third quarter loadings of ammonia-N (kg/day) and 95th percentile discharge volumes (MGD) at five WWTPs in the Tinkers Creek basin, 1984-91.

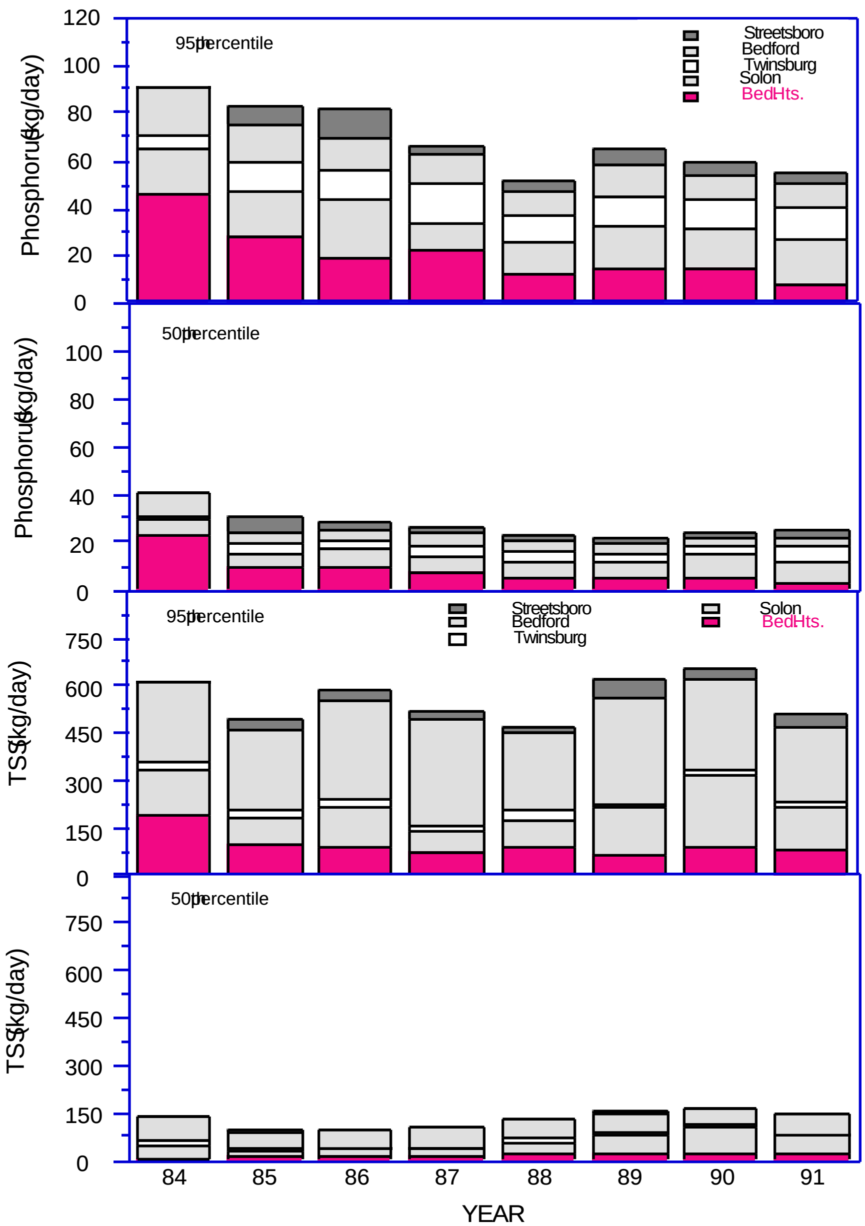


Figure 19. Annual loadings of phosphorus and total suspended solids (TSS) in kg/day at five WWTPs in the Tinkers Creek basin, 1984-91.

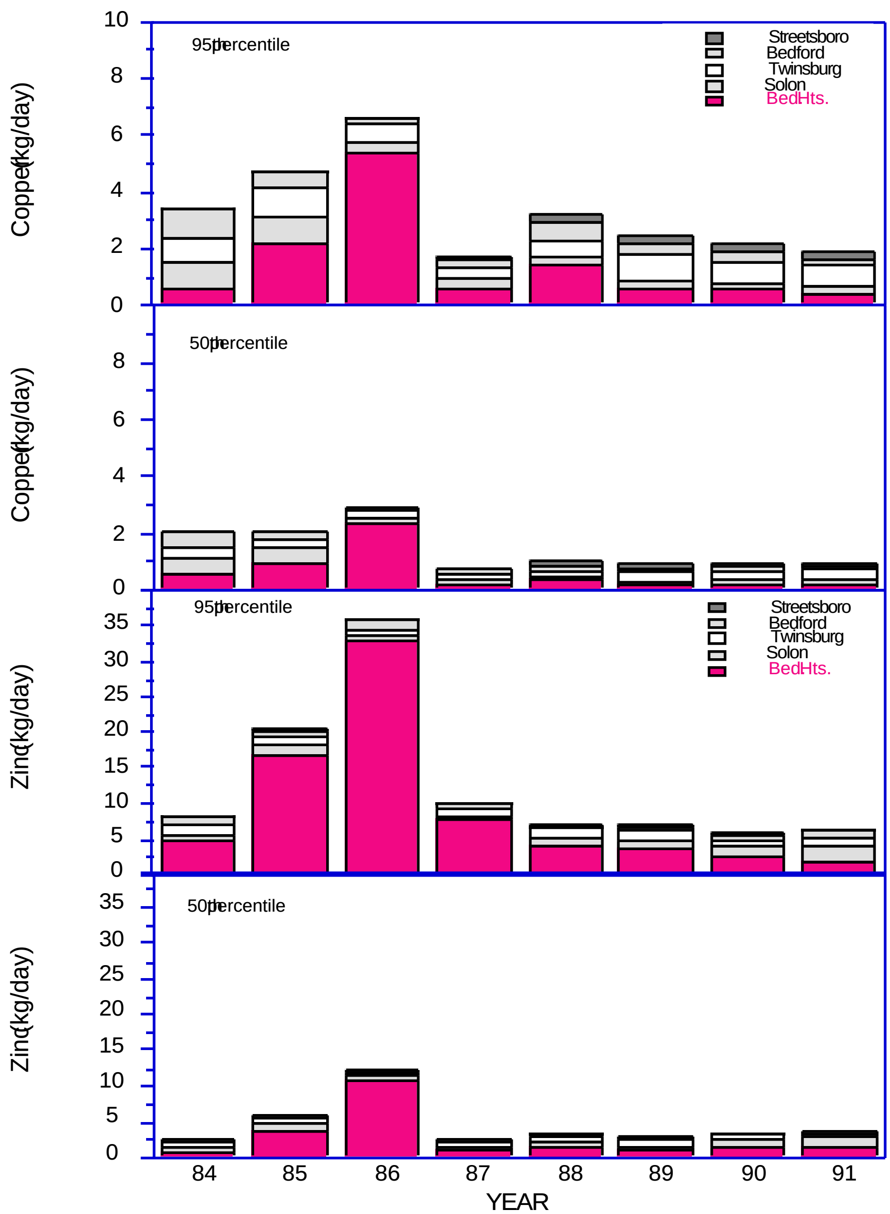


Figure 20. Annual loadings of zinc and copper in kg/day at five WWTPs in the Tinkers Creek basin, 1984-1991.

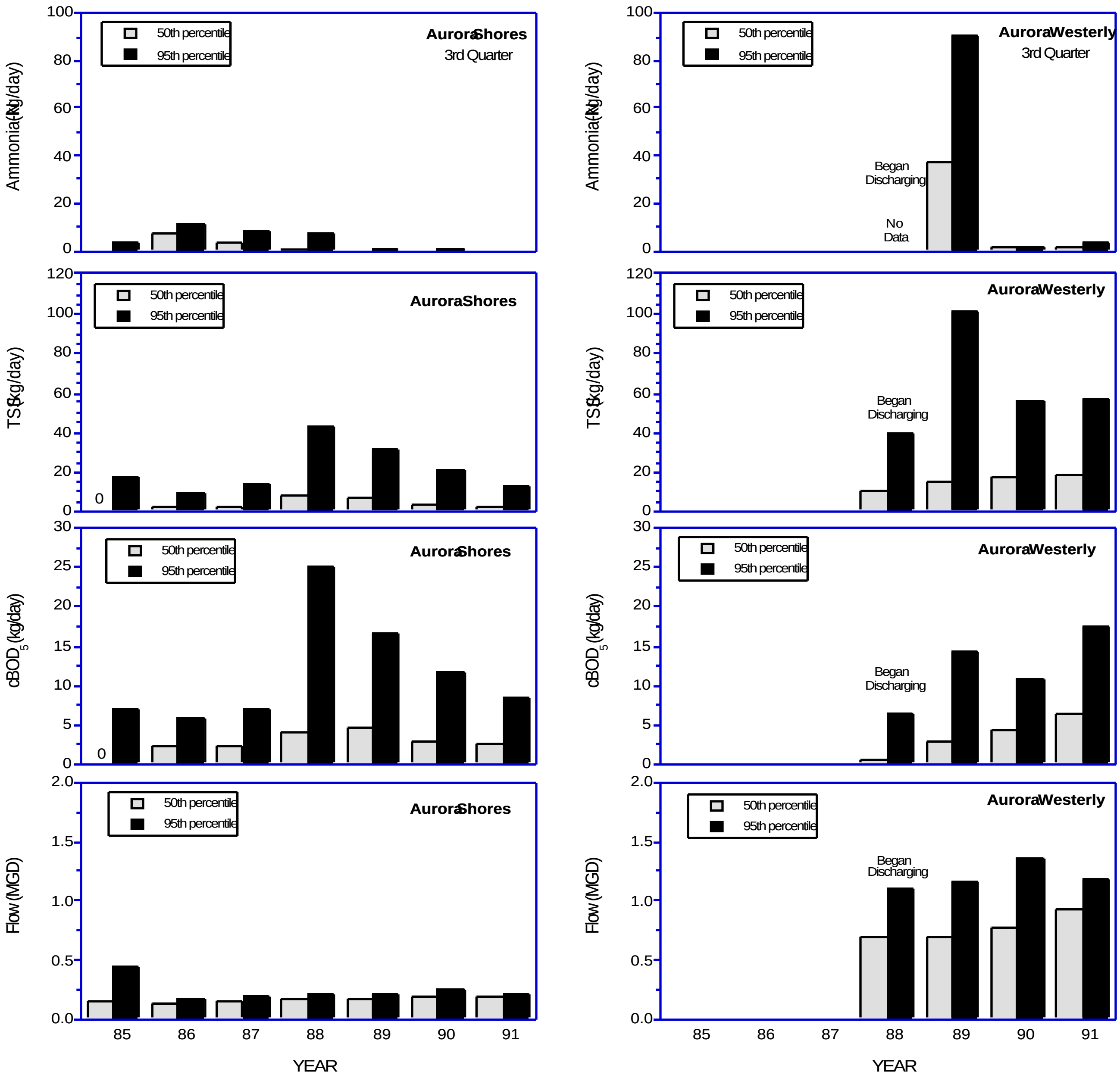


Figure 21. Loadings of ammonia-N (3rd quarter), total suspended solids (TSS), five day carbonaceous biochemical oxygen demand ($cBOD_5$) in kilograms per day (kg/d) and flow (daily/annual) in millions of gallon per day (MGD) from the Aurora Shores WWTP (1985-91) and Aurora Westerly WWTP (1988-91).

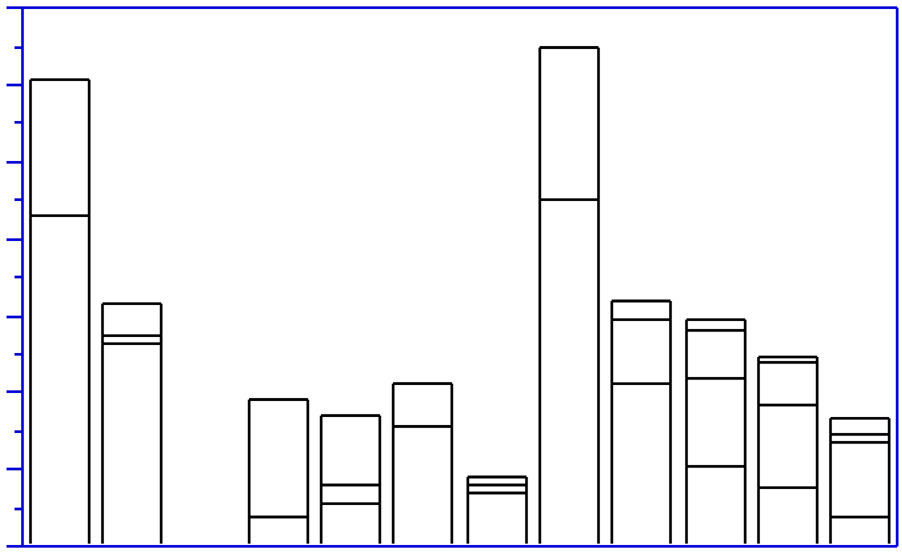


Figure 22. DUMMY PLOT

Pollutant Spills

- Lists of accidental spills, unauthorized discharges, and wild animal kills are good indicators of potential impacts due to episodic increases in pollutant loadings. A review was conducted of spills and wild animal kills in the Cuyahoga River basin (includes Cuyahoga, Summit, Portage and Geauga Counties) from 1978 through 1991. Data were obtained from the Ohio EPA, Division of Emergency and Remedial Response Online System (EROS) database and the Ohio Department of Natural Resources (ODNR), Division of Wildlife Pollution Investigative Reports.

- The numbers of reported spills and unauthorized discharges in the Cuyahoga River basin are summarized, by county, in Table 6. A total of 2,405 spills were recorded during the 14-year period from 1978 through 1991, with a basin wide average of 172 spills per year. Hydrocarbons (oil, gasoline, etc.) were the most common type of spill (45%) followed by miscellaneous chemicals (23%), other or unknown substances (13%), sewage (8%), wastewater (7%) and brine chemicals (4%). Farm chemicals made up less than 1 percent of the spill reports.

- The number of spills and often, the size and severity of spills, was much greater in Cuyahoga County and Summit County, accounting for 82% of reported spills in the basin. These counties include the Cleveland and Akron metropolitan areas and are characterized by high population densities, extensive urban and industrial land usage, large volume municipal and industrial point source discharges, and extensive transportation networks. Cuyahoga County consistently ranked highest in the number of spills, averaging 90/year while the more sparsely populated Geauga County was consistently lowest, with a yearly average of only six spills. All spills categorized by type were highest in Cuyahoga County except brine chemical which was lowest, and farm chemicals that were highest in Summit County. The largest spills reported in EROS occurred in 1978 when approximately 200 million gallons of sewage was discharged to the Cuyahoga River from regulated sewers in Cleveland, primarily during March. Note: Most WWTP bypasses are addressed and recorded through the NPDES permit process; Emergency Response notification is not normally a requirement following these events.

- Included in the Cuyahoga River basin total were 175 spills that occurred in the Tinkers Creek watershed. The majority of spills (135) were located in the lower 12.3 miles of the basin in Cuyahoga County.

- A comparison of the number of spill incidents reported here and those reported in the 1991 Cuyahoga RAP Stage One Report reveals substantial under-reporting of spills in the RAP. A total of 167 spills throughout the basin were cited in the RAP report between 1986 and 1990. In contrast, 1,041 spills were listed during the same period in this report. While it is not known why the spill lists had such widely differing totals, the most recent data do suggest greater risk to streams in the basin from spills than described in the Stage One Report. This is particularly true within the RAP Area of Concern (Ohio Edison Dam to Lake Erie in Summit and Cuyahoga counties) where most spills occurred. Both the RAP report and this document would agree that many more spills have probably occurred in the basin than are recorded in the Ohio EPA EROS database.

- During the 1978 - 1991 period, ODNR pollution investigation reports listed 42 incidents in which a total of 1,506 fish, 39 birds or waterfowl, and unknown or unreported numbers of fish, frogs, crayfish, and ducks were killed (Table 7). In January 1987 an estimated ten tons of winter kill gizzard shad were observed in the navigation channel. Mortality was attributed to the rapid onset of cold temperatures and the resultant physiological changes (i.e., cold shock).

- As with the spills, most fish and wildlife kills occurred in Summit and Cuyahoga counties. Twelve (12) of the 42 incidents in the basin occurred in ponds or lakes and only five kills were reported from the Cuyahoga River mainstem. Nearly one-half of the incidents listed unknown or natural as the cause of the kills.

Table 6. Summary of unauthorized pollutant discharges by county in the Cuyahoga River basin recorded by the Ohio EPA, Division of Emergency and Remedial Response during January 1978 - December 1991.

Cuyahoga River Basin	Cuyahoga	Summit	COUNTY Portage	Geauga	Basin Total
Total Spills	**1,263**	**768**	**290**	**84**	**2405**
Spills/Year (Average)	**90**	**55**	**21**	**6**	**172**
Spill Type					
Hydrocarbon	564	332	153	46	1095
Miscellaneous Chemical	314	194	41	13	562
Sewage	113	53	22	4	192
Wastewater	132	29	5	3	169
Brine Chemical	6	40	34	12	92
Farm Chemical	7	8	2	1	18
Other	162	112	33	9	316
Hydrocarbon amt. (gal.)	269,473	199,169	107,221	25,775	601,638
Hydrocarb. amt./yr. (avg.)	19,248	14,226	7,659	1,841	42,974
All Discharges (known gallons)	NA	NA	NA	NA	354,379,106
Gallons/Year (avg.) 1978-91	NA	NA	NA	NA	25,312,793
Gallons/Year (avg.) 1979-91	NA	NA	NA	NA	11,725,305

Spill Type Descriptions

Hydrocarbon . . . . crude oil, natural gas, fuel oil, diesel fuel, gasoline, kerosene, motor oil, waste oil (EROS Spill Type Code: H).

Miscellaneous chemical chemicals in the use cycle, waste chemicals, dielectric (PCB) fluids, abandoned materials (EROS Spill Type Code: C, WC, GC, PC).

Sewage . . . . sewer bypasses, permit violations, septic waste, manure (EROS Spill Type Code: S).

Wastewater . . . . noncontact cooling water, wastewater without chemical contamination or sewage (EROS Spill Type Code: WW).

Farm chemical . . . . . . fertilizer, pesticide, herbicide, fungicide, algicide, and other chemicals used in agriculture (EROS Spill Type Code: FC).

Brine chemical . . . . . . chemicals used in the production of crude oil, brine byproduct (EROS Spill Type Code: BC).

Other . . . . air contaminants, unknown contaminants, proprietary chemicals, or other items that do not fit in the above categories (EROS Spill Type Code: A, N, O).

Hydrocarbon amount . . *known* gallons of hydrocarbons accidentally or illegally released. Note: these amounts are considered conservative since spill volumes are often reported as “unknown”.

Table 7. List of fish and wild animal kills recorded by Ohio Department of Natural Resources in the Cuyahoga River basin, 1978 - 1991.

Date	Waterbody	Material	County	Number of Fish (Animals) Killed
04-04-78	Magadore Reservoir	Gasoline	Portage	35
01-22-81	Cuyahoga R.	Natural	Portage	Unk
09-08-81	Unnamed Trib.	Natural	Summit	Unk
10-26-81	Springfield Lake Trib.	Chemical	Summit	15
06-09-83	Ohio Canal	Degreaser	Summit	100
07-28-83	Cuyahoga River	Natural	Cuyahoga	Unk
08-10-83	Big Creek	Sewage	Cuyahoga	129
09-24-83	Beaver Creek	Ferric Chloride	Cuyahoga	Unk
10-26-83	Aurora Lake	Sewage	Portage	40
02-02-84	Cuyahoga River	Unk	Cuyahoga	8
04-10-84	Silver Lake	Unk	Summit	Unk
04-13-84	Potter Creek	Unk	Portage	Unk
05-17-84	Fish Creek	Unk	Sum./Port.	Unk
08-08-84	West Br. Cuyahoga R.	Iodine	Geauga	Unk
09-10-84	Tinkers Creek	Unk	Cuyahoga	Unk
09-19-84	Cuyahoga River Trib.	Unk	Summit	Unk
10-18-84	Brandywine Creek	Mud	Summit	Unk
12-31-84	Congress Lake Outlet	Crude Oil	Summit	10 (Geese)
09-25-85	Tinkers Cr./Bear Cr. Trib.	Methyl-Ethyl Keytone	Cuyahoga	34
10-08-85	Aurora Lake	Unk	Summit	Unk
03-18-86	Bridge Creek	Decyl Alcohol	Geauga	Unk
05-27-86	LaDue Reservoir	Paraquat	Geauga	Unk
06-26-86	Parma Lake	Herbicide ($CuSO_4$)	Cuyahoga	Fish, Ducks
08-15-86	Private pond	Trash	Cuyahoga	Unk
10-17-86	Springfield Lake	Natural	Summit	Unk
11-04-86	Little Cuyahoga R. Trib	Unk	Summit	Unk
11-17-86	Brandywine Creek	Unk	Summit	43
11-20-86	Little Cuyahoga River	Unk	Summit	Unk
01-04-87	Brewster Creek	Oil	Summit	3 (Birds)
01-16-87	Cuyahoga River	Natural	Cuyahoga	10 Tons-Shad
01-19-88	Cuyahoga River	Oil	Cuyahoga	Unk (Birds)
06-25-87	Pond	Unk	Summit	Unk
10-10-87	Mud Brook	Diesel Fuel	Summit	19 (Ducks)
11-05-87	Drainage Ditch	Oil	Summit	7 (Ducks)
01-31-88	Orton Creek	Oil	Geauga	Fish, Frogs
08-04-88	Cuyahoga River	Unk	Summit	Unk (Crayfish)
04-09-89	Cuyahoga River Trib.	Oil	Cuyahoga	Unk
05-08-89	Tinkers Creek Trib.	Ammonia (Refrigerant)	Cuyahoga	1,000
06-09-89	Pond	Unk	Portage	Unk
09-14-89	Springfield Lake Outlet	Auto wash	Summit	100
06-21-90	Private lake	Unk	Portage	Unk
09-20-91	Private pond	Unk	Summit	Unk

Chemical/Physical Water Quality

Flow Regime

- Biological and water quality sampling during 1991 was done during a near record dry year. However, flows were recorded in the Cuyahoga River considerably higher than would be expected during a drought relative to 80 percent duration and $Q_{7,10}$ flows (Figure 23). These comparatively higher than expected flows were due to augmentation by reservoir releases and the discharge of treated effluent from industries and municipal WWTPs. The Ravenna, Kent, and Fishcreek WWTPs discharge to the mainstem upstream from the Portage Path gage near Akron. Furthur downstream, the Akron, Hudson, Bedford, Bedford Hts., Solon, Twinsburg, Aurora, and Streetsboro WWTPs discharges are included in flows measured at the Independence gage. The flow hydrograph illustrates that during dry weather, the Cuyahoga River is effluent dominated. The year 1990 was one of the wettest years on record; this is reflected in a comparison with the 1991 flows (Figure 24).

Upper Cuyahoga River and Tare Creek

- A summary of 1991 chemical grab sampling results can be found in Appendix A, Tables 1-2. Exceedences of chronic WWH chemical water quality criteria (Table 8) in the upper Cuyahoga River basin included:

  √ Total iron in 20 of 40 samples (50%);
  √ Dissolved Oxygen in 9 of 35 field measurements (26%) in the Cuyahoga River;
  √ Dissolved Oxygen in 5 of 5 field measurements in Tare Creek (100%);
  √ Fecal coliform bacteria in 1 mainstem sample and 4 Tare Creek samples (25%);

- Dissolved oxygen levels below the WWH daily minimum criterion from RM 89.4-71.7 in nine of the 35 measurements. Two of the mainstem D.O. violations were upstream from known point sources. The low D.O. concentrations upstream from the point sources are the likely result of the combination of bottom reservoir releases, low stream gradient, and extensive wetlands in the area. There was insufficient information collected by this study to separate the effects of point source discharges and the background conditions on the D.O. regime observed downstream from Tare Creek.

- Datasonde results from September 1991 show the same general information as the instantaneous daytime measurements collected earlier in the year (Figure 25; upper plot; Appendix A, Table 9). The lowest D.O. concentrations in the mainstem were in the vicinity and downstream from the wetlands area bordering Tare Creek. Concentrations then gradually increased downstream. There was a small reversal in the increasing D.O. trend at RM 75.8 that correlated with the lower values from instantaneous measurements at Pioneer Trail (RM 71.7). The reason for the decline in D.O. near RM 76-71 is unknown. However, a decrease in pH at the same location suggests algal or macrophyte respiration as a possible cause.

- The Primary Contact Recreation (PCR) fecal coliform criterion was exceeded in one Cuyahoga River sample from RM 87.26, located downstream from Tare Creek, the Middlefield WWTP and Hans Rothenbuhler Cheese. In addition to the point source discharges, livestock wastes and possibly waterfowl in the Tare Creek basin were potential sources of bacterial contamination.

- Mean phosphorus and ammonia concentrations also increased at RM 87.26. Ammonia concentrations dropped to near detection limits at the next downstream site (RM 80.5) and

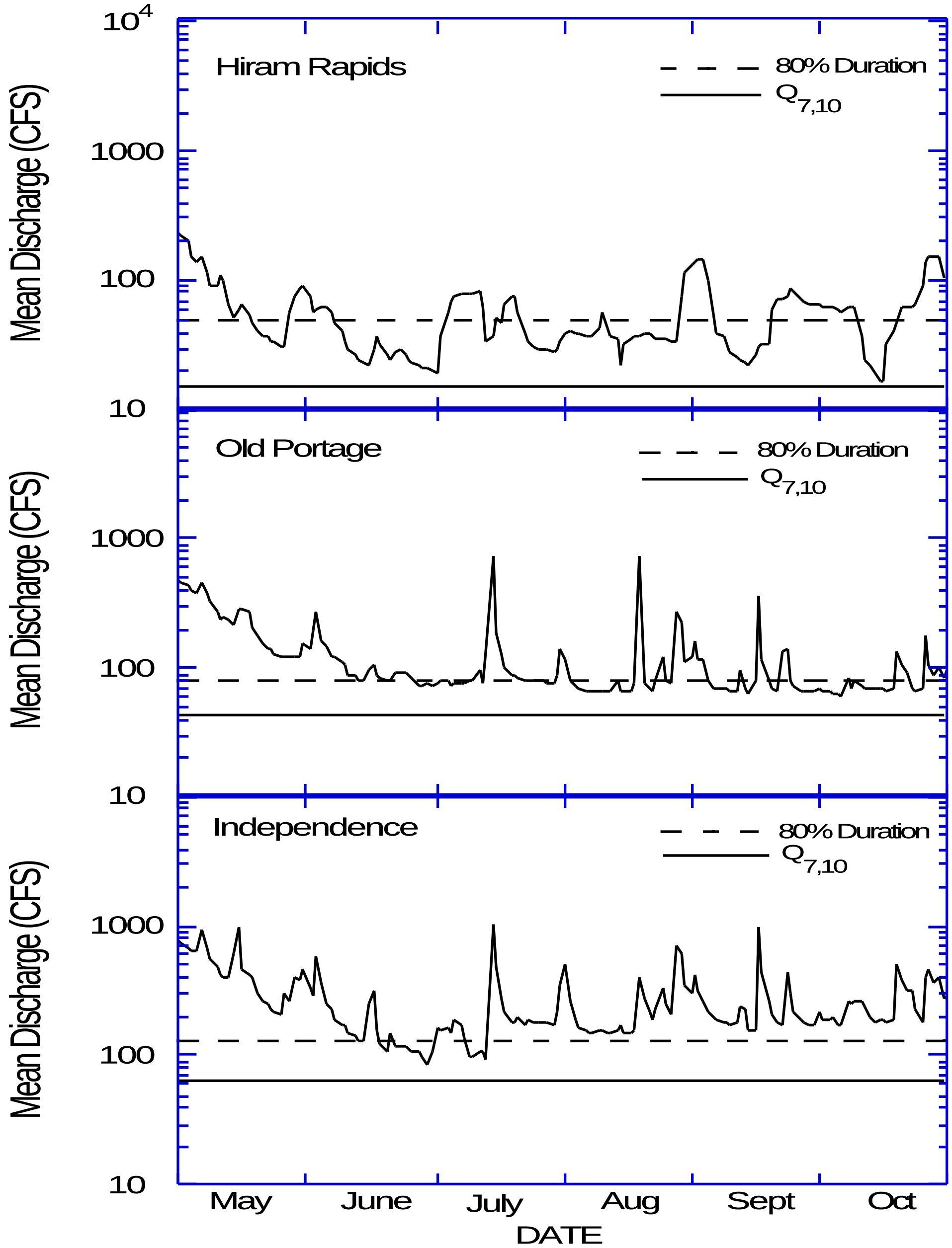


Figure 23. Flow hydrograph for the Cuyahoga River/Creek at Hiram Rapids, Old Portage and Independence, Ohio (RM 75.8, 40.2 and 13.2), May through September,1991. May through November low-flow conditions ($Q_{7,10}$ [15-62 cfs] to 80% duration flow [48-130 cfs]; period of record 1929 to 1978 [all inclusive dates]) are indicated on the flow hydrograph.

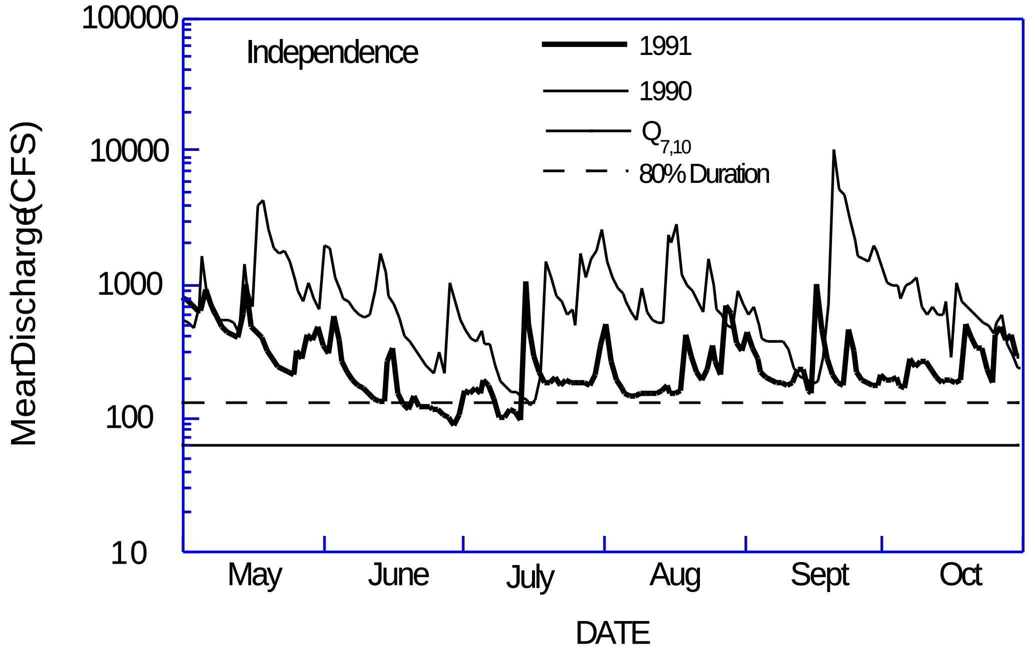


Figure 24. Flow hydrograph for the Cuyahoga River at Independence, Ohio (RM 13.2), May through September,1990 and 1991. May through November low-flow conditions ($Q_{7,10}$ [62 cfs] to 80% duration flow [130 cfs]; period of record 1929 to 1978) are indicated on the flow hydrograph.

remained low downstream to Lake Rockwell. Phosphorus concentrations gradually declined over the next eleven river miles and reached levels similar to those recorded upstream from Tare Creek (Figure 26). Further downstream, two phosphorus results collected on August 13 were much higher than any other sample collected during the survey. Five day carbonaceous BOD levels were low throughout the upper mainstem.

- Flows in the upper Cuyahoga River are regulated by the city of Akron water supply reservoirs East Branch, LaDue, and Lake Rockwell. Abrupt changes in water releases from the reservoirs as shown in Figure 27 result in wide fluctuations in flows that can place added stresses on resident aquatic communities.

- Akron reservoirs release water from both the bottom and top of the water column. Top releases can discharge high concentrations of algae that can contribute to far field diel D.O. problems due to algal photosynthesis/respiration and decomposition. Bottom releases from the hypolimnion can result in immediate low D.O. and high ammonia-N concentrations. Both types of releases contribute to the nutrient enrichment of the river.

- Nitrate-nitrite and ammonia-N compounds showed slight increases downstream from the Mantua WWTP (RM 69.2). No other significant impacts were detected downstream.

Tare Creek

- Dissolved oxygen concentrations in Tare Creek ranged from 0.8 to 3.8 mg/l, well below minimum criteria for both WWH (4 mg/l) and LRW (2 mg/l). These low D.O. concentrations occurred upstream from known point sources and are probably the result of extensive wetlands in the adjacent drainage.

- Fecal coliform criteria were exceeded in all four samples collected from Tare Creek (upstream from all point sources). The most likely sources of contamination were livestock and possibly waterfowl in the wetland area.

- Mean unionized ammonia concentrations in the wetland section of Tare Creek were among the highest found in the study area.

Middle Cuyahoga River

- There were no exceedences of acute WWH criteria for the middle Cuyahoga River detected in chemical grab samples. Exceedences of chronic WWH criteria (Table 8) for the middle Cuyahoga River included:

  √ Total iron in 7 of 24 samples (29%);
  √ Fecal coliform bacteria (see discussion below).

- Samples collected by Ohio EPA in 1991 show the Cuyahoga River from river mile 54.7 to 7.4 was in substantial compliance with chemical water quality criteria for the WWH use designation. During periods of little or no precipitation, wastewater treatment facilities within the Cuyahoga River basin including the Akron and NEORSD Southerly wastewater treatment plants provide adequate treatment of wastewater. Under these conditions, the middle mainstem normally meets chronic and acute water quality criteria for the designated uses.

- Continuous monitor D.O. sampling conducted between Cuyahoga Falls and Independence (RM 45.7 -13.2) indicated D.O. levels throughout most of the middle Cuyahoga River mainstem were well within the established WWH criteria (Figure 25, lower plot; Appendix A, Table 9). However, some D.O. violations were detected in the Ohio Edison dam pool (RM 44.6) which fell below daily minimum (4 mg/l) and nuisance prevention (2 mg/l) criteria.

- Extensive fecal coliform bacteria sampling was conducted during 1989-92 by various agencies including Ohio EPA, Northeast Ohio Areawide Coordinating Agency (NOACA), Northeast Ohio Regional Sewer District (NEORSD), National Park Service (Cuyahoga Valley National Recreation Area [CVNRA]), and USGS. Several of these efforts were coordinated through the Cuyahoga River Remedial Action Plan (RAP). The results show that dry weather (defined as no rainfall for at least three days) fecal coliform bacteria levels in the river within the CVNRA (RM 37.2 to 13.1) are usually below the Primary Contact Recreation (PCR) criterion. However, high coliform counts were detected during dry weather upstream from the CVNRA in the Akron/Cuyahoga Falls area (RM 44.0 to 42.6).

- During 1989, fecal coliform bacteria surveys were conducted in the Cuyahoga River under both dry weather conditions (Table 9 ; Figure 28) and wet weather conditions (Figure 29) as part of the RAP investigation. The following year, 1990, was a wet year and bacteria samples were collected on random dates during the summer (Table 10). These two years of sampling suggested the high coliform counts were a result of CSOs, SSOs and nonpoint source runoff contamination. The surveys also implicated the Little Cuyahoga River as a significant contributor of fecal coliform bacteria to the mainstem. Numerous CSOs and SSOs discharge to the mainstem, the Little Cuyahoga River, and several tributaries in the Akron area during rain events. High coliforms at Cuyahoga Street, upstream from the Little Cuyahoga River, were traced to a sewer on Babb Run and a city of Akron CSO. These sources were corrected once they were discovered.

- Bacteria levels exceed the Primary Contact Recreation (PCR) criterion for up to three days following significant rainfall events. Exceedences were first noted upstream from the Little Cuyahoga River in the Akron/Cuyahoga Falls area. Contamination extended downstream as far as Lake Erie depending upon the severity and areal extent of the rainfall event. Bacteria surveys upstream from Cuyahoga Falls have not been conducted.

- High bacteria counts were recorded in the Little Cuyahoga River even during dry weather periods. Field investigations by Ohio EPA, the National Park Service and work by the City of Akron are continuing to identify and remediate the sources of the contamination.

- Follow-up investigations identified inputs to the Cuyahoga mainstem, tributaries, and the Little Cuyahoga River as the principal contamination sources. In response to this study, the cities of Akron and Cuyahoga Falls initiated corrective actions to repair or replace leaking and broken sewer lines and remove sewer blockages. As a result, the entire Cuyahoga River mainstem now routinely meets the PCR fecal coliform criterion during dry weather.

- Table 11 shows 1991, 1992, and 1993 sample results from a USGS multi-client project to study wet weather fecal coliform and E. coli bacteria contamination in the middle Cuyahoga River. A significant objective of the study was to investigate the changes of in-stream bacteria concentrations with time and distance downstream from the Akron metropolitan area. The samples were collected near peak flow of storm events (flow > 1000 cfs at Old Portage Trail) and after to determine peak to peak travel time from Akron to Independence. The data showed that the most significant fecal coliform bacteria sources in the Cuyahoga River downstream from Akron are from: 1) upstream from Old Portage Trail (RM 40.15), probably from upstream CSOs and SSOs in Cuyahoga Falls and Akron and ; 2) the Akron WWTP just upstream from Bath Road (RM 37.22). Samples collected in 1992 and 1993 showed the WWTP could be a significant contributor to contamination in the mainstem from secondary process bypasses. Current treatment processes are inadequate to properly handle these bypasses. The highest concentrations in the study were found downstream from the Akron WWTP. There are no reported CSOs in the river segment downstream from Old Portage Trail and sanitary sewer overflows in this segment were bulkheaded by the City of Akron in May, 1991. Bacteria concentrations in tributaries to the river, although elevated, were significantly less than the concentrations found in the mainstem. Figure 30 illustrates this wet weather pattern of bacteria contamination in the middle Cuyahoga River.

- It appears that WWTP bypasses and aging municipal collection systems, including sewer breaks, SSOs and CSOs, are the primary sources of the current bacterial contamination in this segment of the Cuyahoga River. Once these sources have been eliminated, nonpoint source contamination will likely be the most limiting factor to future water quality improvements within this portion of the basin.

- Water chemistry samples collected during 1991 showed a steady downstream increase in total lead and total suspended solids concentrations (Figure 31). Although several results approached the chronic WWH criterion for lead, there were no actual exceedences for lead based on the 1991 sampling. There are no numerical WWH criteria for total suspended solids in the WQS. The source(s) of these higher concentrations are not precisely known, but algal turbidity resulting from nutrient enrichment and point source discharged solids are suspected sources. While increased TSS concentrations are generally associated with nonpoint source contributions, the summer of 1991 was exceptionally dry with few runoff events. Thus it seems that the high TSS concentrations were due in part to some source other than nonpoint. Based on visual observations, however, the Cuyahoga River becomes very turbid after significant rainfall and runoff events. This shows that nonpoint source runoff is a substantial contributor of suspended sediment during and shortly after these events.

Lower Cuyahoga River

- There were no exceedences of acute WWH criteria for the Lower Cuyahoga River. (Note: **total** cyanide (12 of 95) samples exceeded the acute criterion for **free** cyanide)

- Exceedences of chronic WWH criteria (Tables 8 and 12) for the lower Cuyahoga River included:

  √ Total Iron (54 of 95 samples; 57%)
  √ Total Copper (3 of 95 samples; 3.2%)
  √ Total Lead (10 of 95 samples; 11%)
  √ Total Zinc (1 of 95 samples; 1.1%)
  √ Total Ammonia as N (7 of 135 samples; 5.2%)
  √ Dissolved Oxygen (34 of 100 manual measurements; 34%)
  √ Total Cyanide (42 of 95 samples exceeded the chronic criterion for *free* cyanide; 44%)

- Low dissolved oxygen concentrations continue to be problematic in the navigation channel. The channel morphology (deepened to allow for commercial ship traffic) and the resultant slow time of travel, is the primary factor effecting dissolved oxygen concentrations. During periods of high river flows, the minimum WWH dissolved oxygen criterion (4 mg/l) is only infrequently violated. However, during low river flows, the dissolved oxygen in the navigation channel frequently is near zero. Violations of the nuisance prevention or LRW criterion (2.0 mg/l) occur frequently during low flow periods and have occurred even as late as December and January. Continuous monitor data were collected during the dry summer months (third quarter) of 1991 (Figure 32, upper plot; Appendix A, Table 9) and under relatively high flow conditions in 1990 (Figure 32; lower plot). The plots reflected the general influence of flow on the D.O. with more severe oxygen depletion observed during the summer, dry weather sampling.

- Occasional exceedences of chronic WWH criteria for total copper, iron, lead, zinc, ammonia-N (Table 8) and cyanide (Table 12;see discussion as follows) also occurred in the navigation channel. The Ohio EPA chemical laboratory was unable to analyze free cyanide in 1991 so all cyanide results were reported as total. However, the water quality standard is based on free cyanide. While the exact relationship between total and free cyanide in the navigation channel is unknown, exceedences of the acute and chronic WWH criteria were noted in Table 12. These data assume the total cyanide was all free cyanide; while this may not be entirely accurate, the data do show that significant amounts of cyanide in some form were often present in the navigation channel. The LTV steel complex was considered the primary source of cyanide.

- As in the middle section of the river, fecal coliform bacteria levels were relatively low during dry weather periods but, based on 1990 results, increased to levels above the PCR criterion following significant rainfall events (Table 10). Bacterial levels can remain elevated for up to 72 hours and then decline below the PCR criterion. Sources of the bacterial contamination include combined sewer overflows, overflows or leaks from sanitary sewers, WWTP bypasses, and nonpoint sources. The elevated levels, while varying in magnitude, occur throughout the river and extend to the Lake Erie nearshore area of Cleveland.

- Total zinc concentrations in this section of the river were high and often approached exceedences of the chronic WWH criterion. The criterion was exceeded once at RM 3.26. All of the higher values were measured in samples collected downstream of the Zaclon 004 discharge (Figure 33; upper plot).

- Figure 33 (lower plot) also shows the relationship of suspended solids in the navigation channel to total lead values. There appears to be a correlation between the concentration of total suspended solids (TSS) and total lead in the lower section of the river. This suggests that high concentrations of heavy metals in the navigation channel may be linked to TSS concentrations in the water column. Therefore, some heavy metal concentrations in the river may be attributed to nonpoint sources rather than point source discharges.

Little Cuyahoga River

- The Little Cuyahoga River from River Mile 10.94 to 0.3 met all applicable chemical water quality standards for parameters analyzed in 1991. The samples were all collected during dry weather flows. However, the Little Cuyahoga River (and the Ohio Canal) is severely affected by sanitary and combined sewer overflows during wet weather. During sample collections septic sediments and sanitary wastes were quite evident in the stream, the residuals of past runoff and discharge events. Wet weather sampling conducted by the city of Akron in the Little Cuyahoga River and Ohio Canal during 1989-92 revealed some very high levels of BOD and TSS in the Akron urban area following rain fall events (Figure 34). National Park Service sampling showed high fecal coliform counts in the Little Cuyahoga River that is now considered the major source of bacterial contamination in the Akron area segment of the mainstem.

- In addition, the Little Cuyahoga River is eroding into the river banks and exposing solid wastes from closed landfills located in the river valley near the confluence with the Cuyahoga River. The landfill waste is a very significant contributor of downstream litter and may contribute to sediment contamination. Akron is continuing remedial action at these landfills to address aesthetic and human health concerns.

Table 8. Exceedences of Ohio EPA Warmwater Habitat (WWH) criteria (OAC 3745-1) for chemical/physical parameters measured in the Cuyahoga River study area, 1991. Exceedences of **acute** and **nuisance prevention** criteria are listed in **bold** type. The WWH criteria for the Navigation Channel (RM 5.5 - 0.0) are used as a reference only. Limited Resource Water (LRW) is the recommended use for the Navigation Channel. (units are µg/l for metals, S.U. for pH, and mg/l for all other parameters). Navigation Channel values are from depth integrated samples of two (2), 15 and 25 feet.

Stream Name	River Mile	Exceedence: Parameter (value)
Cuyahoga River	89.41	D.O.(3.0, 3.2)**
	87.26	D.O.(3.7)**, Fecal Coliform 2800◊
	71.7	D.O. (3.2)**
	67.6 to 7.4	*No Exceedences from Mantua to Big Creek in Cleveland*
	7.10	Cu (35, 50)*; Pb (63, 41)*
Navigation Channel		
	5.00	Pb (27, 24)*; NH_3-N (1.29, 1.14)* D.O. (4.83, 4.38)* D.O. (3.87)‡‡
	4.10	Pb 40*; NH_3 (1.10, 1.71, 1.26)* D.O. (4.37, 4.17)* D.O. (**1.48**, 2.65, 3.77, **1.87**)‡‡
	3.26	Cu 25*; Pb 40*; Zn 152* D.O. (2.27, 2.52, 2.2, 3.1, 2.3)‡‡ D.O. (**1.33**, **1.78**)‡‡‡
	1.95	Pb 32*, NH_3 1.32* D.O. 4.27* D.O. (2.8, 2.22, 2.18, **1.5**, **1.65**, 3.0, 2.37, 3.23, 3.28)‡‡
	0.92	Pb 29*, D.O. (3.37, 2.42, 2.5, 2.3, 2.23, 2.63, 2.87)‡‡ D.O. (**1.83**, **1.35**, **1.73**)‡‡‡
	0.01	Pb (22, 17)*; NH_3 6.42* D.O. (4.28, 4.93, 4.57)* D.O. (3.45, 3.15)‡‡
	72 of 137 iron samples (52.5%) exceeded 1.0 mg/l in the Cuyahoga River.	
Tare Creek		
	1.59	D.O. (3.8, 3.8, 2.4, 3.5)‡‡ D.O. (**0.8**)‡‡‡ Fecal Coliform 2200◊, (3900, 4200, 9000)◊◊
	4 of 5 iron samples (80%) exceeded 1.0 mg/l in Tare Creek.	

Table 8. (continued).

Stream Name	River Mile	Exceedence: Parameter (value)
Tinkers Creek	8.75	Fecal coliform > 2000 ◊
	28.3 to 0.1	*No Other Exceedences; headwaters to mouth*
	26 of 33 iron samples (78 %) exceeded 1.0 mg/l in Tinkers Creek.	
Beaver Meadow Run	0.10	Fecal coliform (3500, 3000)◊◊
Pond Brook	1.41	Fecal coliform 2800 ◊
Mill Creek	2.90 0.45 0.10	Fecal coliform 20000 ◊◊ NH_3 (2.86)* NH_3 (3.48, 3.58)* Fecal coliform 97000 ◊◊
Unnamed Trib. to Mill Creek	0.10	Fecal coliform >67000 ◊◊
Morgan Run	0.01	Cu (**23**)**; D.O. (3.4)** Cu (25[a])*
	9 of 12 iron samples (75%) exceeded 1.0 mg/l in Morgan Run.	
Kingsbury Run	0.01	D.O. (3.1)**, Zn (192[a])*
	2 of 5 iron samples (40%) exceeded 1.0 mg/l in Morgan Run.	

* Indicates an exceedence of numerical criteria for prevention of chronic toxicity (CAC).
** Indicates an exceedence of numerical criteria for prevention of acute toxicity (AAC).
a Hardness data not available, exceedence value assumes a hardness of 200 mg/l.
‡ Violation of the average dissolved oxygen (D.O.) criterion.
‡‡ Violation of the minimum dissolved oxygen (D.O.) criterion.
‡‡‡ Violation of the “nuisance prevention” minimum dissolved oxygen (D.O.) criterion.
◊ Exceedence of the Primary Contact Recreation criterion.
◊◊ Exceedence of the Secondary Contact Recreation criterion.

Table 9. Results of dry weather fecal coliform bacteria survey of the Cuyahoga River (RM 42.6-13.2) and Little Cuyahoga River (RM 42.3/0.3), April 10 to October 24, 1989. Data were collected by Ohio EPA, and the University of Akron. **Bold** indicates values >2000 colonies per 100 ml.

River Mile	Apr 10	Apr 17	Apr 20	May 18	Jun 8	Jul 5	Jul 6	Jul 11	Jul 17	Jul 19	Jul 25	Aug 28	Oct 24
42.6	400	360	580	270	460	1100	1200	1500	**2100**	1700	1600	1600	**2100**
42.3/0.3	**2500**	**4800**	19	480	**2500**	870	340	**9300**	600	590	**5400**	**5800**	**3600**
40.2	1700	1800	270	350	450	1000	720	2000	1100	1000	1100	1500	**2400**
37.2	**3800**	**6400**	**2200**	500	260	680	240	800	550	560	680	500	460
35.3	**2200**	**5700**	200	450	300	290	210	190	350	200	610	340	400
33.2	**3500**	**5200**	120	72	390	120	50	62	81	160	550	100	300
29.2	**3100**	**5800**	110	130	350	250	69	64	69	140	370	160	380
26.5	**3200**	**3700**	75	230	320	220	70	110	110	300	530	120	480
20.3	**3500**	1900	110	270	350	550	250	190	150	250	250	1500	670
17.3	**5700**	810	190	270	410	800	230	180	70	140	210	120	490
13.2	**2200**	500	180	140	470	1000	290	110	66	130	170	83	300

Sampling Location	River Mile	Geometric Mean
Cuyahoga St	42.6	1111
L. Cuyahoga nr mouth	42.3/0.3	1299
Old Portage gage	40.2	984
Bath Rd	37.2	779
Ira Rd	35.3	436
Bolanz Rd	33.2	229
Upstream Peninsula	29.2	257
Boston Mills Rd	26.5	291
Station Rd	20.3	429
Fitzwater Rd	17.3	321
Independence gage	13.2	255

Table 10. Results of fecal coliform bacteria surveys of the Cuyahoga River (RM 35.5 - 0.0) under wet weather conditions during June - October, 1990. Data were collected by Ohio EPA, National Park Service, and NEORSD.

Sampling Location	Number OF Samples	Total Geometric Mean	Percent Exceeding 2000/100 ml
Ira Rd (RM 35.5)	163	3491	61
Boston Rd (RM 26.7)	162	2939	59
Independence (RM 13.8)	163	2076	50
E. 71 & Canal Rd (RM 11.7)	14	360	7
Ust. NEORSD Southerly (RM 11.3)	14	593	21
Dst. NEORSD Southerly (RM 9.8)	17	468	18
Near Bradley Rd. (RM 7.9)	15	332	13
Lower Harvard Ave. (RM 7.2)	18	519	22
Head of Navigation Channel (RM 5.6)	14	715	36
Turning Basin (RM 4.5)	14	2317	57
West Third Ave. (RM 3.3)	19	2007	47
Columbus Ave. (RM 1.4)	13	492	15
Center St. (RM 0.9)	23	680	26
Near Mouth (RM 0.5)	23	507	13
River Rd. - Old River Channel (RM 0.5/0.2)	20	559	0
West End of Old River Channel (RM 0.5/1.0)	11	159	0
River Mouth (RM 0.0)	25	441	20

Table 11. Fecal coliform bacteria concentrations from the Cuyahoga River and selected tributaries (Sept. 4-5, 1991 and Sept. 2-3, 1993) and the Akron WWTP 001 outfall (Sept. 13, 1992 and Sept.3, 1993). Samples were collected near peak river flow after storm events (flow > 1000 cfs at Old Portage Trail). Data from USGS.

Stream	Sampling Location	Mainstem River Mile	Fecal Coliform Bacteria 1993 (colonies / 100 ml)	Fecal Coliform Bacteria 1991 (colonies / 100 ml)
Cuyahoga River	Old Portage	40.15	500,000	56,000
			1,000,000	44,000
			180,000	
			110,000	
			Median **340,000**	**5,000**
Mud Brook	@ mouth	39.78	16,000	7,700
			25,000	12,000
			13,000	
			Median **16,000**	**9,850**
Sand Run	@ mouth	39.12	73,000	3,300
			31,000	4,400
			7,000	
			Median **31,000**	**3,850**
Akron WWTP 001	Effluent	37.45	15,000,000	
			670,000	
				(7-13-92) 250,000
				(7-13-92) 390,000
				(7-13-92) 470,000
			Median **NA**	**NA**
Cuyahoga River	@ Botzum	37.22	2,600,000	320,000
			600,000	340,000
			870,000	180,000
			600,000	210,000
			580,000	57,000
			610,000	38,000
			470,000	37,000
			340,000	
			250,000	
			Median **600,000**	**180,000**
Brandywine Creek	@ mouth	24.16	48,000	8,700
			51,000	7,700
			38,000	8,000

Table 11. (continued).

Stream	Sampling Location	Mainstem River Mile	Fecal Coliform Bacteria 1993 (colonies / 100 ml)	Fecal Coliform Bacteria 1991 (colonies / 100 ml)
Brandywine Creek	@ mouth (cont.)	24.16		6,800
				9,300
			Median **600,000**	**180,000**
Cuyahoga River	@ Jaite	24.10	110,000	320,000
			610,000	180,000
			700,000	180,000
			1,000,000	160,000
			540,000	200,000
			530,000	180,000
				5,100
			Median **575,000**	**180,000**
Cuyahoga River	@ Brecksville	20.80	590,000	
Tinkers Creek	@ mouth	16.36	97,000	7,300
			51,000	7,700
			43,000	4,700
			20,000	6,500
				2,800
				4,500
			Median **47,000**	**5,600**
Cuyahoga River	@ Independence	13.18	320,000	110,000
			230,000	92,000
			320,000	64,000
			530,000	37,000
			150,000	13,000
				8,300
			Median **275,000**	**64,000**

Table 12. Total cyanide concentrations in the lower Cuyahoga River study area, 1991. Although reported as **total** cyanide, the values are referenced to exceedences of Ohio EPA Warmwater Habitat criteria (OAC 3745-1) which are for **free** cyanide. All values are reported in ug/l.

Stream Name	River Mile	Violation: Parameter (value)
Cuyahoga River	7.10	CN (20, 27, 19, 13, 15)*
>Navigation Channel		
	5.6	CN (19, 16, 24, 20)* CN (**48**)**
	4.68	CN (39, 24, 29, 20, 29, 38)* CN (**68**, **78**, **71**, **56**, **67**, **70**, **51**, **49**)**
	4.10	CN (46, 14, 28, 40, 37, 35)* CN (**54**, **59**)**
	3.26	CN (14, 26, 30, 38, 39, 25, 21) CN (**67**)**
	1.95	CN (14, 16, 21, 46, 34, 16) CN (**52**)**
	0.92	CN (23, 30, 19, 23, 38, 17)*
	0.01	CN (14, 18)*
Morgan Run	0.01	CN (42)*; CN (**202**, **788**, **140**, **326**, **635**, 15,**440**, **207**, **818**, **390**, **225**, **204**)***
Kingsbury Run	0.01	CN (**564**, **483**, **258**, **344**, **380**)***

* indicates an exceedence of numerical criteria for prevention of chronic toxicity (CAC).

** indicates an exceedence of numerical criteria for prevention of acute toxicity (AAC).

*** indicates an exceedence of numerical criteria for prevention of acute toxicity inside the mixing zone [*i.e.,* Final Acute Value (FAV).]

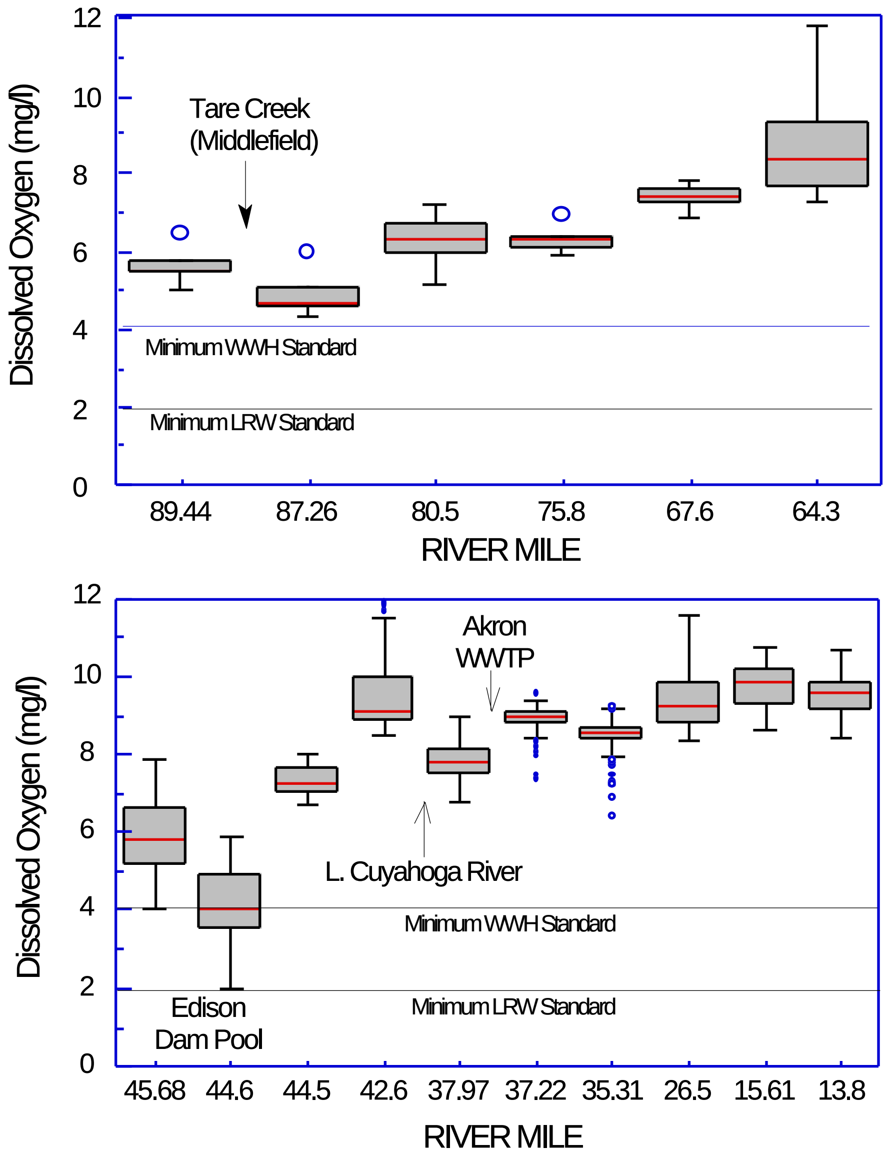


Figure 25. Box and whisker plot of dissolved oxygen continuous monitor data from the upper Cuyahoga River upstream from Lake Rockwell [upper plot] and the middle Cuyahoga River (Stow area to Independence [lower plot]) collected during the summer of 1991.

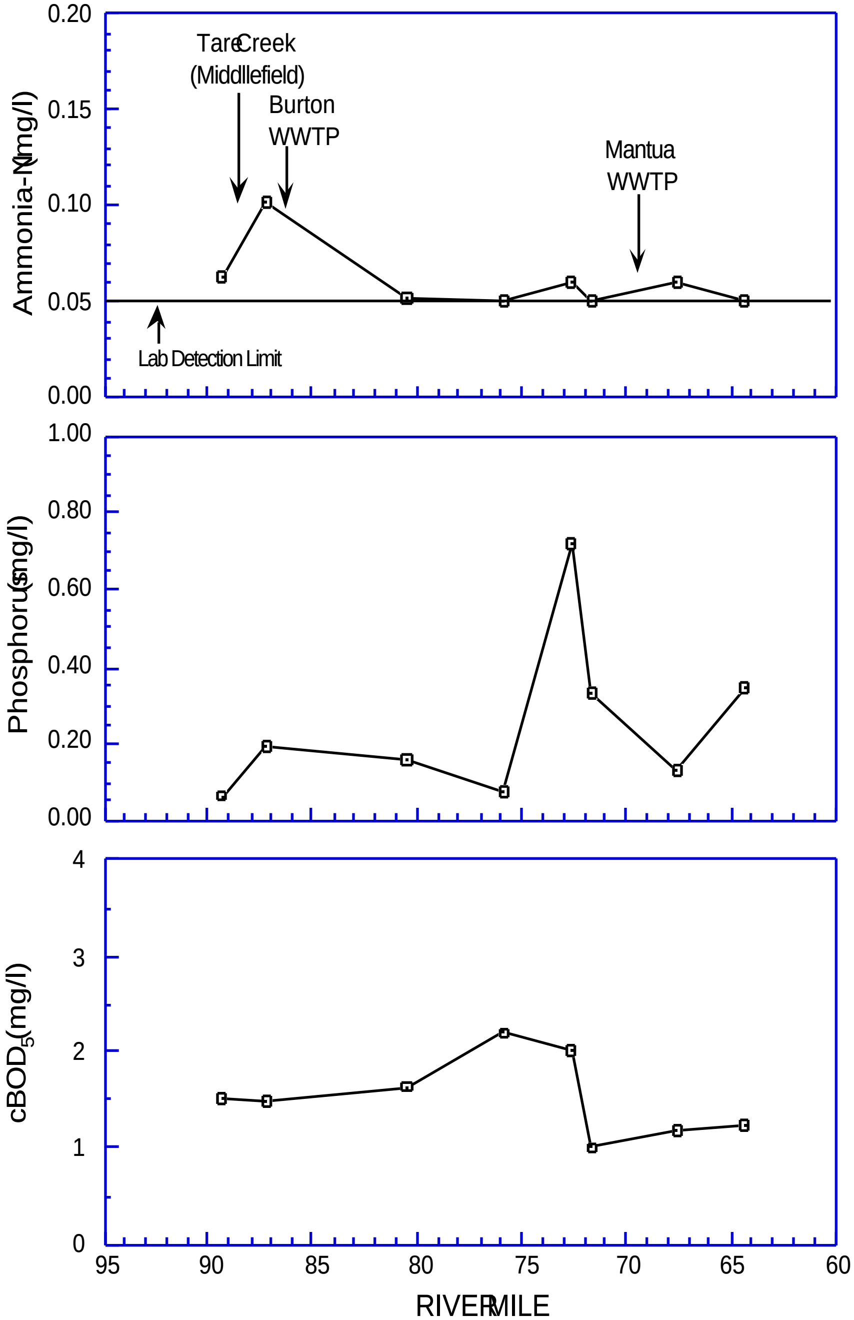


Figure 26. Longitudinal trend of mean ammonia (NH_3-N), phosphorus, and five day carbonaceous BOD in the upper Cuyahoga River mainstem study area, 1991.

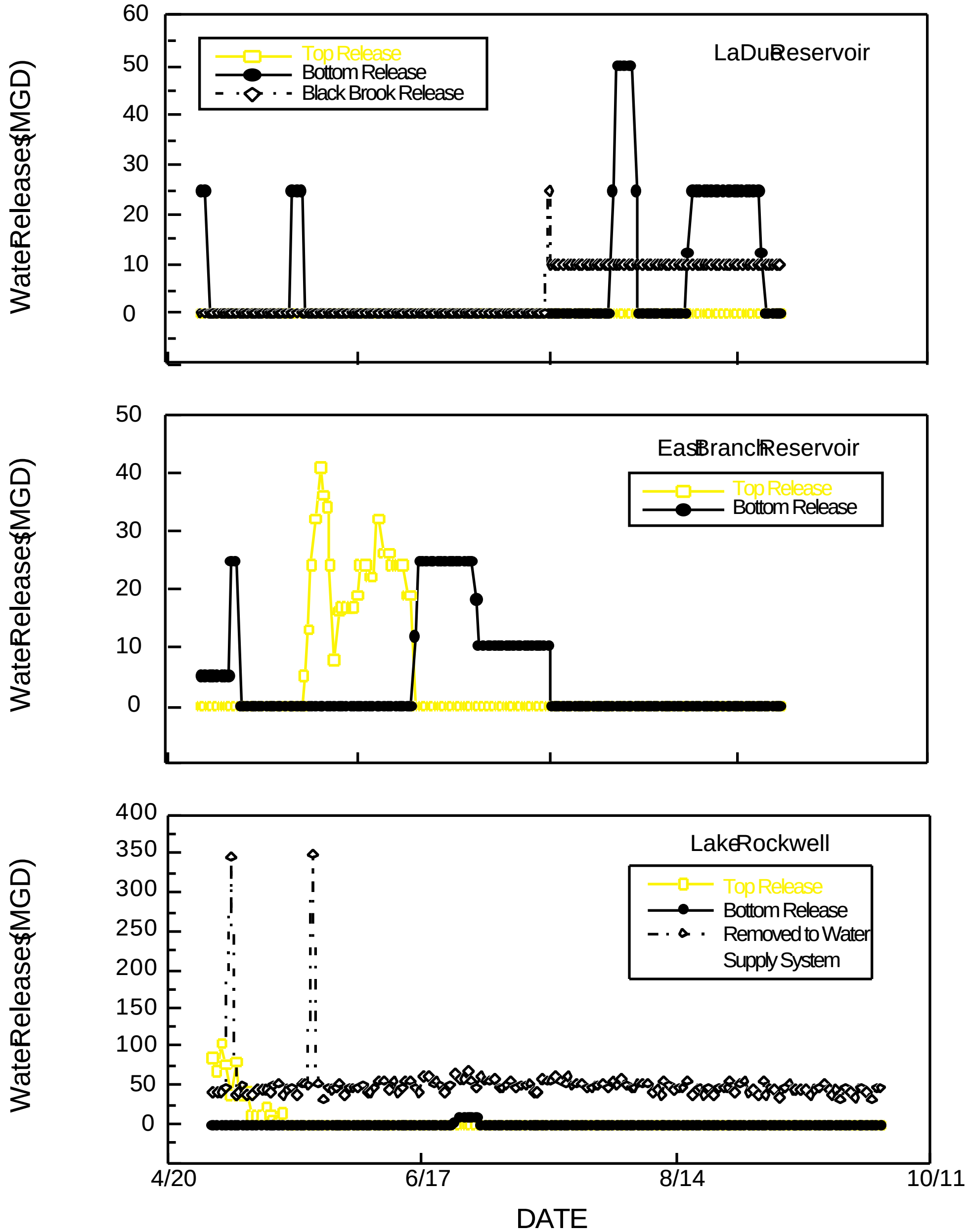


Figure 27. Reservoir releases in millions of gallons per day (MGD) from the three Akron water supply reservoirs in the upper Cuyahoga River basin study area, May to October, 1991.

Figure 28. Fecal coliform bacteria counts at 10 locations in the Akron to Cleveland segment of the mainstem (Cuyahoga St. to Independence) during dry weather conditions (no rainfall in Akron area for $\geq$3 days) April 4-October 24, 1989. Data produced through the efforts of the Cuyahoga River RAP.

Figure 29. Fecal coliform bacteria counts at 10 locations in the Akron to Cleveland segment of the Cuyahoga River mainstem (Cuyahoga St. to Independence) during wet weather conditions (*i.e.*, following significant rainfall in the Akron area) July-September, 1989. Data produced through the efforts of the Cuyahoga River RAP.

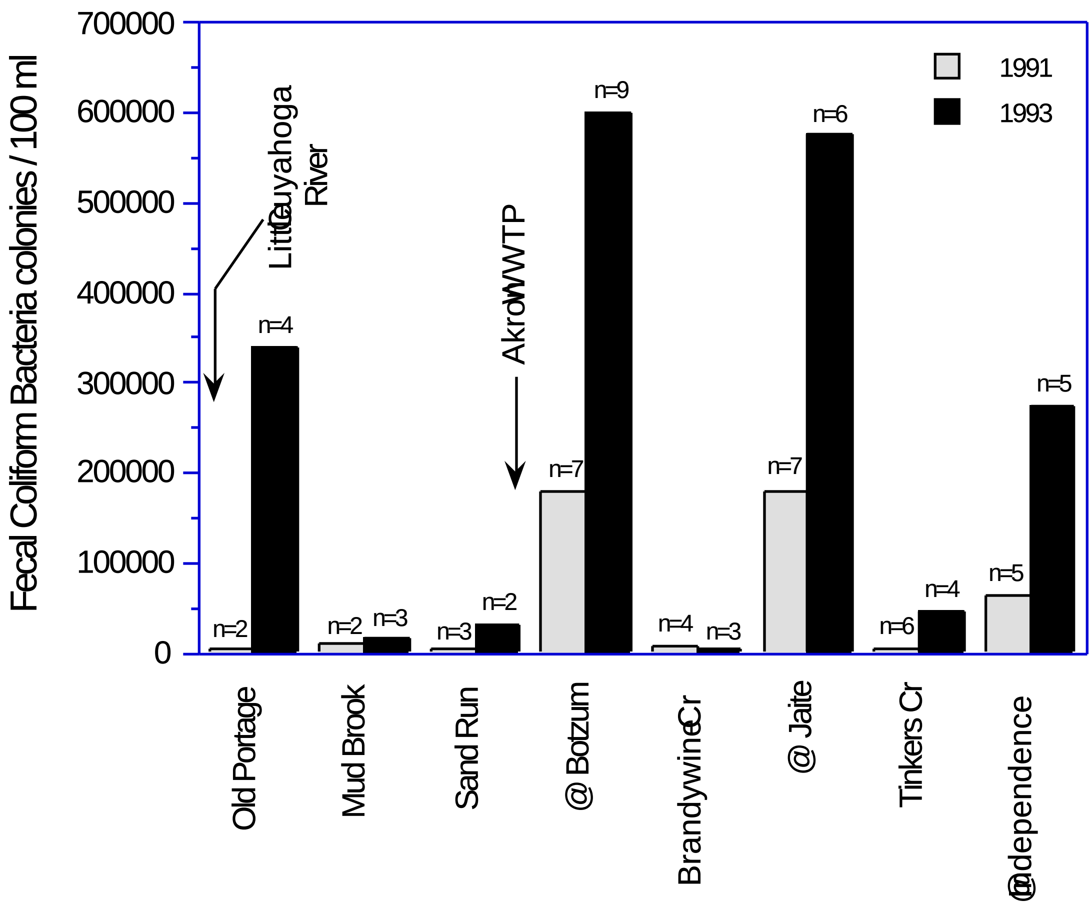


Figure 30. Median fecal coliform bacteria concentrations in the Cuyahoga River and selected tributaries, September 4-5, 1991 and September 2-3, 1993. Samples collected near peak river flows after storm events (flow at Old Portage Trail > 1000 cfs). The tributaries fecal coliform bacteria concentrations, although elevated, contribute significantly smaller concentrations of fecal coliform bacteria than concentrations found in the mainstem. Data from USGS.

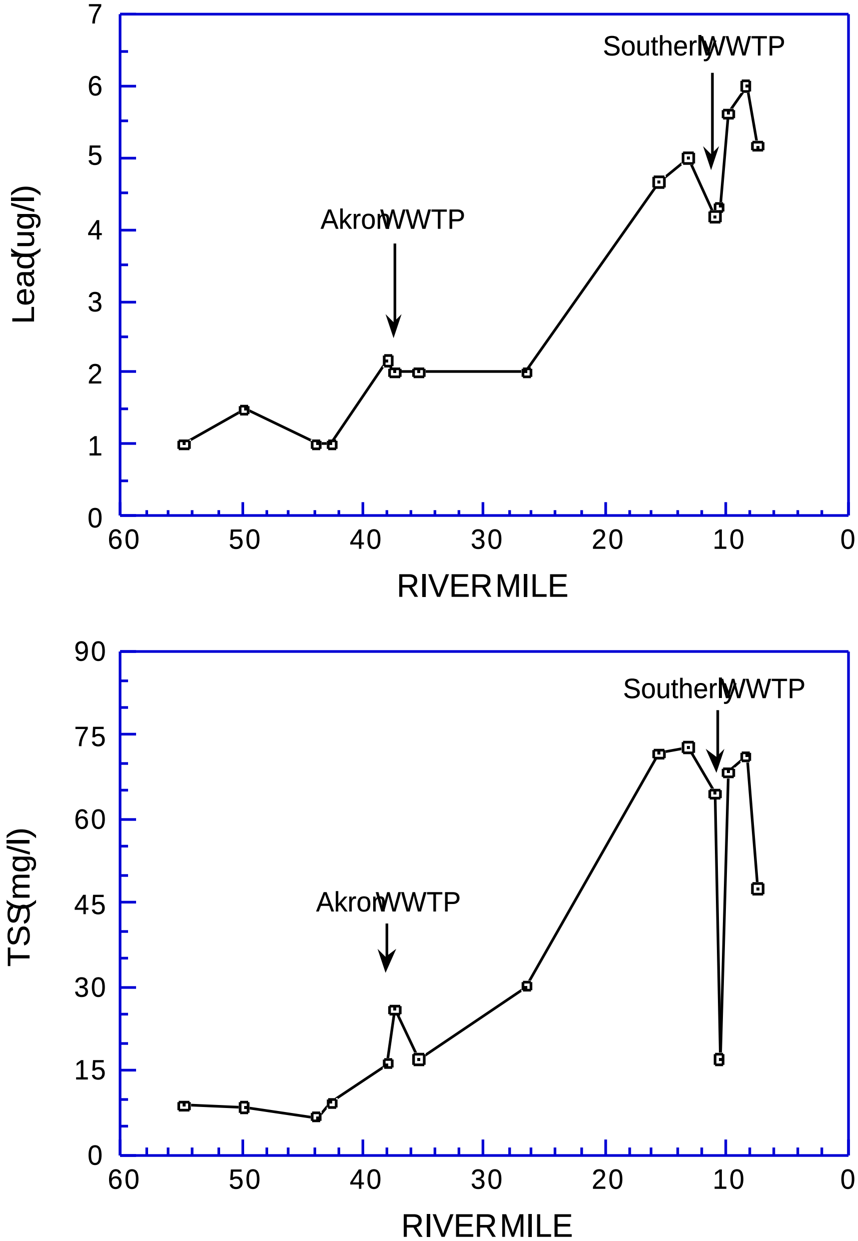


Figure 31. Longitudinal trend of lead and total suspended solids (TSS) in the middle Cuyahoga River mainstem study area, 1991

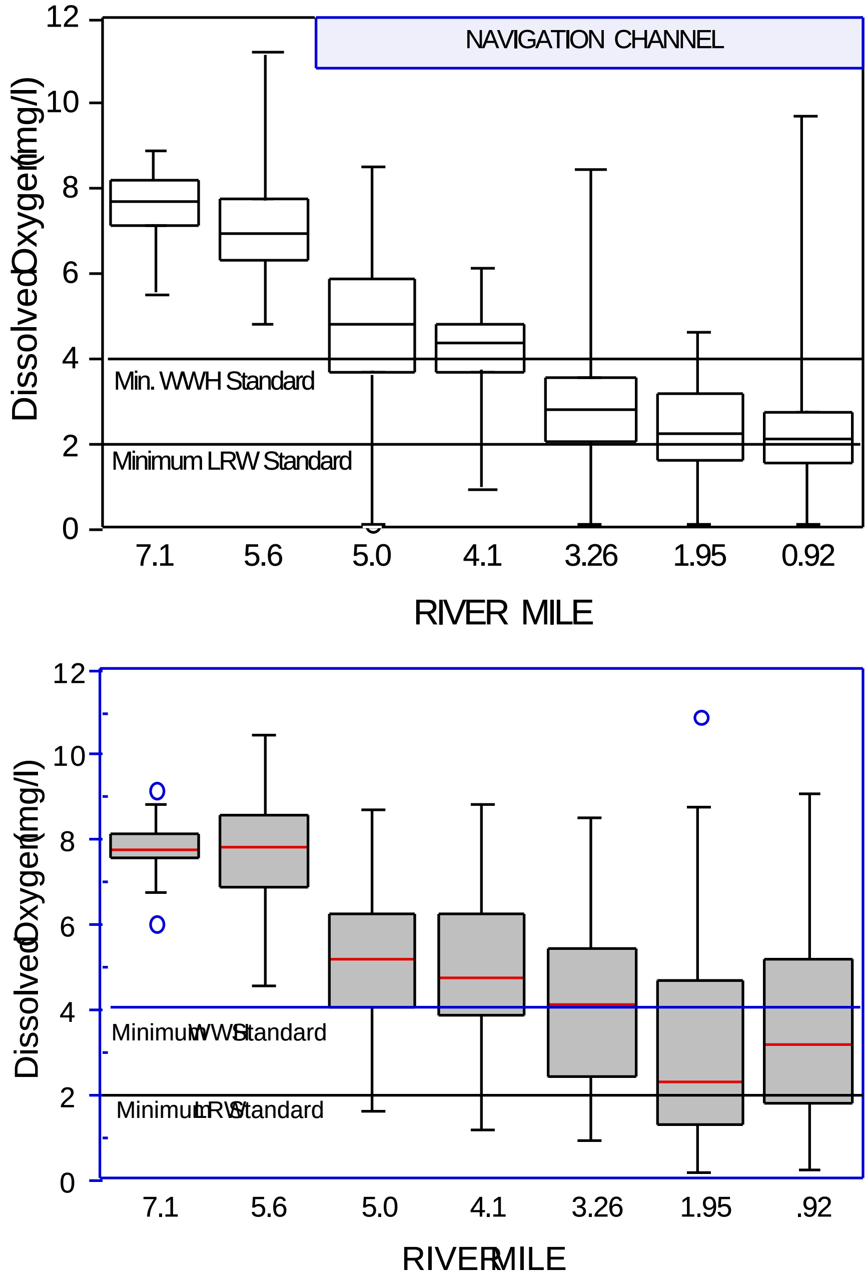


Figure 32. Box and whisker plot of dissolved oxygen continuous monitor data from the Cuyahoga River between Lower Harvard Ave and the mouth (RM 7.1-0.0) during the third quarter of 1991 [July-October (upper plot)] and in 1990 and 1991 [April-October (lower plot)].

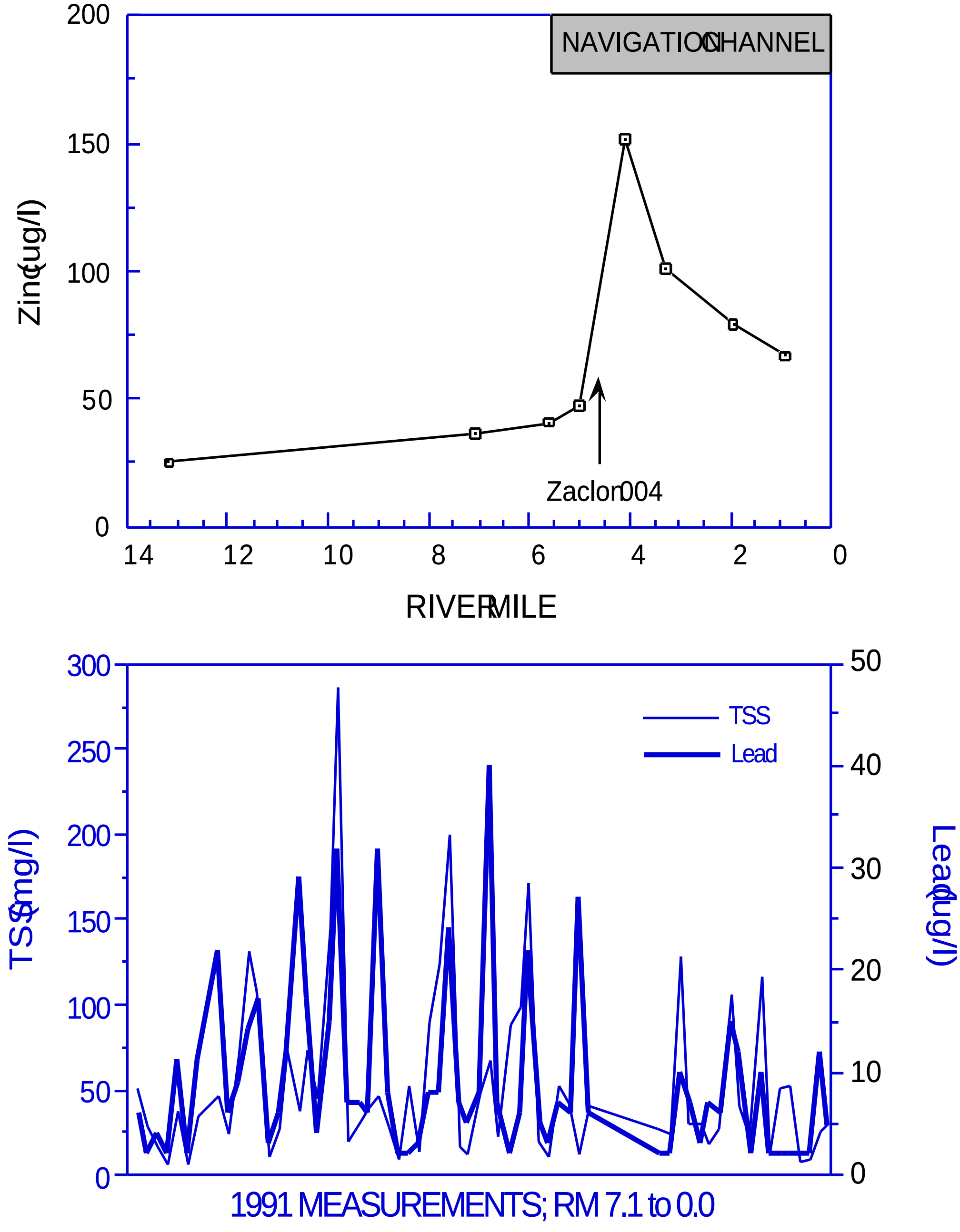


Figure 33. Longitudinal trend of zinc (upper) in the lower Cuyahoga River, 1991 and lead concentrations (lower) compared with total suspended solids (TSS) in samples from the lower 7.1 miles of the mainstem, April 23 to September 27, 1991.

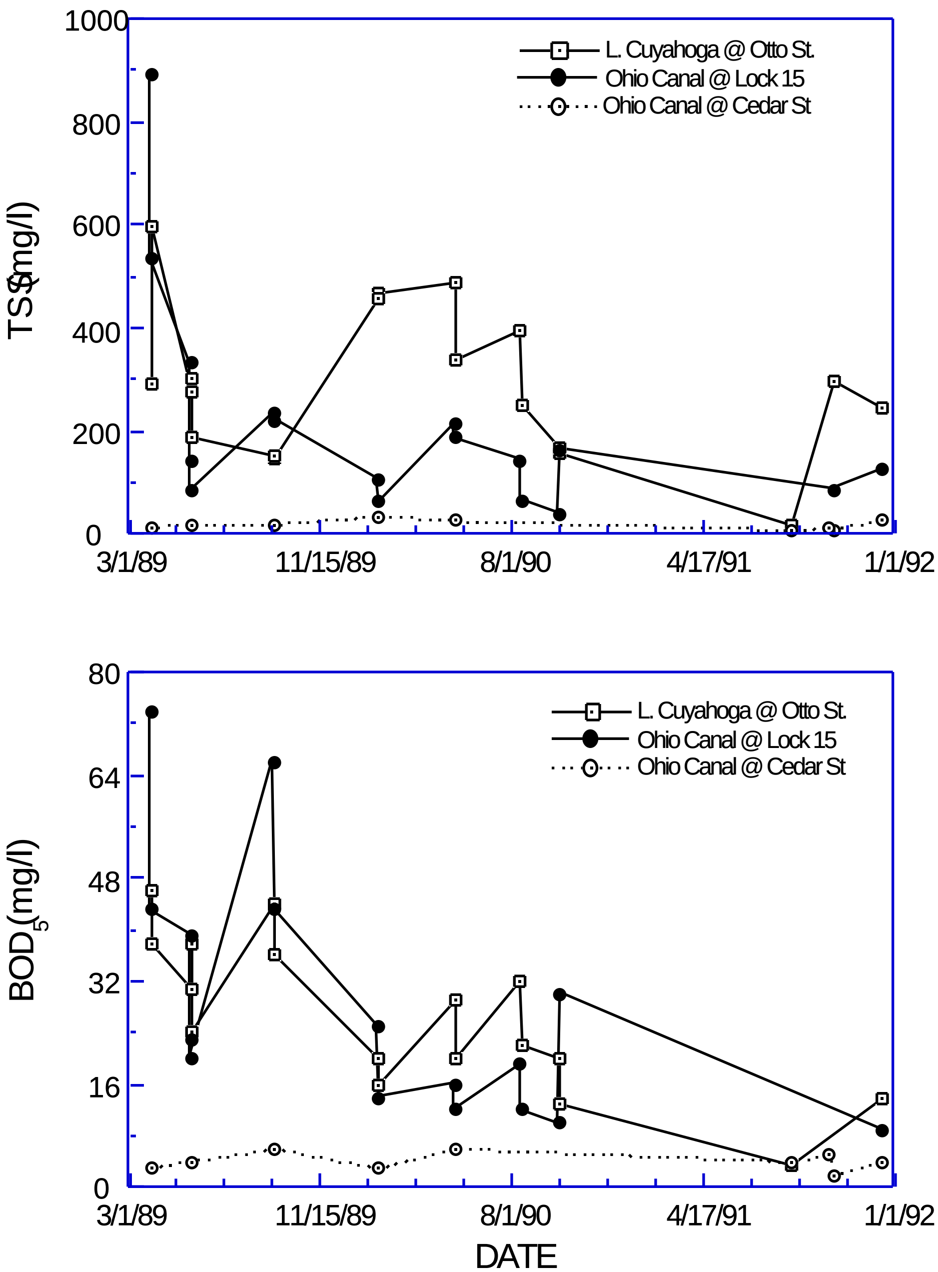


Figure 34. Concentrations of total suspended solids (TSS) [upper] and five day biochemical oxygen demand (BOD_5) [lower] in the Little Cuyahoga River subbasin following rainfall events, 1989-1992. Data collected by the city of Akron.

Tinkers Creek

- Tinkers Creek is the largest tributary of the Cuyahoga River, with a watershed area of 96.4 square miles. Grab water samples were collected under baseflow conditions in an attempt to characterize water quality and document violations and exceedences of acute and chronic water quality criteria. Average flows were somewhat lower during 1991 than the previous survey year of 1984. Hence the 1991 results reflect water quality conditions more greatly influenced by WWTP discharge flows (*i.e.*, a lower amount of upstream dilution water). The 1991 results were compared to those from 1984 to document long-term trends. During 1991, effluent samples were also collected from the Solon, Aurora Westerly, Streetsboro, Bedford, and Twinsburg WWTPs.

- Upstream from the USGS gage at RM 6.3, four major WWTPs (Streetsboro, Twinsburg, Solon Central, Bedford Heights) and two minor WWTPs (Aurora Westerly, Aurora Shores) had an annual 1991 median discharge of 11.61 MGD (17.98 cfs). Downstream from RM 6.3, an additional median flow of 2.18 MGD (3.37 cfs) was discharged by the Bedford WWTP. The only industrial process wastewater discharge is from Zircoa which discharges to Beaver Meadow Run at RM 2.72. All other industrial process wastewater is discharged to the municipal sanitary sewers and is regulated by pretreatment guidelines.

- During the summer of 1991, the 3rd quarter monthly average flow at the USGS gage ranged from 31.4 to 42.5 cfs. Thus, the combined flow of WWTP effluent represented approximately 42 to 57 percent of the average stream flow during the 1991. A much higher percentage of treated wastewater would be expected under $Q_{7,10}$ low flow conditions. A minimum flow of 15 cfs was recorded at the RM 6.3 USGS gage (Figure 35). At this flow WWTP effluent made up 80-90 percent of the stream flow. These data indicate that the present day hydrology of Tinkers Creek is highly influenced by the amount of water that is being diverted from Lake Erie for public drinking water purposes and subsequently discharged by municipal WWTPs.

- The 1991 water chemistry data collected during low flow conditions showed no exceedences of chronic water quality criteria for heavy metals or ammonia-N. Concentrations of these parameters were significantly lower in 1991 than during the previous 1984 survey, especially for copper and ammonia-N.

- Violations of the total iron water quality criterion were observed between RM 25.5 and RM 6.8. Iron is a common element and is a component of clay soils. Mean Fe values above 2000 mg/l were measured at 5 of 11 sampling locations. There appeared to be a positive relationship between the concentrations of total iron and total suspended solids TSS (Figure 36). TSS concentrations *under low flow conditions* were well above the 75th percentile concentrations found at least impacted reference sites in the Cuyahoga River basin. Mean TSS values above 30 mg/l were measured at 5 of 11 sampling locations. The continuous presence of elevated levels of TSS and total iron in the water column may be indicators of factors that presently are limiting the performance of the fish and macroinvertebrate communities in Tinkers Creek.

- During the 1991 survey a number of longitudinal trends in water quality were noted. Hardness was elevated in the headwaters (300-400 mg/l range) and gradually decreased to the 200-250 mg/l range near the mouth. Percent saturation of dissolved oxygen gradually increased from the headwaters to the mouth of Tinkers Creek (Figure 36).

- Continuous monitor sampling (Appendix A; Table 10) found the lowest concentrations of

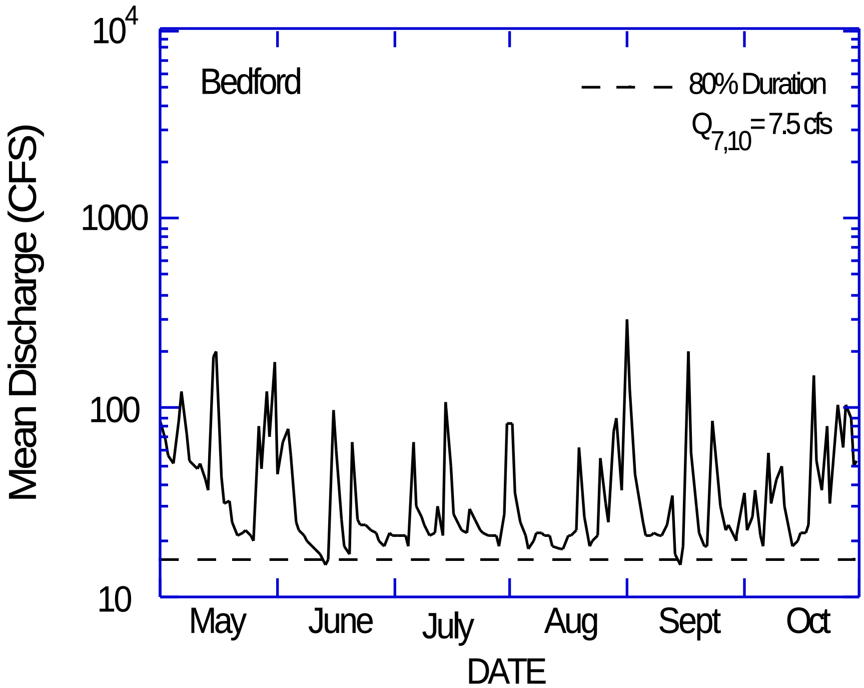


Figure 35. Flow hydrograph for Tinkers Creek at Bedford, Ohio (RM 6.3) May through October 1991. Sampling dates and May through November low-flow conditions ($Q_{7,10}$ [7.5 cfs] to 80% duration flow [48 cfs]; period of record 1961 to 1978) are indicated on the flow hydrograph.

dissolved oxygen at the RM 28.75 headwater station (min. of 4.52 mg/l). The site was upstream from the influence of known point source dischargers or urban runoff. The source of the low dissolved oxygen and high water hardness in the headwaters of Tinkers Creek is most likely due to drainage from the numerous swamps, bogs, and fens found in the upper Tinkers Creek watershed.

- Violations of the 2000/100 ml fecal coliform PCR criterion were observed in the mainstem of Tinkers Creek at RM 8.75, which is below the Ohio Bulk Transfer Company package plant and the Richmond Road mobile home park (MHP) WWTP discharges. Fecal coliform was below 500/100 ml at all other mainstem stations sampled, which is well below the 1000/100 ml PCR criterion. Elevated counts (3500, 3000/100 ml) were found at the mouth of Beaver Meadow Run and the source was traced to a leaking sanitary sewer line at a location above the Solon Central WWTP discharge. The leak was corrected and background levels of fecal coliform bacteria were recorded in late August 1991. Two samples at RM 1.41 on Pond Brook showed fecal coliform counts of 2800 and 930/100 ml. This site is downstream from the Aurora Shores and Aurora Westerly WWTPs.

- Sampling upstream and downstream from the BFI Glenwillow and the Inland Reclamation landfills did not show evidence of any impacts on chemical water quality that could be attributed to landfill runoff and/or leachate.

Tinkers Creek Tributaries

- Chemical grab samples collected near the mouths of Pond Brook, Hawthorn Run, and Beaver Meadow Run indicated no exceedences of acute or chronic criteria with the exception of dissolved oxygen as measured by continuous monitors. Exceedences of fecal coliform bacteria were found in Pond Brook and Beaver Meadow Run. Elevated counts in Beaver Meadow Run were traced to a leaking sanitary sewer and the problem was corrected by the end of August 1991. Minor but inconsistent violations of the 2000/100 ml PCR fecal coliform criterion were observed in lower Pond Brook downstream from the Aurora Shores and Aurora Westerly discharges.

- Continuous monitor results collected during 1991 and 1989 indicated D.O. problems in many sections of Pond Brook (Figure 37). Data from August of 1989 revealed severe D.O. depletion immediately upstream and downstream from the Aurora Westerly WWTP (RM 1.58-1.41). Concentrations as low as 0.06 mg/l were detected and all samples were below the minimum average MWH criterion of 4 mg/l. D.O concentrations were generally higher upstream, near the Aurora Shores WWTP. However, samples below MWH criteria were recorded, both upstream and downstream from the WWTP. Conditions were less severe in 1991 but concentrations still dropped below MWH criteria at three of the four sampling locations between the Aurora Shores WWTP and the mouth. Continuous monitoring at RM 0.05 in the Aurora Westerly WWTP tributary also showed improved minimal dissolved oxygen conditions from 1989 (minimum of 1.91 mg/l) to 1991 (minimum of 4.19). In Pond Brook, dissolved oxygen minimums of 0.06 mg/l and 2.65 mg/l were recorded in 1989 and 1991 respectively.

- Some water quality problems noted in the 1989 survey may have been related to unusually high discharges of ammonia at the Westerly WWTP as the plant was coming on line. Historical discharge data indicated above average loadings during the period and a 1989 chemical sample from Pond Brook RM 0.3 revealed high levels of ammonia in-stream (7.13 mg/l).

- In Hawthorn Creek, a minimum dissolved oxygen of 1.62 mg/l was observed at RM 0.08, downstream from the Bedford Hts. WWTP discharge. In Beaver Meadow Run, a minimum D.O. value of 3.17 mg/l was found at RM 2.75, well upstream from the Solon WWTP discharge.

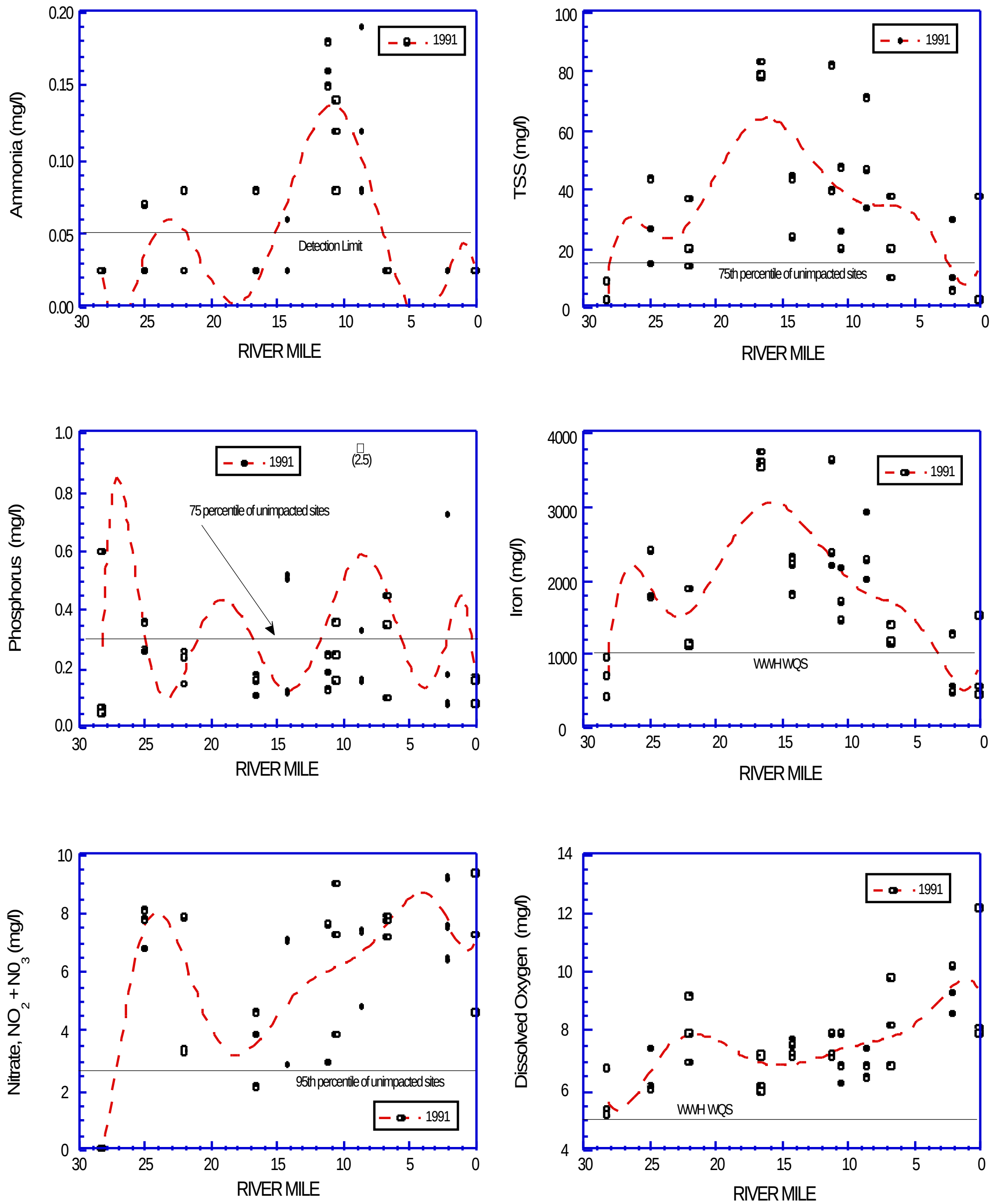


Figure 36. Longitudinal trend of ammonia, total suspended solids (TSS), phosphorus, iron, nitrate (total nitrate plus nitrite) and dissolved oxygen in Tinkers Creek, 1991. "Unimpacted" site percentiles are based on analysis of Ohio EPA historical chemical data (Brown, 1988).

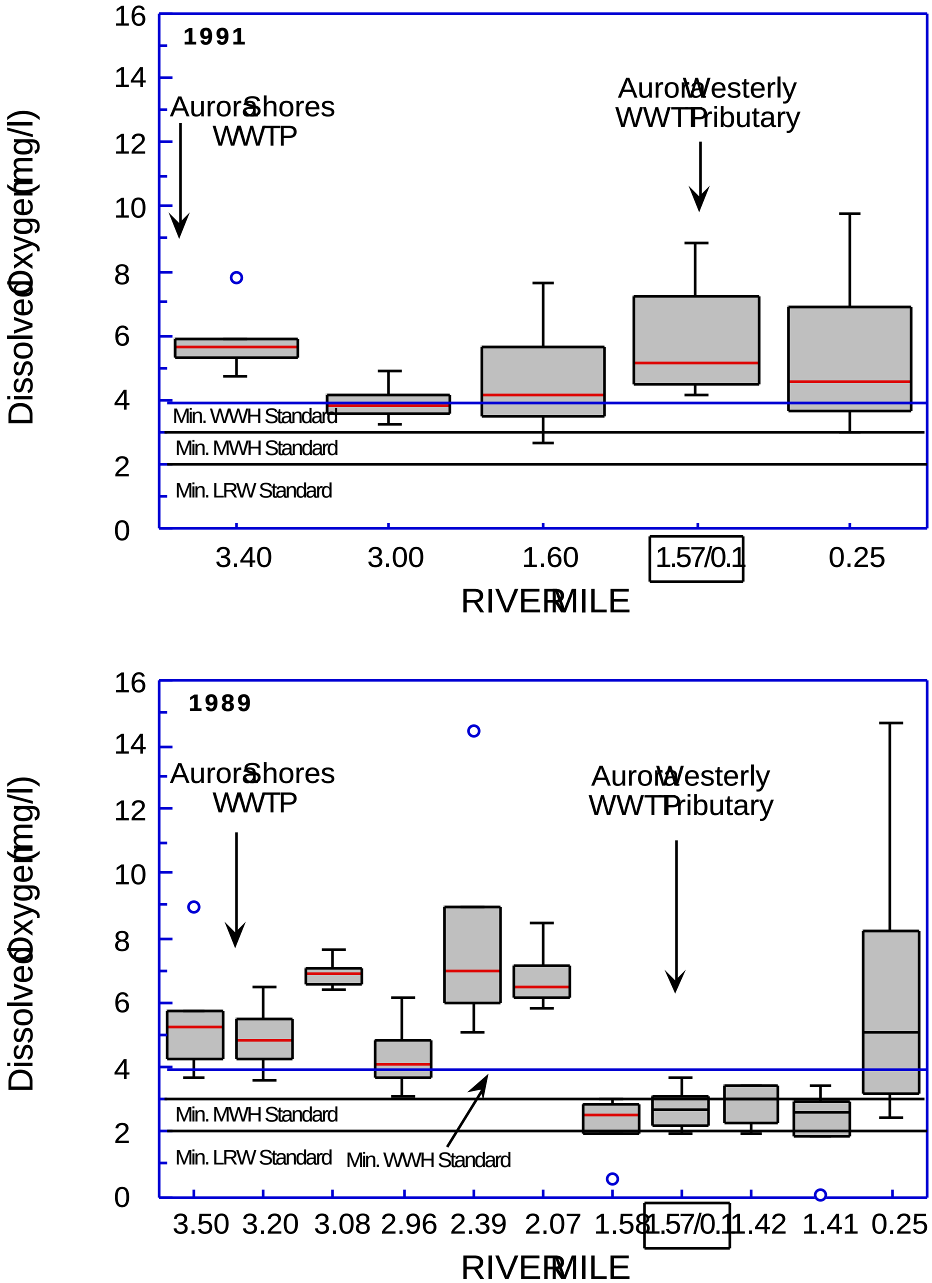


Figure 37. Box and whisker plots of dissolved oxygen continuous monitor data from the Pond Brook watershed collected during the summers of 1991 (upper plot) and 1989 (lower plot).

Sediment Chemistry

Cuyahoga River Basin

- The 1991 sediment metals data for the Cuyahoga River basin from the headwaters to Big Creek (RM 61.0-7.4) was evaluated based on sediment classification criteria described by Kelly and Hite (1984) and can be found in Table 13. Sampling locations downstream from Big Creek to the mouth are presented in Table 14 and stations within the navigation channel were evaluated using criteria from Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments (U.S.EPA 1977). Tinkers Creek sediment metals are located in Table 15. Additional sediments metals and sediment organics data for all 1991 locations are located in Appendix A; Tables 3-8.

- All sediment concentrations for metals upstream from Lake Rockwell (RM 61) were in the non-elevated or slightly elevated ranges. The concentrations of all metals increased downstream from Lake Rockwell and except for arsenic, cadmium, and zinc, remained mostly in the slightly elevated range. The highest arsenic value in the study area occurred downstream from the Ohio Edison dam pool at RM 43.8, possibly the result of runoff from coal storage at the recently abandoned Gorge Electric Generating Station (EGS). Zinc was highly elevated at this location as well.

- Downstream from the Little Cuyahoga River, arsenic, cadmium, chromium, lead, and zinc concentrations increased with the latter two highly elevated (Figure 38, upper plot). Lead and zinc showed additional increases downstream from Mill Creek and Big Creek in Cleveland. These metals were also highly and extremely elevated in Mill Creek, suggesting an influence from numerous urban sources and possibly landfills.

- Copper sediment concentrations were evaluated in the Cuyahga River from the Munroe Falls dam to the Lake Erie estuary (Station RMs 49.78-6.1). The concentrations frequently exceeded levels at ecoregional reference sites (e.g., Breakneck Creek RMs 14.7 and 6.85) by an order of magnitude. However, based upon Kelly and Hite criteria from Illinois, the sediments were in the non or slightly elevated ranges. The same Cuyahoga River sediments were classified as polluted or heavily polluted using criteria from the Pollution Classification of Great Lakes Harbor Sediments (U.S. EPA, 1977).

- Copper, arsenic, cadmium, and chromium levels increased significantly in the navigation channel (Table 14). Zinc concentrations were also significantly elevated, particularly near the Zaclon discharge and downstream. Some increases in this segment were partly attributable to smaller sediment particle size and the corresponding increase in fine clays and silt (Figure 38, lower plot). Contaminants more readily adhere to these finer, depositional particles in the navigation channel. Except for a short segment at the head of the ship channel, dredgings from the channel exceed criteria established by the U.S. EPA for open lake disposal. Therefore, the sediments must be placed in a confined disposal area.

- Lead, zinc, iron, and arsenic sediment concentrations from the navigation channel usually exceeded the heavily polluted criteria based on Pollutional Classification of Great Lakes Harbor Sediments (U.S.EPA 1977). Cadmium, chromium, and copper exceeded the criteria in only one or two of the samples. Copper concentrations, although below the U.S. EPA guidelines, were much higher in the navigation channel than in other sections of the river. Figure 38 shows that sediment particle size is a major influence on heavy metal concentrations in sediments in the Cuyahoga River Basin.

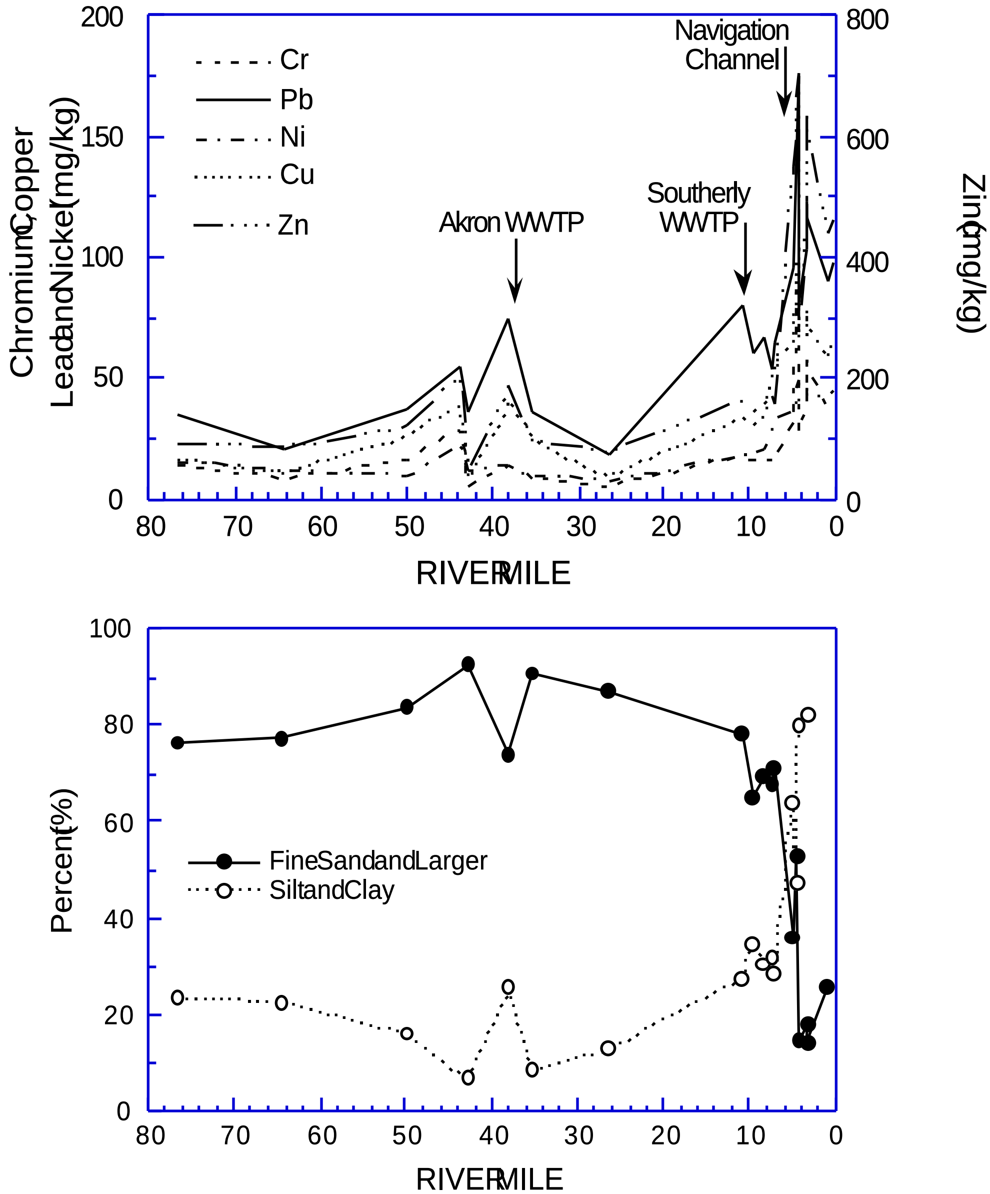


Figure 38. Concentrations of selected sediment metals in the Cuyahoga River mainstem from RM 76.5 to the mouth (Upper Plot), and associated sediment particle sizes [grouped by percentage (Lower Plot)] at 1991 sampling locations.

- No pesticides or PCBs were found above detection limits in sediments collected in 1991 in the Cuyahoga River upstream from the navigation channel (Appendix A; Table 8). However, PCB's were found in very low concentrations in sediment samples collected within the navigation channel. Total PCB concentrations were all below 1 mg/kg (ppm) which is a very low value for sediments in an urban area. DDT and metabolites and low levels of PCBs were detected in Kingsbury Run (RM 0.1). Base neutral acid compounds (BNAs) and other organic tentatively identified compounds (TICs) were elevated near Clark Avenue (RM 5.0), downstream from Kingsbury Run (RM 4.1) and in Kingsbury Run at the mouth. Benzene, toluene and xylene (especially toluene) concentrations were higher within the urban area of Cleveland. These compounds are common constituents of refined petroleum.

- The only priority pollutant organic compound found in the sediment samples upstream from Lake Rockwell (RM 61) was the PAH compound fluoranthene at RM 64.3 (250 ug/kg). Flouranthene is a compound that is primarily derived from combustion of organic material (e.g., diesel fuel, gasoline, coal) and is ubiquitous in the environment. The concentration at RM 64.3 was not considered abnormally high.

Sediment Toxicity

- Sediment samples collected by Ohio EPA in 1991 for chemical analysis were split with the NEORSD and the University of Akron for sediment bioassay testing. NEORSD conducted 7-day chronic *Ceriodaphnia dubia* tests on the sediments in their service area (Figure 39) and at reference locations. Organisms were placed in solutions of 600 grams of sediment per one liter of reconstituted water. The NEORSD tests showed no toxicity at the reference sites, at sites immediately upstream and downstream from the Southerly WWTP (RM 10.95, 9.50, RM 8.3), and at Center Street (RM 0.92). Sediment toxicity was observed at RM 7.4 (LC50-92%), 5.0 (LC_{50}-14.13), 4.3 (LC_{50}-10%), 4.1 (LC_{50}-6%), 3.26 (LC_{50}-48%), 0.0 (LC_{50}-46%) and Kingsbury Run at RM 0.1 (LC_{50}-18.6%). The areas of the ship channel exhibiting the greatest toxicity were near the recently closed LTV coke oven discharges. Most of the toxicity occurred after the third day which suggests acute ammonia toxicity was probably not occurring. Toxicity tests on sediments from the near shore area of Lake Erie also showed various degrees of toxicity.

- The University of Akron conducted *Ceriodaphnia dubia* and *Photobacterium phosphorium* tests at most of the Ohio EPA sediment sampling locations. However, these results were not yet available for review.

Little Cuyahoga River

- Lead and zinc exceeded highly and extremely elevated criteria at Little Cuyahoga River sampling locations (Table 13). Besides urban runoff, there are several closed sanitary landfills in this area of the Cuyahoga and Little Cuyahoga River valleys. River channels have eroded into some of the landflills and the city of Akron has attempted bank stabilization efforts at several sites. Total lead, cadmium, copper, and zinc water quality criteria exceedences were recorded in the Little Cuyahoga during rainfall events in 1986.

- Concentrations of organic compounds in the Little Cuyahoga River were similar to concentrations found in the Cuyahoga River mainstem near Akron (Appendix A; Tables 5-7).

Breakneck Creek

- Arsenic exceeded the highly elevated criterion at RM 14.7, a regional reference site. The concentration (22.1 ug/kg) was highly elevated according to the Kelly and Hite (1984) criteria and elevated according to a 1986 Ohio EPA sediment study (Heitzman 1987). The exact source of the arsenic contamination is not completely known. However, the results obtained at two upstream Cuyahoga River tributary (Breakneck Creek, Tinkers Creek) and presumably least impacted sites indicate the high values may be naturally occurring (see Tinkers Creek discussion below).

- Breakneck Creek sediment BNAs, volatiles, and pesticide/PCB concentrations were low and appeared to reflect background reference site quality.

Tinkers Creek

- Sediment samples for heavy metals were collected at five mainstem locations in Tinkers Creek (RM 28.3-0.1; Table 15). Extremely and highly elevated levels of arsenic and iron were detected at the most headwater station (RM 28.3). The site was upstream from any known point sources or urban runoff but downstream from an extensive wetland area that may in part explain the high value. Matisoff *et al.* (1982) reported on the unusually high arsenic concentrations in the groundwater in northeast Ohio and that these were frequently correlated with high iron concentrations in lower pH waters. Wetland areas would provide the type of setting where the reduction of ferric hydroxides would foster the release of arsenic and iron into the water.

- Sediment samples collected downstream from RM 15.0 showed no values above highly elevated concentrations. However, all metals did show a slight increase at RM 8.75 (Richmond Rd.) which is downstream from a number of potential point sources (*i.e,* Ohio Bulk Transfer Co., Richmond MHP WWTP, Richmond Rd. Pump Station).

- Sediment metals concentrations from the mouth of Deer Lick Run were highly elevated for arsenic, cadmium, and zinc. These elevated parameters most likely represent the after effects of pollutant loadings from previous industrial and WWTP discharges and unregulated hazardous waste sites that no longer have direct discharges to Deer Lick Run. Concentrations from the mouths of Beaver Meadow Run and Hawthorn Creek were generally lower and none exceeded the elevated range.

- One sediment sample for organics at the mouth of Tinkers Creek showed concentrations of PCB-1242 (38.21ug/kg) and PCB-1248 (48.32 ug/kg). Other organics detected at this station were benzo (k) fluoranthene (0.80 mg/kg), d-BHC (1.30 ug/kg), and aldrin (1.21 ug/kg).

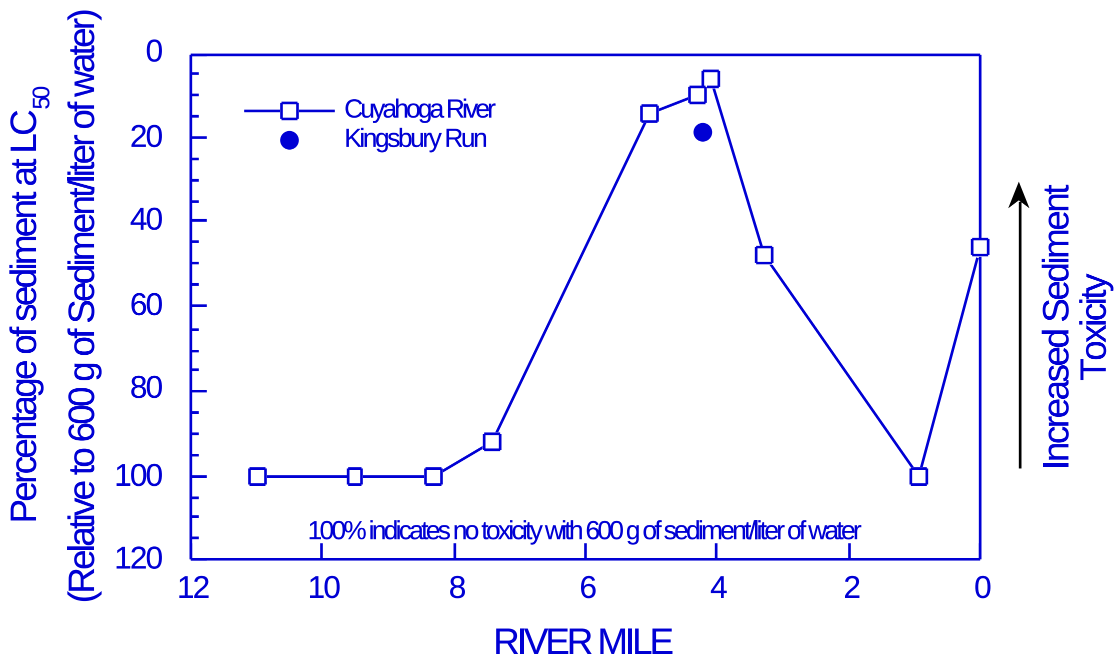


Figure 39. Sediment bioassay results from 12 stations in the Cuyahoga River and Kingsbury Run, 1991. (Data from NEORSD).

Table 13. Concentrations of heavy metals in sediments of the Cuyahoga River between River Mile 76.51 and 7.40 collected in June and September 1991. All parameter concentrations were ranked based on a stream sediment classification system described by Kelly and Hite (1984).

	Sediment Concentration (mg/kg dry weight)							
River Mile	As	Cd	Cr	Cu	Fe	Pb	Zn
Cuyahoga River							
76.51	9.4[b]	<0.94	14[a]	15.4[a]	19200[b]	35.3[b]	89.8[b]
64.30	10[b]	<0.69	8.5[a]	11.1[a]	17700[a]	20.2[a]	86.9[b]
< Lake Rockwell / Kent							
49.78	13.7[c]	**2.4[d]**	15.9[a]	25.9[a]	16100[a]	36.7[b]	121[c]
< Ohio Edison Dam							
43.80	**30.4[e]**	1.4[c]	28.4[c]	38[a]	26600[c]	54.9[c]	**204[d]**
42.60	7.6[a]	<0.46[a]	5.6[a]	8.3[a]	12200[a]	36.6[b]	53.5[a]
< Little Cuyahoga River							
37.97	16.6[c]	<0.58	13.6[a]	40.8[b]	18200[b]	**73.8[d]**	**190[d]**
< Akron WWTP							
35.31	13.4[c]	<0.53	8.6[a]	26[a]	12300[a]	36.4[b]	94.6[b]
26.50	9.5[b]	<0.46[a]	5.9[a]	9.4[a]	10800[a]	18.1[a]	78.7[a]
< Mill Creek							
10.95	11.7[c]	**3.6[d]**	17.5[b]	33.5[a]	18600[b]	**80.2[d]**	165[c]
< NEORSD Southerly WWTP							
9.70	12.1[c]	0.66[b]	15.5[a]	30.6[a]	18600[b]	**60.5[d]**	146[c]
8.30	14.1[c]	1.1[c]	17.8[b]	34.5[a]	19500[b]	**66.8[d]**	159[c]
7.40	13.6[c]	0.77[b]	15.7[a]	50.2[b]	18900[b]	53.9[c]	**173[d]**
Breakneck Creek							
14.7	**22.1[d]**	<0.57	5.2[a]	4.7[a]	16400[a]	10[a]	47.5[a]
6.85	8.7[b]	<0.48[a]	4.6[a]	5.8[a]	10400[a]	7.7[a]	34.4[a]
Little Cuyahoga River							
10.95	**17.6[d]**	1.1[c]	31.2[c]	22.7[a]	20400[b]	**67.5[d]**	136[c]
2.14	8.5[b]	<0.46[a]	17[b]	57.6[b]	15300[a]	**152[e]**	**174[d]**
< Ohio Canal							
0.3	12.5[c]	<0.56	15.8[a]	37[a]	20700[b]	**101[e]**	**219[d]**
Mill Creek							
2.9	5.2[a]	<.51[b]	9.1[a]	15.9[a]	13900[a]	20.4[a]	67.7[a]
0.67	10.0[b]	<.72[b]	31.8[c]	72.9[c]	24700[c]	**65.7[d]**	**341.0[e]**
0.18	8.8[b]	<.49[a]	22.1[b]	40.1[b]	17300[a]	**82.4[d]**	**182.0[d]**

[a] Non-elevated; [b] Slightly elevated; [c] Elevated; **[d] Highly elevated**; **[e] Extremely elevated**

Note: The Kelly and Hite classification system addresses relative concentrations, but does not directly assess toxicity.

Table 14. Concentrations of heavy metals in sediments in the lower part of the Cuyahoga River study area (dst. Big Creek), June and September 1991. All parameter concentrations were ranked based on a stream sediment classification system described by Kelly and Hite (1984) or Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments (U.S.EPA 1977) as appropriate. Note: The Kelly and Hite classification system addresses relative concentrations but does not directly assess toxicity. Nickel was not evaluated by Kelly and Hite.

	Sediment Concentration (mg/kg. dry weight)							
River Mile	As	Cd	Cr	Cu	Fe	Pb	Ni	Zn
Cuyahoga River								
< Big Creek								
7.10	12.9[c]	0.54[b]	15.9[a]	56.9[b]	19800[b]	**64.8[d]**	32.7	158[c]
6.10	7.8[a]	<0.5[a]	17.1[b]	94.0[b]	18100[b]	37.7[b]	48.6	**242**[d]
< Navigation Channel								
5.50	**10.3**	1.3**	26.0†	**76.8‡**	22100†	**70.6‡**	32.7†	**263‡**
< LTV 022 & 005								
5.30	**14.7‡**	3.0**	39.1†	**78.2‡**	**30900‡**	**118‡**	47.2†	**341‡**
5.00	**12.9‡**	3.0**	31.8†	**64.2‡**	**25800‡**	**95.3‡**	36.3†	**548‡**
5.00	**11.6‡**	2.1**	33.2†	**77.2‡**	**25300‡**	**80.3‡**	35.7†	**304‡**
< Zaclon								
4.52	**14.0‡**	**7.6‡**	47.9†	**597‡**	**23600‡**	**153‡**	24.7†	**2500‡**
4.30	**8.6‡**	**6.2‡**	**94.9‡**	**105‡**	**34200‡**	**175‡**	49.0†	**704‡**
4.30	**14.8‡**	3.9**	50.1†	**89.7‡**	**31000‡**	**141‡**	39.3†	**880‡**
< Kingsbury Run								
4.10	**14.7‡**	2.3**	27.6†	**66.5‡**	**28900‡**	**81.3‡**	41.1†	**271‡**
4.10	**12.9‡**	4.1**	85.4†	**121‡**	**30500‡**	**200‡**	39.7†	**738‡**
3.26	**19.8‡**	4.0**	42.8†	**67.7‡**	**33300‡**	**104‡**	43.2†	**492‡**
3.26	**17.3‡**	**6.2‡**	57.2†	**79.1‡**	**34200‡**	**122‡**	46.1†	**643‡**
3.26	**19.1‡**	5.2**	52.7†	**72.6‡**	**33000‡**	**117‡**	43.1†	**604‡**
3.26	**19.1‡**	5.2**	52.7†	**72.6‡**	**33000‡**	**117‡**	43.1†	**604‡**
3.26	**14.6‡**	2.4**	39.8†	**63.6‡**	**30900‡**	**92.5‡**	40.0†	**463‡**
2.80	**11.5‡**	1.4**	51.2†	**84.5‡**	**28100‡**	**605‡**	34.9†	**615‡**
1.95	**19.3‡**	4.1**	72.2†	**80.3‡**	**33500‡**	**144‡**	50.2†	**574‡**
0.92	**15.9‡**	3.2**	37.3†	**58.8‡**	**32500‡**	**89.6‡**	42.7†	**441‡**
0.80	**13.9‡**	1.7**	60.8†	**83.8‡**	**33400‡**	**120‡**	40.4†	**669‡**
0.00	**16.1‡**	3.5**	39.7†	**68.8‡**	**33800‡**	**102‡**	45.6†	**474‡**
0.00	**16.6‡**	<0.98	47.6†	**69.5‡**	**33400‡**	**97.4‡**	42.7†	**390‡**
Old River Channel								
0.80	**13.8‡**	1.7**	77.7	**70.6‡**	28,900[b]	**226[d]**	47.4	**526**
Kingsbury Run								
0.05	**10.3‡**	3.5**	**284‡**	**226‡**	**28800‡**	**223‡**	38.9 †	**863‡**
0.05	6.1†	1.9**	**174‡**	**103‡**	**23100‡**	**230‡**	24.1 †	**418‡**

[a] Non-elevated; [b] Slightly elevated; [c] Elevated; [d] **Highly elevated**; [e] **Extremely elevated**
U.S.EPA Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments:
** Lower Limits not established; * Nonpolluted; † Moderately Polluted; ‡ **Heavily Polluted**

Table 15. Concentrations of heavy metals in sediments of the Tinkers Creek study area, 1991. All parameter concentrations, excluding nickel, were ranked based on a stream sediment classification system described by Kelly and Hite (1984).

	Sediment Concentration (mg/kg. dry weight)							
River Mile	As	Cu	Cd	Cr	Fe	Pb	Ni	Zn
Tinkers Creek								
28.30	**58[e]**	16[a]	0.4[a]	7[a]	**35000**	36[b]	24	87[b]
14.32	**17[d]**	16[a]	0.3[a]	10[a]	23500[c]	25[a]	16	90[b]
11.24	9[b]	19[a]	0.3[a]	7[a]	19900[b]	25[a]	15	96[b]
8.70	14[c]	27[a]	0.7[b]	16[b]	25100[c]	43[c]	NA	119[c]
0.15	8.1[b]	9.0[a]	<0.55[b]	16.8[a]	14200[a]	29.1[b]	NA	79.1[a]
0.10	12[c]	22[a]	0.4[a]	11[a]	22500[b]	27[a]	21	110[c]
Beaver Meadow Run								
0.10	15[c]	15[a]	0.3[a]	7[a]	18700[b]	23[a]	15	87[b]
Hawthorn Run								
0.15	14[c]	14[a]	0.1[a]	19[b]	20200[b]	21[a]	NA	58[a]
Deerlick Run								
0.01	**23[d]**	78[c]	**2.2[d]**	36[c]	30800[c]	17[a]	49	**283[d]**

[a] Non-elevated; [b] Slightly elevated; [c] Elevated; **[d] Highly elevated**; **[e] Extremely elevated**

Note: The Kelly and Hite classification system addresses relative concentrations but does not directly assess toxicity.

Evaluation of Sediment PAHs for Fish Tumorigenic Potential for the Cuyahoga River and Navigation Channel

Introduction

The following procedures could be used with other information to hypothesize the fish tumorigenic (*i.e.*, tumor producing) potential of sediment PAHs, to screen existing PAH sediment data to locate PAH "hot spots," to identify locations for follow-up evaluation (*e.g.*, sediment PAH analysis, fish histopathology, or other biomarker tests) and to identify where remedial activities (*e.g.*, dredging to remove contaminants) may be necessary to lessen or remove the PAH impact to fish populations.

Caution should be used when reviewing negative conclusions (*i.e.*, very low or low tumorigenic potential present) based upon the results of various procedures used in this evaluation for the following reasons:.

- Existing data from the navigation channel (RM 5.6 to 0.0) are from samples collected for analysis at mid-channel locations. Local hot spots might be present, but not identified by the mid-channel sampling. Samples collected upstream from RM 5.6 should be sufficient for identifying hot spots.

- Potential effects from other carcinogenic inorganic and organic chemicals may have been present at tumorigenic concentrations, but were not evaluated.

It was not possible to determine if an elevated fish tumor incidence potential exists based upon a comparison of the Cuyahoga River and tributaries sediment PAH data to the Black River sediment PAH data. This procedure is very crude in attempting to extrapolate tumorigenic potential. Several factors should be kept in mind:

- The Black River data used to compute ratios were from one sample collected at a coke oven outfall where PAH concentrations were highest.

- Annual, selective removal of Cuyahoga River Federal Navigation Channel sediment probably reduces PAH concentrations at sediment collection sites (mid-channel) where dredging occurs. The Cuyahoga River might only appear less PAH contaminated when compared to the Black River.

- PAH hot spots may exist in the lower Cuyahoga River in areas outside the federal navigation channel.

- Elevated tumor incidence may be caused by a combination of PAHs and other carcinogenic chemicals in the sediment. Low or near anoxic dissolved oxygen conditions and other environmental stresses in the Ship Channel may also contribute.

- The Cuyahoga River/Black River ratio procedure may identify tumorigenic potential only at extremely contaminated sites like those found in the Mahoning River (Estenik 1988).

Cuyahoga River Mainstem

The hypothesized sediment PAH tumorigenic sediment potential for river segments identified by geographic location and/or geographic barriers for the Cuyahoga River mainstem are as follows:

- Cuyahoga River sediments upstream from U.S. Route 422 (RM 76.51) have not been analyzed for PAHs. Geographic locations within this segment where sediment PAHs should be evaluated are East Branch Reservoir (RM 91.07) and Bridge Creek (Cuyahoga River Confluence at RM 83.2).

- The Cuyahoga River segment from U.S. Route 422 (RM 76.51) to the Munroe Falls dam (RM 50.0) appeared to have very low sediment PAH tumorigenic potential. However, two (2) WWTPs and the Kent urban area are located upstream. It is likely that high sediment PAH tumorigenic potential extends upstream from the dam. Lake Rockwell (RM 57.7) and the Kent dam pool (RM 54.8) should be evaluated for sediment PAH contamination because of their potential to act as sediment sinks.

- The Cuyahoga River segment from the Munroe Falls dam (RM 50.0) to RM 43.8, downstream from the Ohio Edison dam (RM 45.1), has a high sediment PAH tumorigenic potential.

- The Cuyahoga River segment downstream from the Little Cuyahoga River (RM 42.27) to RM 40.3 (dst. Old Portage Trail) showed very low sediment PAH tumorigenic potential, primarily due to the lack of extensive depositional areas.

- The Cuyahoga River sediment downstream from Old Portage Trail (RM 40.3) and RM 37.97 (upstream Akron WWTP [RM 37.45]) has not been analyzed for PAHs. Tumorigenic potential in this segment should be evaluated. Several Akron CSOs and SSOs are located within this segment and are a potential source of PAHs.

- The Cuyahoga River segment from RM 37.97 (upstream Akron WWTP [RM 37.45]) to Ira Road (RM 35.31) showed high sediment PAH tumorigenic potential. This segment begins approximately 0.5 miles above the Akron WWTP 001 outfall (RM 37.45).

- The Cuyahoga River segment from Ira Road (RM 35.31) to RM 9.7 (dst. NEORSD Southerly WWTP and Conrail Railroad) showed varying sediment PAH tumorigenic potential from very low to intermediate. Mill Creek is affected by CSOs, SSOs and leachate from landfills and enters the mainstem at RM 11.49. Additional sediment samples should be collected and analyzed for PAHs upstream and downstream from the Station Road dam (RM 20.8).

- The Cuyahoga River segment downstream from the NEORSD Southerly WWTP and Conrail Railroad (RM 9.7) to RM 7.1 (Lower Harvard Rd.) showed a high sediment PAH tumorigenic potential. Additional sediment samples should be collected and analyzed for PAHs between RM 10.95 to RM 9.7.

- The Cuyahoga River segment from RM 7.1 (Lower Harvard Road) to the Cuyahoga River navigation channel (RM 5.6) showed intermediate sediment PAH tumorigenic potential.

- The Cuyahoga River navigation channel (RM 5.5 to RM 0.0) had very high sediment PAH tumorigenic potential. Histopathological studies have shown an elevated tumor incidence in brown bullhead (*Ictalurus nebulosus*) slightly higher than that reported for brown bullheads in the Black River (Black and Baumann 1991; Baumann *et al.* 1991; Baumann *et al.* 1987a; Baumann *et al.* 1987b; Baumann and Mac 1988).

Cuyahoga River Tributaries
Hypothesized sediment PAH tumorigenic sediment potential for river segments identified by geographic location and/or geographic barriers for the Cuyahoga River tributaries are as follows:

- Breakneck Creek sediment PAH tumorigenic potential between Homestead Avenue (RM 14.7) and Summit Road (RM 6.85) is very low.

- The Little Cuyahoga River sediment PAH tumorigenic potential varied from intermediate (Gilchrist Road [RM 10.95]) to high (Main Street and downstream [RM 2.14 - 0.3]) to very low at the mouth (RM 0.1).

- Tinkers Creek had very low sediment PAH tumorigenic potential at RM and RM 3.6 upstream and downstream from Deer Lick Run.

- Morgan Run (a stormwater drainage conveyance) sediment should be collected and analyzed for evaluation of sediment PAH tumorigenic potential at the Cuyahoga River Confluence.

- Kingsbury Run had very high sediment PAH tumorigenic potential at the mouth (RM 0.1 to RM 0.05). Additional sediment PAH samples should be collected and analyzed in Kingsbury Run.

Fish Tissue Contamination

NOTE: Following completion of this section, the Ohio Department of Health issued a fish consumption advisory in March 1994 for the Cuyahoga River from the Ohio Edison dam pool (RM 45.1) to the river's mouth (RM 0.0). The advisory recommends that white suckers less than 11 inches in length be restricted to not more than one meal per week, carp and white suckers greater than 11 inches be restricted to one meal per month, and brown and yellow bullhead be restricted to one meal every two months.

Cuyahoga River RAP Sampling

- Fish tissue samples were collected under the direction of the Cuyahoga Remedial Action Plan (RAP) in 1989, 1990 and 1992 within the designated Area of Concern (AOC) and at two (2) control locations. The collections were made at six Cuyahoga River mainstem locations between RM 63.3 and RM 10.0 and from one Chagrin River location at RM 5.1. Collections were also made at five Lake Erie near shore locations between Lakewood and Eastlake. The sampling locations are shown in Figure 40. A total of 95 composite samples consisting of 370 fish were analyzed and included nine (9) QA/QC samples. The analysis included 68 samples from within the AOC. The Cuyahoga River at State Route 303 at Shalersville (RM 63.3) and the Chagrin River at Daniels Park (RM 5.1) were used as river control sites. The Lakewood and Eastlake sampling locations were used as Lake Erie control sites.

- Of the 130 priority pollutants analyzed in fish fillets collected for the Cuyahoga River RAP in 1989, 1990, and 1992, twenty-seven (27) contaminants were detected. These included three (3) polychlorinated biphenyl (PCB) mixtures, 11 pesticide compounds, seven (7) volatile organic compound and six (6) heavy metals. (Appendix B; Table 1).

- The U.S. Food and Drug Administration (U.S. FDA) has published applicable action levels for total PCBs, seven (7) of the detected pesticide compounds, and one (1) of the detected heavy metals (mercury). Of these chemicals, only total PCB concentrations exceeded or approached

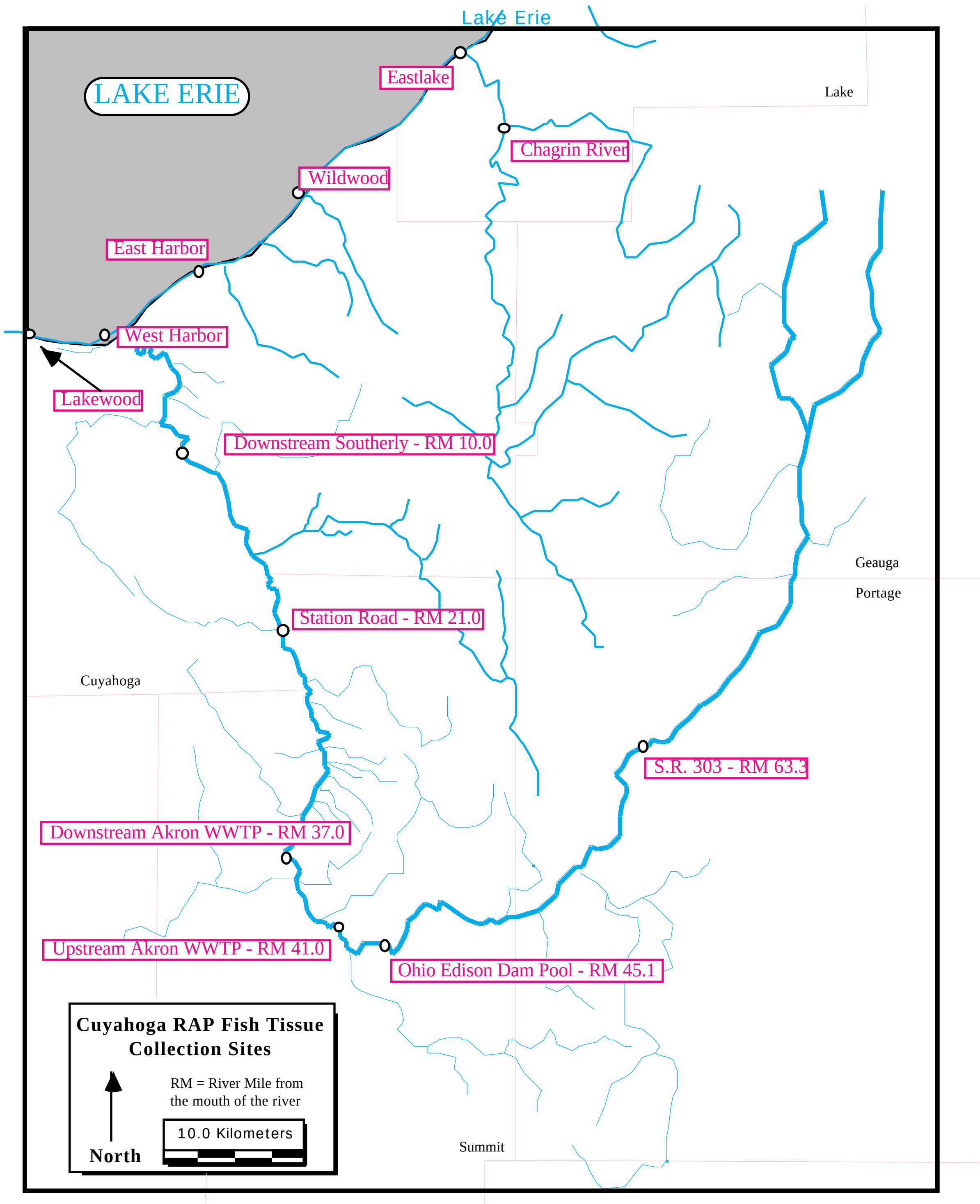


Figure 40. Cuyahoga RAP fish tissue sampling locations in the Cuyahoga River basin, Chagrin River basin and Lake Erie near-shore, 1989-92.

the applicable U.S. FDA action level in any of the mainstem samples. PCBs were detected in 77 of the 86 samples, including samples from the control sites.

- The ability of an organism to bioaccumulate lipophilic organic chemicals is assumed to be proportional to its lipid content (U.S. EPA 1993). Furthermore, lipid content is a better general predictor of fish PCB levels than body size (Rasmussen *et al.* 1990). Since PCBs are lipophilic and lipid content varies between fish species and between individuals, lipid normalization is necessary to characterize relative site contamination by PCBs.

- Tables 16-17 and Figures 41-43 present a site-to-site comparison of lipid-normalized PCB concentrations. This comparison shows that fillets from fish in the Cuyahoga River between RM 41.0 and RM 10.0 are more contaminated by PCBs than the river control sites. The comparison also shows that there is no difference in PCB concentrations between the Lake Erie AOC and Lake Erie control sites. Contamination levels in all Lake Erie fillets were similar to that of fillets from the Cuyahoga River between RM 41.0 and RM 10.0. Fish from the Cuyahoga at RM 64.3 and the Chagrin River contained significantly less contamination.

- The Cuyahoga River site exhibiting the highest level of PCB contamination when all species are considered is at RM 41.0 within the city of Akron. Station RM 41.0 is downstream from the Little Cuyahoga River and upstream from the Akron WWTP. The median lipid-normalized PCB concentration at this site exceeded the maximum lipid-normalized PCB concentrations at all of the other sites in the study area. However, the concentration was not statistically significant using the Kruskal-Wallis non parametric test.

- The Great Lakes Sport Fish Advisory Task Force prepared a document entitled Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory (1993, unpublished). This document proposed consumption advisory groups based on a health protection value of 5×10^{-5} mg/kg/day PCB residues in sport fish. The health protection value considers available toxicological data, with an emphasis on adverse reproductive and neuro-developmental effects in humans.

- Table 17 presents mean concentrations of total PCBs in the 1989, 1990, and 1992 RAP fish fillet samples by species collected. Figures 42 and 43 compare the mean concentrations in the fillet samples with the draft consumption advice group levels.

- No fish species collected had a mean total PCB concentration falling into the most restrictive "no consumption" advisory group. However, no species with high lipid content or omnivorous feeding habits (*i.e.*, carp, catfish, etc.) had mean concentrations for which consumption would be less restrictive than "one-meal-per-month." The mean concentration in Lake Erie carp (after adjustment for skin-off fillets) and yellow bullhead were highest and fell into the "one meal per two months" advice group.

- Conversely, all sport fish species sampled (*i.e.*, black bass, other sunfish, walleye, perch), except freshwater drum, had mean PCB concentrations falling into the "unrestricted" consumption advisory group. The Lake Erie freshwater drum mean PCB concentration fell into the second least restrictive "one-meal-per-week" advice group.

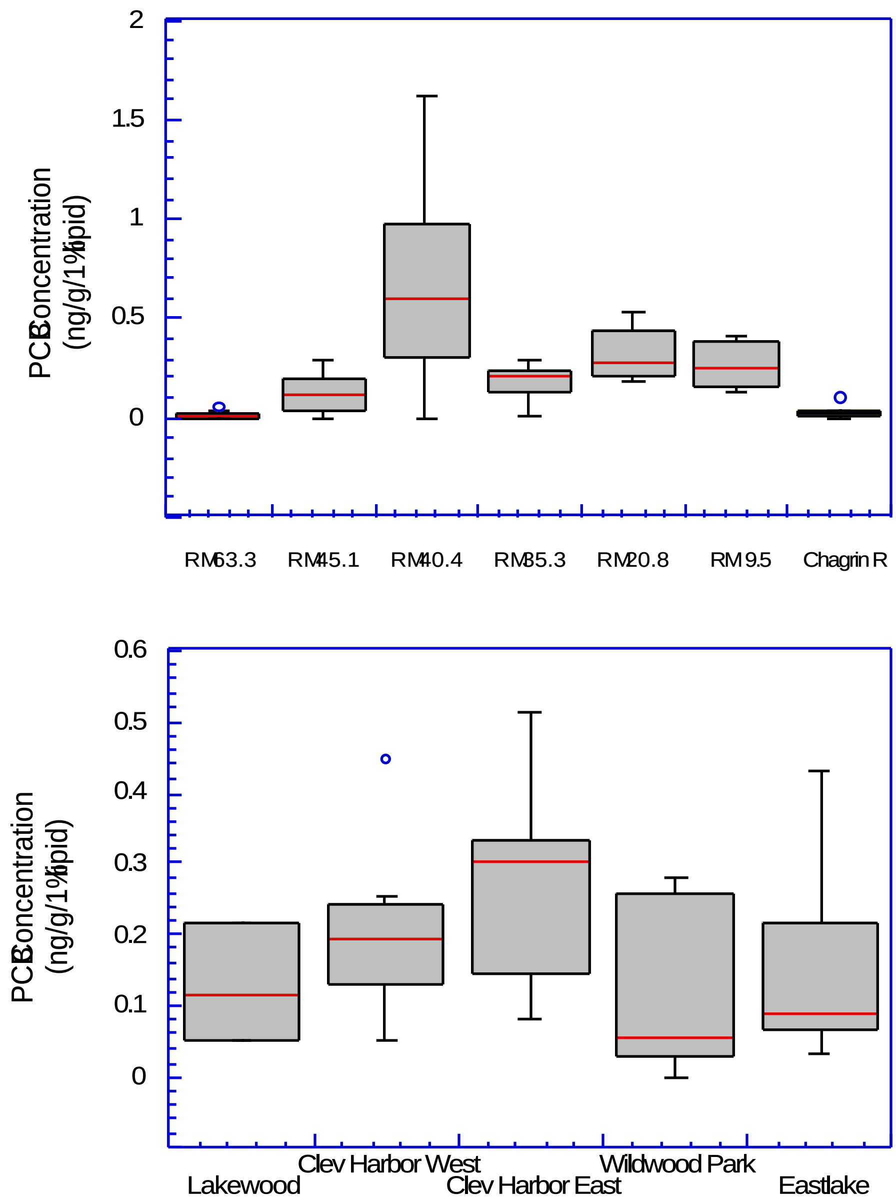


Figure 41. Lipid normalized total PCB concentrations in fish tissue samples from Cuyahoga River stations (Upper Plot) and Lake Erie harbor and near-shore stations (Lower Plot) in 1989, 1990 and 1992.

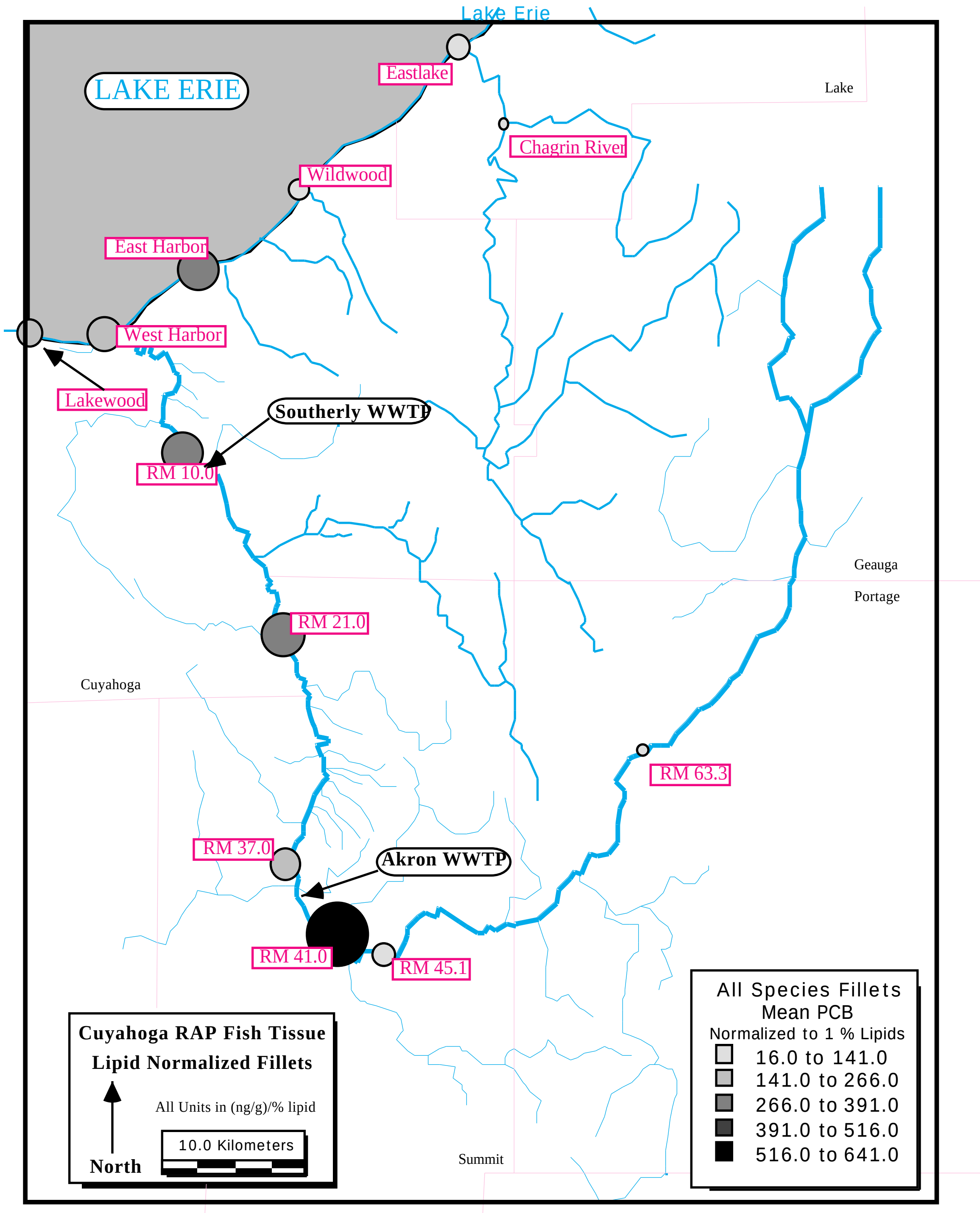


Figure 42. Mean PCB concentrations in fish tissue for all species at Cuyahoga RAP sampling locations in the Cuyahoga River basin, Chagrin River basin and Lake Erie near-shore, 1989-92. Fillet concentrations are normalized to 1% lipids.

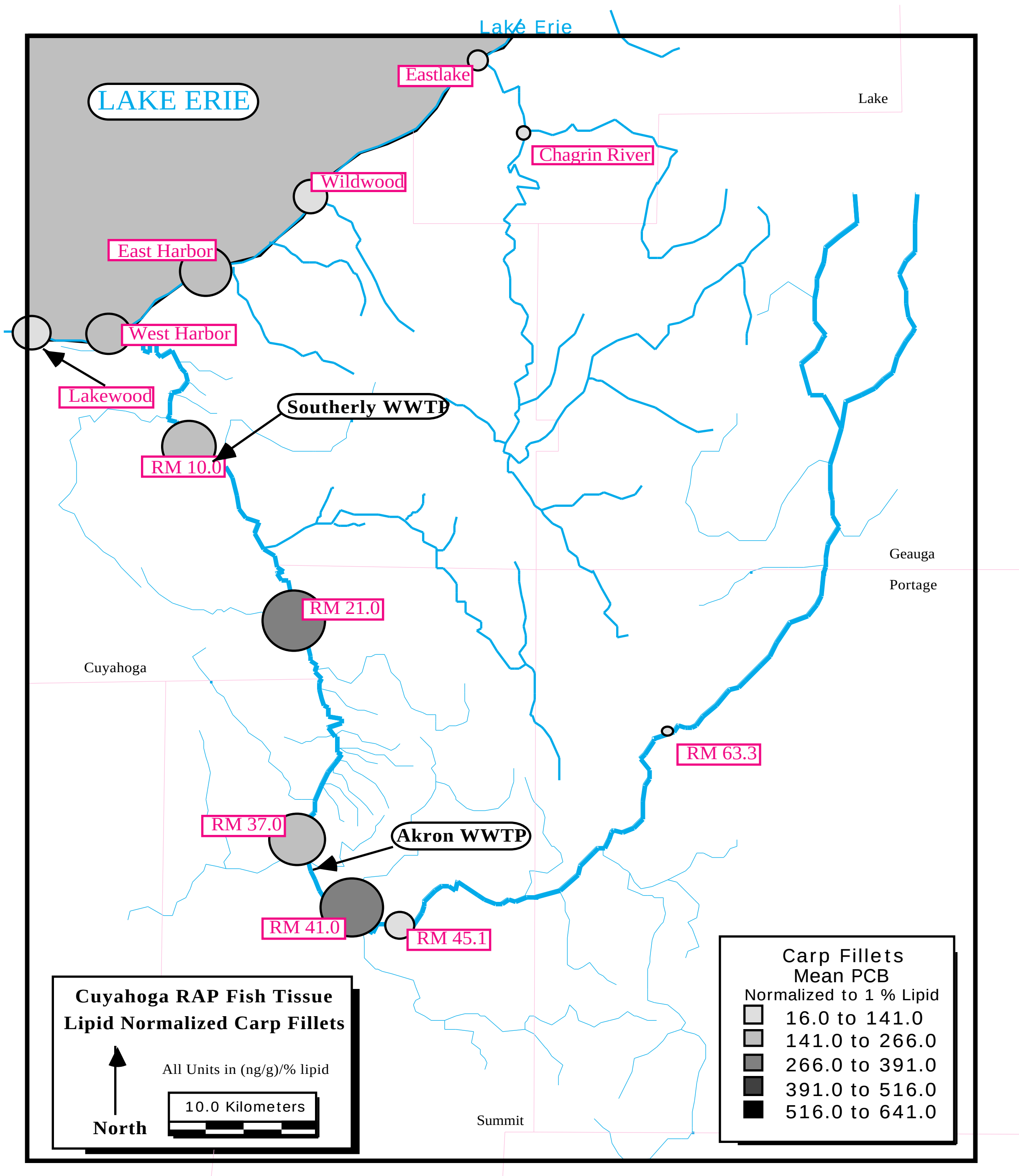


Figure 43. Mean PCB concentrations in fish tissue for carp at Cuyahoga RAP sampling locations in the Cuyahoga River basin, Chagrin River basin and Lake Erie near-shore, 1989-92. Fillet concentrations are normalized to 1% lipids.

- In Table 18 concentrations of contaminants detected in fillets analyzed for the National Study of Chemical Residues in Fish (U.S. EPA 1992) are compared with data from the Cuyahoga RAP fish tissue study. The U.S. EPA sponsored National Study involved sampling fish fillets from 106 to 182 "targeted sites" throughout the nation including locations with identified municipal, industrial, urban, and agricultural pollutant sources. The National Study also involved sampling of fish fillets at "background sites" lacking identified anthropogenic sources of pollutants.

- Generally, the PCB and pesticide concentrations measured in samples between RM 41.0 and RM 10.0 and the Lake Erie control sites were similar to those reported in the National Study for targeted sites. Furthermore, the PCB and pesticide concentrations measured in samples from RM 63.3 and the Chagrin River control sites were generally lower than those from the other Cuyahoga River sites and the Lake Erie near shore sites. However, concentrations were slightly higher than those reported in the National Study for background sites.

- One notable exception is the pesticide methoxychlor, which has wide usage for insect control. Methoxychlor was detected in the tissue samples at levels generally higher than at the National Study targeted and background sites. Nearly all of the detections of methoxychlor, which is moderately biodegradable, occurred in the 1990 samples. No applicable U.S. FDA Action Level for methoxychlor currently exists.

- Another notable exception was with heptachlor epoxide, a metabolic breakdown product of the insecticide heptachlor. Most of the uses of heptachlor had been canceled by 1983, and its sale was banned in the U.S. after August 1987. However, heptachlor sorbs to sediments and along with heptachlor epoxide are highly persistent and bioaccumulative. In two samples (common carp at RM 10.0 in 1989 and yellow bullhead at the Cleveland Harbor west location in 1990) heptachlor epoxide concentrations exceeded the maximum value reported in the National Study. Nevertheless, these values were well below the applicable U.S. FDA Action Level, and the median values were below detection limits.

- The pesticide endrin was detected in a common carp sample at RM 21.0 in 1989; the concentration exceeded the maximum value reported in the National Study. Endrin was used for many pest control applications before cancellation of its registration in 1984. Like heptachlor epoxide, it is highly persistent and bioaccumulative. The reported concentrations of endrin were all well below the applicable U.S. FDA Action Level, and the median values were below detection limits.

- Concentrations of mercury were generally higher at control sites than in the Cuyahoga River between RM 41.0 and RM 10.0 and the Lake Erie near shore. Mercury is considered the only metal that significantly bioaccumulates. These results are consistent with data from the National Study that showed mercury concentrations were generally higher in samples from background sites than in samples from the targeted sites. Sources of mercury in surface waters are considered largely due to natural occurrence and atmospheric deposition.

Fish Age/Growth Results

- ODNR Division of Wildlife personnel examined fish scales collected from fish used in this study to learn age and growth. Seasonal fish growth patterns are reflected in the scales of fish and can be used to infer the age of an individual fish. The age determinations suggest there is no difference in the growth rate of fish from within the AOC compared to fish of the same species collected from control areas.

Table 16. Total PCBs Normalized to 1% Lipids in 1989-1992 Cuyahoga RAP Fish Fillets (mg PCB/kg)/% lipid

	Maximum	Mean	Median
River Reference Sites			
Chagrin RM 5.1	0.094	0.022	0.014
Cuyahoga RM 63.3	0.056	0.016	0.012
River AOC Sites			
Cuyahoga RM 45.1	0.301	0.119	0.107
Cuyahoga RM 41.0	1.615	0.641	0.592
Cuyahoga RM 37.0	0.280	0.173	0.209
Cuyahoga RM 21.0	0.530	0.314	0.268
Cuyahoga RM 10.0	0.412	0.272	0.255
Lake Erie AOC Sites			
Cleveland Harbor West	0.447	0.198	0.193
Cleveland Harbor East	0.514	0.275	0.303
Wildwood Park	0.280	0.103	0.056
Lake Erie Reference Sites			
Lakewood	0.218	0.128	0.117
Eastlake	0.431	0.144	0.089

Table 17. Mean Concentrations of Total PCBs by species in nanograms per gram (ng/g) detected in 1989-1992 Cuyahoga RAP Fish Fillets.

	River Sites		Lake Erie Sites	
Species (Common Name)	AOC	Control	AOC	Control
Common Carp	733	126	1,011	809
White Sucker	338	13.0	-	-
Golden Redhorse	-	27.2	-	-
Yellow Bullhead	1,095	29.8	632	-
Brown Bullhead	903	-	345	-
Rock Bass	-	ND	24.8	-
Pumpkinseed	14.7	-	54.1	-
Bluegill	9.9	-	-	-
Smallmouth Bass	-	18.0	-	-
Largemouth Bass	38.5	-	25.7	88.0
Black Crappie	-	ND	-	-
Yellow Perch	-	-	ND	-
Walleye	-	-	33.8	215
Freshwater Drum	-	-	159	255

ND = Not detected. NA = Not applicable.

Table 18. Summary of mean, maximum and median concentrations of PCBs, pesticides and mercury in fish tissue samples from the Cuyahoga River and Lake Erie RAP Area of Concern (AOC) sites and Reference Sites, 1989-92.

Chemical (U.S. FDA Action Level) Station	Concentration (ng/g)		
	Maximum	Mean	Median
Total PCB[a] (U.S. FDA Action Level = 2,000 ng/g)			
RAP Lake Erie AOC Sites	1,644	407	117
RAP River AOC Sites	1,802	468	253
National Study Targeted Sites	5,148	477	84
RAP Lake Erie Control Sites	2,315	485	252
RAP River Control Sites	355	37	20
National Study Background Sites	45	11	ND
p,p'-DDE (U.S. FDA Action Level = 5,000 ng/g)			
RAP Lake Erie AOC Sites	117.1	32.2	10.0
RAP River AOC Sites	161.5	23.4	11.4
National Study Targeted Sites	2,820.0	130.6	14.6
RAP Lake Erie Control Sites	119.5	41.2	22.9
RAP River Control Sites	45.5	15.8	13.1
National Study Background Sites	43.0	13.0	4.4
p,p'-DDD (U.S. FDA Action Level = 5,000 ng/g)			
RAP Lake Erie AOC Sites	71.2	20.3	5.2
RAP River AOC Sites	77.0	13.7	5.5
National Study Targeted Sites	NA	NA	NA
RAP Lake Erie Control Sites	58.2	15.7	9.9
RAP River Control Sites	20.5	6.4	5.2
National Study Background Sites	NA	NA	NA
p,p'-DDT (U.S. FDA Action Level = 5,000 ng/g)			
RAP Lake Erie AOC Sites	22.7	3.3	ND
RAP River AOC Sites	25.0	4.3	ND
National Study Targeted Sites	NA	NA	NA

Table 18. (continued)

Chemical (U.S. FDA Action Level) Station	Concentration (ng/g) Maximum	 Mean	 Median
p,p'-DDT (continued)			
RAP Lake Erie Control Sites	11.4	2.5	ND
RAP River Control Sites	5.1	1.0	ND
National Study Background Sites	NA	NA	NA
Dieldrin (U.S. FDA Action Level = 300 ng/g)			
RAP Lake Erie AOC Sites	24.8	3.5	ND
RAP River AOC Sites	14.0	3.2	2.4
National Study Targeted Sites	405.0	15.1	0.8
RAP Lake Erie Control Sites	13.3	5.6	3.0
RAP River Control Sites	10.7	2.1	ND
National Study Background Sites	ND	ND	ND
Endrin(U.S. FDA Action Level = 300 ng/g)			
RAP Lake Erie AOC Sites	ND	ND	ND
RAP River AOC Sites	20.2	0.6	ND
National Study Targeted Sites	13.9	0.3	ND
RAP Lake Erie Control Sites	ND	ND	ND
RAP River Control Sites	0.9	0.2	ND
National Study Background Sites	ND	ND	ND
Heptachlor Epoxide (U.S. FDA Action Level = 300 ng/g)			
RAP Lake Erie AOC Sites	47.8	5.0	ND
RAP River AOC Sites	44.8	5.3	ND
National Study Targeted Sites	40.7	1.0	ND
RAP Lake Erie Control Sites	27.1	4.0	ND
RAP River Control Sites	1.8	0.1	ND
National Study Background Sites	ND	ND	ND
Lindane (U.S. FDA Action Level = NA)			
RAP Lake Erie AOC Sites	ND	ND	ND
RAP River AOC Sites	2.0	0.1	ND
National Study Targeted Sites	6.7	0.3	ND

Table 18. (continued)

Chemical (U.S. FDA Action Level) Station	Concentration (ng/g) Maximum	 Mean	 Median
Lindane (continued)			
RAP Lake Erie Control Sites	ND	ND	ND
RAP River Control Sites	0.7	ND	ND
National Study Background Sites	ND	ND	ND
Methoxychlor (U.S. FDA Action Level = NA)			
RAP Lake Erie AOC Sites	71.9	9.9	ND
RAP River AOC Sites	48.3	3.9	ND
National Study Targeted Sites	5.2	0.1	ND
RAP Lake Erie Control Sites	49.0	8.0	ND
RAP River Control Sites	28.1	1.5	ND
National Study Background Sites	ND	ND	ND
Mercury (U.S. FDA Action Level = 1,000 ng/g)			
RAP Lake Erie AOC Sites	280	88	80
RAP River AOC Sites	262	122	92
National Study Targeted Sites	1,660	305	240
RAP Lake Erie Control Sites	469	166	120
RAP River Control Sites	347	205	226
National Study Background Sites	1,770	470	380

[a] Total PCBs normalized to 1% lipids (mg PCB/kg) / % lipid

Biomarker Study

- Additional fish sampling for biomarkers was conducted at four Cuyahoga River and Little Cuyahoga River sites in the Akron area. The survey was part of a statewide project by the U.S.EPA, Office of Research and Development (Environmental Monitoring Systems Laboratory) and Miami University in collaboration with Ohio EPA. The purpose of the sampling was to collect liver and blood plasma samples from common white suckers (*Catostomus comersoni*) to detect physiological and biochemical responses (*i.e.*, biomarkers) to various chemical and environmental exposures. Indicator tests reported here include ethoxyresorufin-o-deethylase (EROD), blood urea nitrogen (BUN) and hepatic glutathione (GSH) activities.

  EROD measures a class of metabolic enzymes induced by planar xenobiotics such as polyaromatic hydrocarbons (PAHs) and halogented hydrocarbons (*e.g.*, PCBs). EROD is not believed to be induced by exposure to metals or radionuclides. A value below 100 pmol EROD/mg protein is a conservative indication of non-induction, i.e., the organism has not been greatly exposed. Scores greater than 100 suggest induction, an indication that significant exposure to these contaminants has taken place and there is detoxification activity by the fish.

  BUN is a measure of the amount of nitrogenous waste, usually as ammonia or urea, which is present in fish blood. For white sucker, values greater than 2 mg ammonia/dl plasma are considered elevated. Elevated BUN can be caused by the elevated concentration of nitrogenous compounds in water (nitrites, nitrates, ammonia, etc.), high pH, or damage to the gills and kidney that inhibits the ability of the fish to excrete nitrogenous wastes.

  GSH is elevated with the generation of free radicals. A GSH score below 0.6 is considered nominal.

- Biomarker values were measured from white suckers in the Cuyahoga River at RMs 64.5 (upstream Lake Rockwell), 42.6 (upstream Little Cuyahoga R.), 37.1 (downstream Little Cuyahoga R.), 35.3 (downstream Akron WWTP), and in the Little Cuyahoga River near the mouth (RM 0.2).

- EROD activity was elevated at all four sites, but was especially elevated at RM 42.6 and in the Little Cuyahoga River at RM 0.2 (Figure 44). Also, a fish collected at RM 37.1, downstream from the Little Cuyahoga River, had the highest EROD value in the study area (EROD = 937). These sites near Akron had EROD values that were among the highest for white suckers found at the 30 sites sampled in Ohio during 1991 and 1992. Halogenated coplanar aromatic hydrocarbons (a sub-group of PAHs) are suspect since these compounds are especially good inducers of EROD activity and can induce EROD to the levels seen at these sites. Fish tissue sampling also found the highest levels of PCB contamination downstream from the Little Cuyahoga River at RM 41.0. Ironically, this segment of the study area has low tumorigenic potential based on the lack of PAHs in the sediment.

- In the experience of U.S. EPA, EROD levels in the Little Cuyahoga River suggested levels of PAH or halogenated hydrocarbons equal to or exceeding the gross sediment contaminated areas of the Little Scioto near Marion and the Ottawa River downstream from the BP America refinery and chemicals plant in Lima Ohio. Community responses including the IBI, ICI, MIwb, and DELT anomalies suggested a complex toxic impact in these two study areas.

- GSH levels were elevated at all sites and, like EROD activity, show exposure to xenobiotics (e.g., PAHs, PCBs, pesticides).

- BUN was slightly elevated for white suckers at RMs 64.5, 42.6, and 35.3 and highly elevated at RM 37.1, downstream from the Little Cuyahoga River (BUN was not analyzed in the Little Cuyahoga).

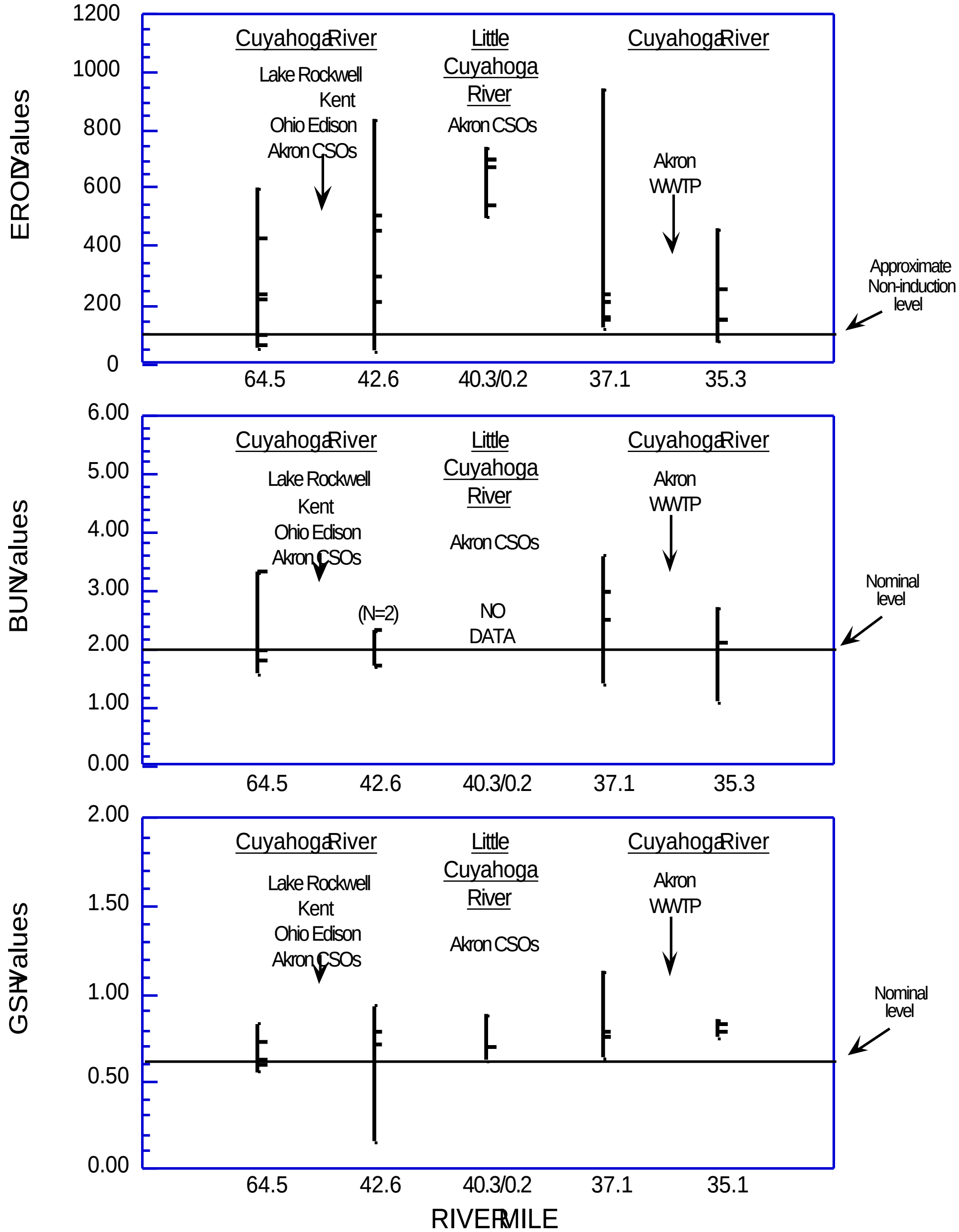


Figure 44. "High Low" graphs of GSH, EROD, and BUN levels (max, min., intermediate) in white suckers from four sites on the Cuyahoga River and one site on the Little Cuyahoga River in the Akron area, 1990.

Physical Habitat for Aquatic Life

- Drainage patterns within the Cuyahoga River basin contain a diverse array of aquatic habitats, including both lotic (*i.e.*, headwater streams to large river) and lentic (*i.e.*, estuary, glacial lakes, reservoirs, and marshes) systems. The diversity of basin habitats is largely due to influences from a variety of water and ice-laid Wisconsin age glacial deposits (Goldthwait *et al.* 1967). Hydromodifications, including flow diversion, wetland drainage, channelization, reservoir storage and release, effluent discharges (Shindel 1991), and dredging also affect physical habitat quality.

- Macrohabitats in the Cuyahoga River basin were evaluated at 28 mainstem fish sampling stations and 27 tributary stations. Mainstem habitat conditions were evaluated and summarized for six relatively homogeneous stretches of the river from the headwaters to Lake Erie (Table 19). Summary statistics and a matrix of warmwater and modified warmwater habitat attributes for all stations in the survey are presented in Table 20.

Upper Cuyahoga River (East Branch to Lake Rockwell)

- The upper Cuyahoga River contains different physical habitats upstream and downstream from Hiram Rapids (RM 76.0). The upper reaches in Geauga County downstream from the East Branch Reservoir flows through low relief lacustrine (lake) deposits (Goldthwait *et al.* 1967) and contains predominantly pooled habitats with silt and clay substrates. To enhance land drainage through wetlands, most of the channel upstream from U.S. Rt. 422 was channelized near the turn of the century. As a result, this reach contains a moderately low mean QHEI of 52.3 (range 47.0 - 63.0) due to a prevalence of modified habitat attributes. Some recovery from the initial channel modifications was evident, however. Instream cover was generally extensive throughout this reach and was provided by dense patches of submergent and emergent vegetation, woody debris structure, and undercut banks. Although historically reduced in many Ohio streams, aquatic vegetation was particularly diverse and abundant throughout the upper Cuyahoga River mainstem. Mid-channel species included tape (eel) grass (*Vallisneria americana*), pondweeds (*Potamogeton* spp.), waterweed (*Elodea canadensis*), coontail (*Ceratophyllum demersum*), and yellow water lily (spatterdock; *Nuphar advena*) while the margins contained dense patches of pickerel weed (*Pontederia cordata*), smart weeds (*Polygonum* spp.), arrowhead (*Sagittaria latifolia*), and duckweed (*Lemna* spp.). During the survey, flows varied considerably within this segment due to reservoir releases.

- The lower part of this segment from Hiram Rapids (RM 76.0) to SR 303 (RM 64.5) contained a markedly different array of physical habitats with a considerably higher mean QHEI of 74.6 (range 66.0 - 83.0). Geologically, this segment of the river flows through higher relief areas containing kames, eskers, outwash areas, and moraines. As a result, the channel contains shallower, more diverse aquatic habitats consisting of alternating riffles, runs and pools. Channel modifications appeared localized (*e.g.*, near bridges) and the substrates were predominated by glacial materials (gravel, cobble, and boulders). Dense patches of aquatic macrophytes continued to be prominent throughout this segment. Turbidity levels decreased markedly at Pioneer Trail Road and remained unusually low downstream to SR 303 with the bottom substrates clearly visible across the channel at most locations.

Middle Cuyahoga River (Kent to Harvard Avenue)

- The middle Cuyahoga River also flows through two geologically different areas, but maintains alternating series of riffles, runs, and pools throughout. Despite the geological differences, the quality of the habitat remained similar and conducive to WWH use throughout the 47.5 mile segment. Mean QHEIs were 73.3 (range 72.5 - 74.0) between Kent and Munroe Falls, 77.9 (range 65.0 - 86.0) downstream from the Ohio Edison dam to Boston Mills, and 71.3 (range 63.0 - 75.5) downstream from Tinkers Creek to Harvard Avenue. Predominant substrates within the channel, however, did change from coarse glacial material (cobble and boulder) to finer, post-glacial material (silt, sand, and gravel) as the channel flowed through alluvial deposits downstream from the Little Cuyahoga River. Several gorges also exist within the middle segment and contain localized reaches containing high gradient riffle-run complexes over exposed bedrock. Downstream from Tinkers Creek the channel cuts through alluvial material adjacent to lacustrine deposits (Goldthwait *et al.* 1967). Unlike the reach upstream from Lake Rockwell, aquatic vegetation was conspicuously absent in the middle section. Riparian encroachment, dumping, and the construction of dikes continue to threaten riverine habitats downstream from the NEORSD Southerly WWTP discharge.

Lower Cuyahoga River (Estuary and Navigation Channel)

- Physical habitats within the lower 5.8 miles of the Cuyahoga River have been significantly altered due to extensive channel and riparian modifications for industrial and navigation purposes. Compared to the rest of the mainstem, this segment had the lowest overall quality of aquatic habitats. The lower mainstem separates into two segments; 1) the estuary effect area upstream from the navigation channel (RM 5.8) and, 2) the extensively modified and maintained navigation channel (RM 1.4 - 5.0).

- The estuary effect area upstream from the navigation channel has been modified in terms of bank shaping, concrete revetments, and riparian encroachment, but it has not recently been dredged and is not under maintenance. The QHEI score of 55.5 reflects an increasing presence of modified attributes, but some warmwater attributes are retained.

- The navigation channel has been dredged to a uniform depth of 28 feet and is maintained by annual dredging. The mean QHEI of 33.3 (range 25.0 - 48.0) reflects the almost exclusive predominance of modified attributes at the three fish sampling locations and probably overrates the habitat of the navigation channel. The ratio of modified to warmwater attributes was much higher than any other segment of the mainstem and suggested an inability to support the WWH use designation. Shallow nearshore habitats (ecologically important littoral areas) are virtually absent along the vertical bulkheads and sheet piling in the maintained navigation channel downstream from RM 5.5. Urban and industrial encroachment has not only eliminated the riparian corridor, but the adjacent wetlands that characterize Lake Erie estuaries.

Tare Creek

- Tare Creek had poor physical habitats at RM 3.2 (QHEI = 39.5) due to unrestricted livestock access and the removal of riparian vegetation. False and eroding banks were present at the fish sampling location. Physical habitats changed markedly where Tare Creek flows through an extensive wetland between SR 608 and SR 87.

Little Cuyahoga River

- The Little Cuyahoga River contains relatively good physical habitat throughout most of its length with a mean QHEI of 68.0 (range 64.0 - 75.0). Alternating series of riffles, runs, and pools characterize the lotic habitat throughout much of the mainstem. Most of the flow in the Little Cuyahoga River comes from a combination of glacial lake outlets, Mogadore Reservoir, urban runoff, and the Ohio-Erie Canal.

Tinkers Creek and Tributaries

- Physical habitats in Tinkers Creek were predominated by warmwater attributes as evidenced by a mean QHEI of 72.6 (range 60.5 - 82.5). Substrates varied between sites, but consisted primarily of sand, gravel, cobble, and bedrock. Smaller sediments were also common at RM 28.8 (wetland muck) and RM 8.5 (silts). Tinkers Creek also contains waterfalls (>4 ft.) at RM 6.2 and RM 21.8. Alternating series of riffles, runs and pools were present at most sites.

- Three headwater tributaries of Tinkers Creek (Pond Brook, Beaver Meadow Run, and Hawthorne Creek) were also included in the study area. Physical habitat quality, as reflected by QHEI scores were conducive to WWH communities in Beaver Meadow Run (QHEI = 80.0) and Hawthorne Creek (QHEI = 80.5), but not in Pond Brook. The mean QHEI of 35.1 in Pond Brook (range 28.0 - 41.0) reflected recent channelization activities.

Table 19. Average QHEI scores for six relatively homogenous segments of the Cuyahoga River mainstem based on fish sampling conducted during July - September, 1991.

Segment Description Upstream River Mile	Downstream River Mile	Sample Location River Mile	Sample Location QHEI	**Segment Average QHEI**
East Branch to Dst. U.S. Route 422				
(RM 89.4	RM 80.5)	89.4	47.0	**52.3**
		87.3	47.0	
		80.5	63.0	
Hiram Rapids to Ust. Lake Rockwell				
(RM 5.8	RM 64.5)	75.8	70.5	**74.6**
		71.7	79.0	
		67.5	66.0	
		64.5	83.0	
Kent to Dst. Munroe Falls				
(RM 54.6	RM 49.8)	54.6	72.5	**73.3**
		49.8	74.0	
Gorge to Boston Mills				
(RM 44.0	RM 26.7)	44.0	84.0	**77.9**
		42.6	86.0	
		38.6	76.5	
		37.4	65.0	
		37.2	79.5	
		35.3	81.0	
		26.7	73.0	
Dst. Tinkers Creek to Harvard Avenue				
(RM 15.9	RM 7.1)	15.9	73.0	**71.3**
		11.5	71.5	
		10.5	72.0	
		10.3	69.0	
		8.9	75.5	
		8.3	72.5	
		7.4	63.0	
		7.1	73.5	
Estuary and Navigational Channel				
(RM 5.8	RM 1.4)	5.8	55.5	38.9
		5.0	27.0	
		3.3	25.0	
		1.4	48.0	

Table 20. Qualitative Habitat Evaluation Index (QHEI) matrix showing modified and warmwater habitat attributes for the Cuyahoga River study area, July - September, 1991.

Table 20. (continued).

Table 20. (continued).

Biological Community Assessment

Macroinvertebrate Community

Cuyahoga River Mainstem

- Artificial substrate samples were collected at 27 locations in the Cuyahoga River mainstem from RM 89.4 - 1.2 (Table 21; Figure 45; Appendix C). Narrative evaluations ranged from exceptional at three locations upstream from Lake Rockwell (RM 71.7-64.2) to poor at each of three locations within the navigation channel (RM 5.0-1.2). Communities were generally in the good to marginally good range throughout most free flowing sections of the river. Departures into the fair range were limited to a wetland area in the extreme headwaters (RM 89.5-80.4), two sites in the Akron municipal area (RM 42.8) and downstream from the Akron WWTP (RM 37.2). Both the Akron and NEORSD Southerly WWTP mixing zone communities (RMs 37.4 and 10.5, respectively) were also in the fair range.

Upper Cuyahoga River (East Branch Reservoir to Lake Rockwell [RM 89.4- 64.2)

- Communities in the upper mainstem, upstream from Lake Rockwell, ranged from fair to exceptional and showed an improving trend with increased distance downstream (Figure 45; upper plot). Potential impacts from the Middlefield and Hans Rothenbuhler Cheese WWTPs (Tare Creek watershed) and the Burton WWTP (RM 86.58) were masked by background influences. These included sluggish current velocities encountered between RM 89.5 and 80.4, extensive wetlands adjacent to the mainstem and in lower Tare Creek, and water supply reservoir releases in the upper basin between RM 91.1 and 76.6.

- Communities between RM 75.8 and 64.2 consistently improved from the good to the exceptional ranges with increased distance downstream. Community densities peaked at RM 75.8 (9622 organisms/sq. ft.) which is located downstream from all major reservoir releases, point sources in the Middlefield area, and the large wetland areas. Densities gradually declined to moderate levels from RM 75.8-64.2 although, a sharp decline at RM 71.7 may have been related to sampler disturbance. Improvements in macroinvertebrate community performance appeared to reflect reductions in nutrient enrichment and improving water quality and habitat conditions from upstream to downstream. The highest quality communities in the Cuyahoga basin study area occurred in this segment.

- The Mantua WWTP at RM 68.8 had no detectable impact on macroinvertebrate community performance 1.2 and 4.5 miles downstream.

Middle Cuyahoga River (Kent to Harvard Avenue [RM 54.4 -7.1])

- Community performance between Lake Rockwell and the Little Cuyahoga River (RM 54.5 - 42.8) ranged from good to marginally good excepting RM 42.8, which dropped into the fair range (ICI = 28) (Figure 45; middle plot). All samples reflected degraded quality conditions when compared to the exceptional communities observed upstream from Lake Rockwell. Community responses suggested enrichment effects associated with numerous potential sources including instream impoundments, municipal and industrial point osrce discharges and increased urbanization in the Kent, Cuyahoga Falls, and Akron areas. An increase in the percentage of enrichment tolerant oligochaetes at RM 42.8 was the major reason the ICI declined below the WWH biocriterion. This change may have been related to a sanitary sewer discharge from the Cuyahoga Falls sewer system discovered in Babb Run, which enters at RM 43.8. Leachate from abandoned landfills near RM 42.8 was also a potential source of impact.

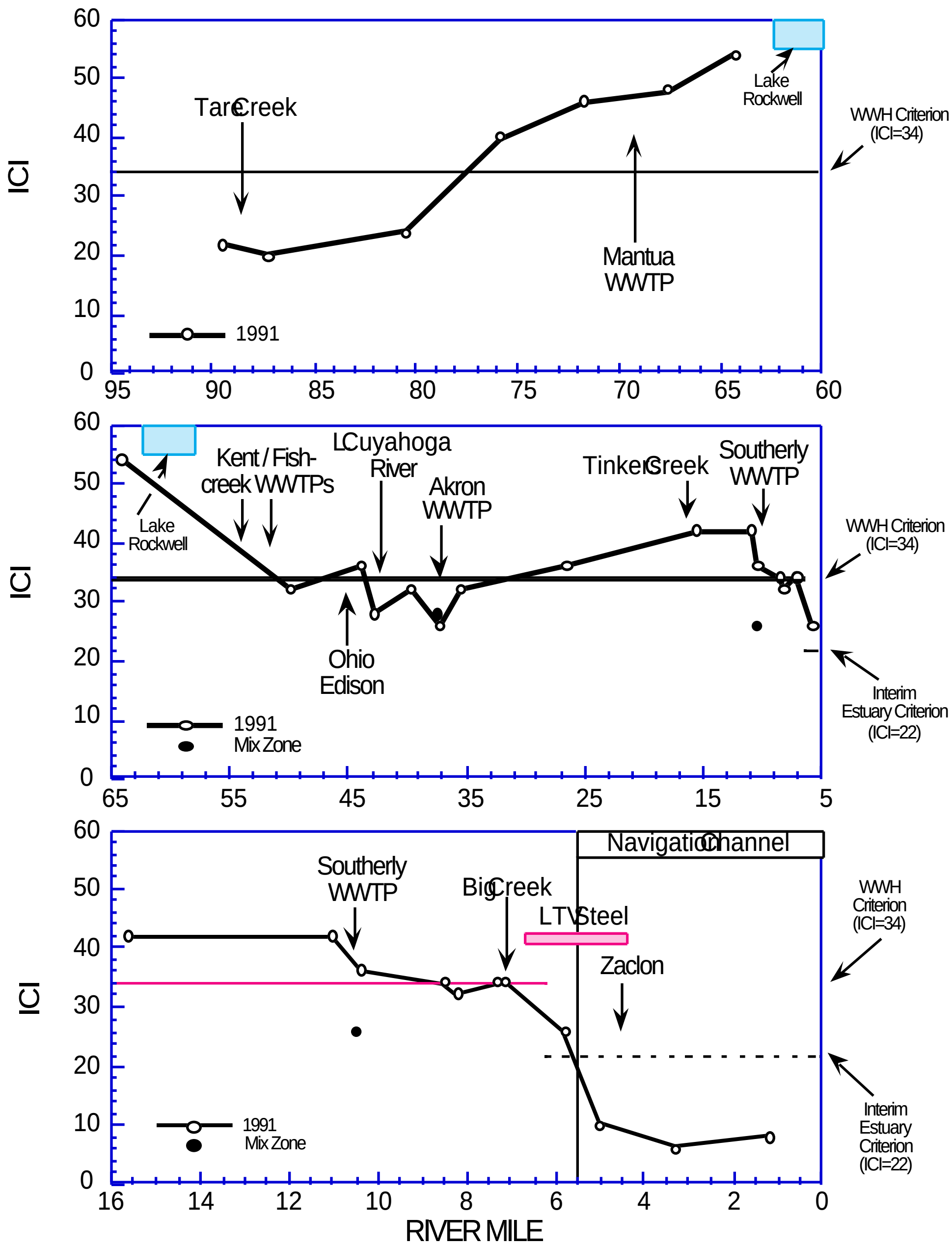


Figure 45. Longitudinal trend of the Invertebrate Community Index (ICI) in upper, middle, and lower sections of the Cuyahoga River mainstem study area (station RMs 89.5 to 1.2), 1991. Some overlap in survey areas between graphs is presented for continuity in longitudinal trends.

- The Little Cuyahoga River had no measurable impact on the already degraded mainstem communities. The ICI increased by four points 1.3 miles downstream from the confluence (RM 39.7) and was in nonsignificant departure from the WWH biocriterion.

- The ICI of 28 in the Akron WWTP mixing zone (RM 37.4) was in the fair range but assemblages were not indicative of acutely toxic conditions. The predominance of toxic sensitive midges of the tribe Tanytarsini (46.7% of the total organisms), correspondingly lower numbers of toxic tolerant taxa, and a relatively high community density (1074 orgs./sq.ft.) were *not* indicative of a toxic response.

- Immediately downstream from the mixing zone, the ICI of 26 at RM 37.2 also fell in the fair range. The assemblage was quite similar to that found in the mixing zone except for incidences of abdominal gill damage on hydropsychid caddisfly larvae. Similar examples of “burned” or “reduced gills” were described by Simpson and Bode (1980) downstream from a WWTP discharging high residual chlorine. Damaged specimens were not observed upstream from the WWTP, in the WWTP mixing zone, or at additional downstream locations between Akron and Cleveland (RM 35.3-11.0). It is uncertain why damage was only observed at RM 37.2 but this may have been related to a physical factor such as effluent mixing, longer exposure periods, or drift. Regardless, the community response signature was not indicative of acutely toxic conditions.

- Community performance at the remaining locations between Akron and the NEORSD Southerly WWTP improved to the marginally good and good ranges with increased distance downstream. ICI scores ranged from 32 at RM 35.3 to 42 at RMs 15.6 and 11.0. Increases in the ICI coincided with increased caddisfly richness and abundance, increased EPT taxa, and reductions in the abundance of tolerant and dipteran/non-insect taxa. However, mayfly richness and abundance were depressed throughout the middle mainstem, beginning downstream from Lake Rockwell and the Kent area, and declining further near Akron and the Akron WWTP. The percent abundance ICI metric score of “6” at RM 11.0 was the only location between RM 49.8 - 11.0 where the two mayfly metrics scored greater than “0” or “2”.

- Sampling in the NEORSD Southerly WWTP mixing zone (RM 10.5) suggested a localized toxic impact. The ICI of 26 was comparatively high (fair range) for this type of impact response and some sensitive taxa occurred in the sample. However, densities on the artificial substrates were reduced (103 orgs./sq.ft.), the qualitative sample was predominated by the toxic tolerant midge *Cricotopus bicinctus*, and abdominal gill damage was observed in nearly all hydropsychid caddisflies.

  Qualitative sampling on the north side of the river, opposite the mixing zone, yielded more EPT taxa (12 vs. 6), higher taxa richness (49 vs. 32) and a community composition similar collections upstream from the 001 discharge. The Southerly WWTP began dechlorinatiing after the 1991 survey. Follow-up investigations should be done to confirm if the observed toxic impacts observed in 1991 were due to chlorine toxicity as indicated by the toxic response signature (Simpson and Bode 1980).

- The ICI improved to 36 immediately downstream from the WWTP mixing zone, exceeding the WWH biocriterion of 34. ICI scores ranged from 32-34 at four additional downstream locations between RM 8.5 and 7.1, reflecting marginally good to good water quality conditions. The incidence of gill deformities in hydropsychid caddisflies declined sharply and no damaged specimens were observed by RM 8.3, approximately two miles downstream from the WWTP.

Except for a gradual increase in the abundance of tolerant organisms, no significant impacts were observed downstream from American Steel Wire, the Bradley Road Smelters, or Big Creek.

Lower Cuyahoga River (Estuary and Navigation Channel [RM 5.8 - 1.2)

- An estuary sample from RM 5.8, immediately upstream from the navigation channel, was in the good range (ICI = 26; Figure 45, lower plot) based on the interim biocriterion of 22 for Lake Erie river mouths. The absence of mayfly or caddisfly taxa on the natural substrates probably resulted from the large amounts of oil that saturated the coarser substrates along the east bank and the poor quality, depositional substrates in the main channel.

- ICIs from the three sites within the navigation channel between RM 5.0 and 1.2 were consistently low and ranged from 10 at RM 5.0 to 6 at RM 3.3. These values were well below the interim biocriterion for Lake Erie river mouths and community performance was poor. Oligochaetes were overwhelmingly predominant at RM 5.0 (8730 individuals; 93% of the quantitative sample), but were less predominant downstream as the sewage and toxic tolerant midge *Dicrotendipes simpsoni* increased in abundance. Several midge specimens from RMs 3.3 (east bank) and 1.2 (west bank) had noticeable labial plate (mouthpart) deformities associated with sediment contaminants in harbors and lakes (Warwick et. al., 1987; Warwick, 1988). A strong oily odor and sheens were evident in the fine bottom sediments at these sites.

- Dense fingernail clam populations of the genus *Sphaerium* were collected with sediment grab samplers at RM 1.2 but only spent (dead) shells were found at RM 3.3. The collections of dead shells suggested a catastrophic decline in water quality (possibly related to low D.O. levels) at RM 3.3. Healthier bottom populations near the mouth may have benefitted from intrusions of cooler, more oxygenated Lake Erie waters that can stratify and flow under the warmer Cuyahoga River in the lower section of the navigation channel. Fingernail clams had not been found by Ohio EPA in the ship channel since macroinvertebrate sampling began in 1987.

Tare Creek

- The ICI of 58 at RM 3.1 was clearly in the exceptional range and among the highest scores in the Ohio EPA database. A total of 71 taxa were collected including diverse populations of midges, mayflies, and caddisflies. One factor in the very high ICI score was the spring fed flow in Tare Creek that, despite a small drainage area of less than five square miles, was sustained throughout the late summer sampling period. Flows in comparable small streams from the Ohio EPA reference site data base are often intermittent under late summer drought conditions and yield correspondingly lower quality benthic communities.

Little Cuyahoga River

- Macroinvertebrate community performance in the Little Cuyahoga River changed from very good at RM 11.0 (ICI = 44) to poor at RM 3.8 (qualitative sample only), upstream from the Ohio Canal. Near the mouth (RM 0.3) the ICI of 16 was in the lower fair range. Declines in the Akron area were characterized by reductions in taxa richness, mayfly and caddisfly richness and abundance, and sharp increase in the percentage of tolerant and other dipteran/non-insect populations. Impacted sites were located downstream from combined sewer overflows, sanitary sewer overflows and urban runoff sources in Akron. Communities at RM 3.8 may have also been affected by marginal habitat quality and the recent presence of heavy equipment (bulldozer) in the stream. In contrast to previous surveys, the influence of industrial point sources should have lessened since only ground water cleanup, stormwater and non-contact cooling water (no process wastewater) are now discharged to the Little Cuyahoga River.

Tinkers Creek and Tributaries

- Macroinvertebrates were collected at 15 locations (ten quantitative, five qualitative) in the Tinkers Creek basin including Pond Brook, Hawthorne Creek, Beaver Meadow Run and the mainstem (Table 21; Figure 46). Narrative evaluations in Tinkers Creek ranged from exceptional at RM 28.8 and 25.0 to poor downstream from the Inland Reclamation landfill (RM 7.4). Poor performance was also observed in Pond Brook (RM 3.5) downstream from the Aurora Shores WWTP, and in Beaver Meadow Run (RM 0.1) downstream from the Solon WWTP.

- Mainstem communities declined from the exceptional range to the good range downstream from Pond Brook (RM 22.1). No significant additional impacts were observed downstream from the Twinsburg WWTP (RM 14.3) or the Glenwillow Landfill (RM 11.2). The ICI did decline to the marginally good range (nonsignificant departure from the WWH biocriterion) at RM 10.3, downstream from the confluence with Beaver Meadow Run.

- Impacts were severe downstream from the Inland Reclamation Landfill at RM 8.5. The ICI of 12 was in the poor range resulting from sharp declines in mayfly and caddisfly richness and abundance and a corresponding increase in the percentages of other diptera/non-insects and tolerant taxa. Oil sheens and a persistent oily smell were evident.

- Communities improved downstream, but remained in the fair range at three locations between RM 7.4 and the mouth (ICI = 28 at RM 7.4 and 0.1; “fair” qualitative evaluation at RM 2.4). Increases were observed in seven of the 10 ICI metric scores at RM 7.4, but additional improvements in metric scores downstream were offset by an increase in enrichment tolerant oligochaetes, other dipteran/non-insect taxa, and decreases in mayfly abundance. Tinkers Creek appeared moderately degraded before its confluence with the Cuyahoga River.

Pond Brook, Beaver Meadow Run, and Hawthorn Creek

- Most Pond Brook sampling locations had been extensively modified by channelization, current velocities were sluggish or non-detectable, and habitats were of poor quality. The stream also flows through large wetland areas and is periodically impounded by beaver dams between the Aurora Shores and Aurora Westerly discharges. Macroinvertebrate sampling included qualitative (natural substrate) collections at RM 3.8 and 3.4 (immediately upstream and downstream from the Aurora Shores WWTP) and quantitative (artificial substrate) sampling at RM 1.4 (downstream from the Aurora Westerly WWTP). Community performance ranged from fair at RM 3.8 and RM 1.4 (ICI=16) to poor at RM 3.4. The RM 3.4 site yielded only 11 total taxa and mayflies and caddisflies were absent. However, evaluation of potential impacts form the Aurora Shores discharge were confounded by the severely limited habitat conditions at the site (deep, channelized; soft substrates of muck, detritus and silt). Overall, habitat limitations and possible wetland influences were considered major reasons for the low quality communities collected from Pond Brook.

- Macroinvertebrate community performance in two tributaries, Hawthorne Creek and Beaver Meadow Run, was fair and poor, respectively. Both streams had good riffle-pool development and structurally similar macroinvertebrate populations (32 and 31 qualitative taxa, respectively). However, Hawthorne Run yielded larger numbers of mayfly and caddisfly taxa (four) compared to Beaver Meadow Run (two), resulting in the higher evaluation.

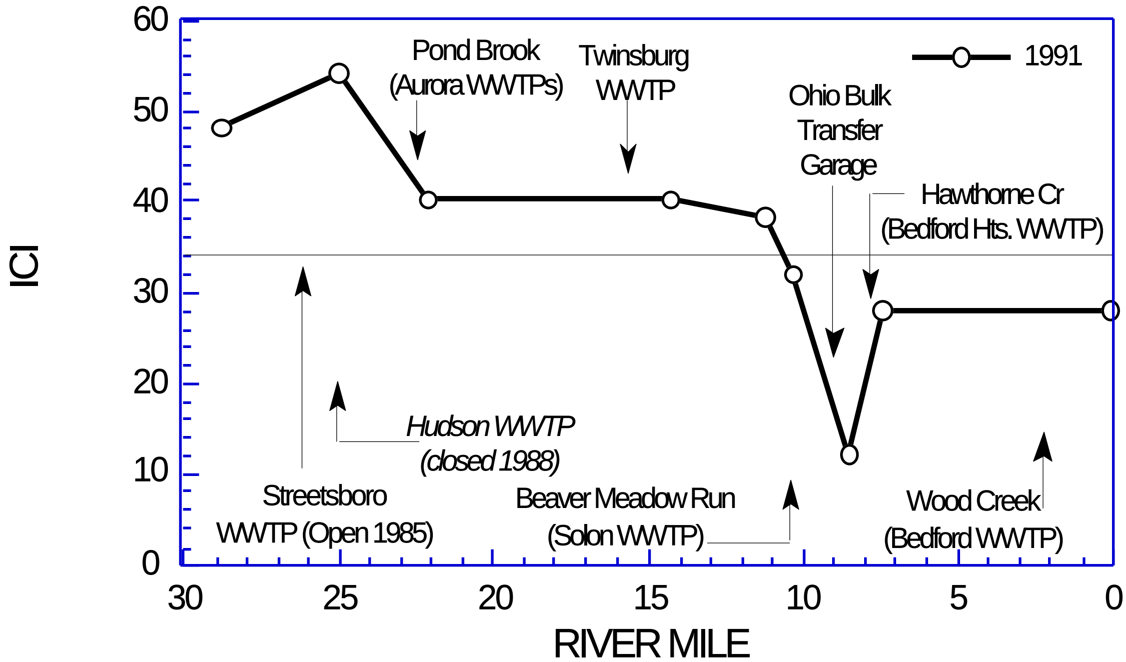


Figure 46. Longitudinal trend of the Invertebrate Community Index (ICI) in Tinkers Creek, 1991.

Table 21. Summary of macroinvertebrate data collected from artificial substrate samplers (quantitative) and natural substrates (qualitative sampling) in the Cuyahoga River basin study area, July -September , 1991.

		Quantitative Evaluation				
Stream River Mile	Relative Density	Quant. Taxa	Qual. Taxa	Qual. EPT[b]	ICI	Narrative Evaluation[a]
Cuyahoga River						
89.5	204	25	30	4	22*	Fair
87.3	755	32	35	0	20*	Fair
80.4	1835	35	43	9	24*	Fair
75.8	9622	33	42	11	40	Good
71.7	524	51	56	19	46	Exceptional
67.6	1936	51	60	18	48	Exceptional
64.2	719	59	66	24	54	Exceptional
54.4	Samplers Lost	NA	54	11	NA	Good
49.8	1727	35	37	8	32[ns]	Marg. Good
44.0	2110	36	31	6	36	Good
42.8	1648	35	40	7	28*	Fair
39.7	1825	40	42	6	32[ns]	Marg. Good
37.4 (Mix Zone)	1074	37	27	3	28*	Fair
37.2	1358	34	40	6	26*	Fair
35.3	2179	37	26	5	32[ns]	Marg. Good
26.5	1790	33	33	7	36	Good
15.6	1734	34	48	12	42	V. Good
11.0	784	43	37	13	42	V. Good
10.5 (Mix Zone)	103	39	32	6	26	Fair
10.4	310	41	33	10	36	Good
8.5	328	43	41	8	34	Good
8.2	317	42	45	11	32[ns]	Marg. Good
7.3	296	39	35	13	34	Good
7.1	811	48	48	12	34	Good
Cuyahoga River Estuary						
5.8 (East Bank)	519	31	17	0	26	Good
Cuyahoga River Navigation Channel						
5.0	1886	19	19	1	<u>10</u>*	Poor
3.3	1280	14	5	0	<u>6</u>*	Poor
1.2	896	15	23	0	<u>8</u>*	Poor
Tare Creek						
3.1	1062	43	50	11	58	Exceptional
Little Cuyahoga River						
11.0	714	42	40	8	44	V. Good
3.8	Samplers Lost	NA	17	3	NA	Poor
0.3	613	28	28	4	16*	Fair

Table 21. (continued).

			Quantitative Evaluation			
Stream River Mile	Relative Density	Quant. Taxa	Qual. Taxa	Qual. EPT[b]	ICI	Narrative Evaluation[a]
Tinkers Creek						
28.8	412	44	60	14	48	Exceptional
25.0	237	39	41	8	54	Exceptional
22.1	513	40	37	7	40	Good
14.3	356	35	38	9	40	Good
11.2	341	37	42	6	38	Good
10.3	214	37	40	10	32[ns]	Marg. Good
8.5	154	28	33	4	12*	Poor
7.4	234	33	42	6	28*	Fair
2.4	Samplers Lost	NA	44	7	NA	Fair
0.1	322	46	26	8	28*	Fair
Pond Brook						
1.4	1264	26	26	2	16*	Fair

			Qualitative Evaluation		
Stream River	No. Qual Taxa	Qual. EPT[b]	Relative Density	Predominant Organisms	Narrative Evaluation[a]
Cuyahoga River					
54.4	54	11	Mod-High	Midges, caddisflies	Good
10.4	49	12	Low-Mod	Mayflies, midges	Good
Little Cuyahoga River					
3.8	17	3	Low	Midges	Poor
Tinkers Creek					
2.4	44	7	Mod	Caddisflies, midges	Fair
Pond Brook					
3.8	35	4	Low	Midges	Fair
3.4	11	0	Low	Backswimmers, damselflies, midges	Poor
Beaver Meadow Run					
0.2	31	2	Low	Midges, black flies baetid mayflies, caddisflies	Poor
Hawthorne Run					
0.8	32	4	Low	Midges baetid mayflies	Fair

Table 21. (continued).

Stream River	No. Qual Taxa	Qual. EPT[b]	*Qualitative Evaluation* Relative Density	Predominant Organisms	Narrative Evaluation[a]
Miscelaneous Cuyahoga River Tributaries (see pages 164-171)					
Yellow Creek					
4.1	23	11	Mod.	Caddisflies, mayflies, crayfish	V. Good
1.7	29	11	Mod	Caddsflies, mayflies , water pennies	V. Good
0.1(1988)	54	12	Mod-High	Caddisflies	V. Good
North Fork Yellow Creek					
0.3	30	10	Mod	Caddisflies, dipterans, non-red midges	V. Good
Fish Creek					
0.4	30	6	High	Mayflies, caddis-flies, isopods	Fair
Furnace Run					
0.9	31	13	Mod.	mayflies, caddis-flies, riffle beetles	Exceptional
Brandywine Creek					
0.3	29	6	High	Caddisflies Baetis spp	Fair
Mill Creek					
0.2	22	4	Low	Nonred midges baetid mayflies	Poor
Big Creek					
0.1	16	2	Low	Leeches, snails, damselflies	Poor

a A qualitative narrative evaluation based on best professional judgement is used when quantitative data is not available to calculate the Invertebrate Community Index (ICI) scores.
b EPT= total Ephemeroptera (mayflies), Plectoptera (stoneflies) and Tricoptera (caddisflies).
c Average Tolerance Value calculated as the average of the weighted ICI for each taxa.
* Significant departure from ecoregion biocriteria (>4 ICI units); poor and very poor results are underlined.
ns Nonsignificant departure from biocriterion (<4 ICI units).

Ecoregion Biocriteria: Erie/Ontario Lake Plain (ECBP)

INDEX	WWH	EWH	MWH[d]
ICI	34	46	22

d - Modified Warmwater Habitat for channel modified areas.

Fish Community

Cuyahoga River Mainstem

- Fish were collected at 28 Cuyahoga River locations from RMs 89.4 - 1.4 (Table 22, Figures 47-49; Appendix D). Narrative evaluations ranged from exceptional at one site upstream from Lake Rockwell (RM 71.7) to very poor in the NEORSD Southerly WWTP mixing zone (RM 10.5). Beginning in the Edison Gorge and extending downstream to Lake Erie (RM 44.0-1.4), all other IBI and MIwb values ranged from fair to poor and were below applicable WWH or interim Lake Erie estuary criteria.

Upper Cuyahoga River (East Branch Reservoir to Lake Rockwell [RM 89.4 - 64.5])

- Fish community performance within the upper 24.9 mile segment of the Cuyahoga River ranged from fair to exceptional (Table 22; Figure 47). A cumulative total of 5169 fish consisting of 37 species and one hybrid was collected from the seven sampling locations. Community performance improved from fair to marginally good as the river flowed from the low gradient previously channelized segment to good and exceptional in the higher gradient natural reach between U.S. 422 and SR 303 (RM 80.5 - 64.5). MIwb and IBI values met or exceeded the WWH biocriteria at the five locations between RM 80.5 and 64.5, partially met at RM 89.4, but failed to meet the biocriteria at RM 87.2. Despite wetland conditions habitat was adequate (QHEI = 63) and fish community performance downstream from U.S. 422 was very good. The species composition between RM 89.4 and 80.5 included a predominance by tolerant and intermediate species; these included bluntnose minnow, white sucker, golden shiner, pumpkinseed, and spotted sucker predominating by numbers and common carp, white sucker, and spotted sucker predominating by weight. Between RM 75.8 and 64.5 the community shifted to a predominance in numbers by more sensitive species such as common shiner, hornyhead chub, river chub, rock bass, logperch, yellow bullhead, bluntnose minnow, and spotted sucker. In terms of biomass, northern hog sucker, common shiner, smallmouth bass, northern pike, golden redhorse, rock bass, carp, white sucker, and yellow bullhead predominated.

- The highest incidence of external deformities, erosion, lesions/ulcers, and tumors (DELT anomalies) on fish in the upper Cuyahoga River (which ranged from 0.0 - 5.7%) occurred at Hiram Rapids where the channel flows from wetlands into shallower more diverse habitats. The percent DELT at RM 75.8 also increased slightly from July (3.4%) to August (5.7%). Yellow bullheads contained the highest number of DELT anomalies that shifted primarily from erosion in July to large lesions during August. The two samples at this site had a cumulative total of 29 individual fish with one or more DELT anomalies, the second highest number in this segment including the three boat sites. These percentages are elevated sufficiently to show a stress related impact to the fish community and strongly deviated from ecoregional expectations (the DELT IBI metric scored a "1"). DELT anomalies were also elevated (2.0 - 2.8%) downstream from the East Branch Reservoir at SR 87 (RM 87.2). Reservoir releases frequently occur from both locations and may be the source of impact (*i.e.*, low D.O. and possible chemical contamination).

- Recovery occurred downstream at Pioneer Trail Road (RM 71.7) where the highest quality fish assemblage within the study area was observed. A diverse (28 species), abundant (1279 fish/km, 82.5 kg/km), and a well-organized assemblage of nongame and sport species was due to good water quality and diverse physical habitats. The percent DELT anomalies were also relatively low (0.27 - 0.56%) and the MIwb and IBI met the Exceptional Warmwater Habitat (EWH) biocriteria. Physical attributes of the site included alternating deep runs and pools, clean sand and gravel substrates, extensive cover from submergent and emergent vegetation, moderately swift current, and clear water. A good forested riparian corridor provided a buffer from adjacent residential and agricultural land uses. Also worth noting was the coexistence of healthy populations of hornyhead and river chubs, two types of minnows recently identified as declining species (Ohio EPA 1992). Rosyface shiner, another declining species was also collected at RM 71.7. Sport species were predominated by rock bass, smallmouth bass, and northern pike.

Middle Cuyahoga River (Kent to Harvard Avenue (RM 54.6- 7.1)

- Beginning downstream from Lake Rockwell, fish community performance declined from good to poor despite similar habitats and a greater number of fish species than in the upper reach (Table 22; Figure 48). Mean community index values fully met the WWH biocriteria at Kent (RM 54.6; upstream from the Kent and Fishcreek WWTPs), partially met below the Munroe Falls dam (downstream from the WWTPs), and failed to meet the biocriteria at all 13 locations sampled downstream from the Ohio Edison Dam. The mean MIwb value was within 0.1 unit of partially meeting the biocriterion at RM 42.6, however, and fully met the biocriterion during the September sample. Mean MIwb and IBI values declined to 8.8 and 37.5 between Kent and Munroe Falls; and to 6.7 and 22.5 from the gorge to Harvard Avenue compared to values observed in the upper mainstem (9.1 and 45.4, respectively).

- Narrative evaluations of the fish assemblages ranged from good to fair between Kent and Munroe Falls and fair between the gorge and the Little Cuyahoga River. Assembelages were fair to poor between the Little Cuyahoga River and the NEORSD Southerly WWTP, then declined to poor from the WWTP to Big Creek. Performance was poor to fair immediately downstream from Big Creek (RM 7.1). The declining quality of fish assemblages in the middle Cuyahoga River appeared primarily due to a combination of increased urban and industrial influences (*i.e.,* point source discharges, CSOs/SSOs, spills, and urban runoff).

- Compositional changes between Kent and Cleveland were also indicative of declining community performance due to pollution impacts. Downstream from Lake Rockwell, the number of sucker and intolerant species, and the percent round-bodied suckers declined in the catches enough that these IBI metrics consistently scored “1” at most of the sites. The fish assemblage in Kent showed relatively good water quality and was predominated numerically by greenside darter, common shiner, bluntnose minnow, and river chub and in terms of biomass by northern hog sucker followed by river chub.

- The assemblage remained similar downstream at Munroe Falls except for common carp, which became overwhelmingly predominant by weight. Downstream from the Ohio Edison dam (and upstream from the Little Cuyahoga River), central stoneroller became numerically predominant and the biomass remained mostly common carp (82%). The highest cumulative number of species (33) of the 28 locations sampled in the Cuyahoga River occurred at RM 42.6. Many sport species were collected including northern pike, walleye, channel catfish, bullheads, largemouth and smallmouth bass, rock bass, and other sunfish. The highest mean relative biomass of fish in the study area also occurred at RM 42.6, an indication of increasing nutrient or organic enrichment.

- Fish sampling results downstream from the Little Cuyahoga River revealed more severe water quality impacts. At RM 38.6, MIwb and IBI values declined, fewer species were captured, and bluntnose minnow, white sucker, and common carp (all highly tolerant species) were the predominant species. The overall percent tolerant species increased from 28% upstream to 61% downstream. Top carnivores and sport species were virtually absent from the catch and the percent insectivores also declined enough to cause the IBI to score a “1” for this metric.

- The Akron WWTP mixing zone (RM 37.4) was sampled three times during the survey and the community response showed no evidence of acute toxicity. However, nutrient enrichment was suggested by the highest mean relative number of fish of the 28 locations sampled in the Cuyahoga River mainstem. The mean MIwb and IBI values reflected fair community performance and scores were similar or slightly higher than the upstream or downstream locations.

- Downstream from the Akron WWTP, MIwb and IBI values continued to show fair to poor performance over the next 25.7 river miles. Compositional shifts included increased numbers of creek chub at RMs 37.2 (downstream Bath Rd.) and 35.3 (upstream from Ira Rd.) and spotfin shiner at RMs 26.7 (Boston) and 15.9 (upstream Hillside Rd.). Gizzard shad predominated by numbers at RMs 15.9 and 11.5 (upstream from the NEORSD Southerly WWTP). By weight, the percent white sucker had decreased by RM 26.7 and common carp represented 61 - 83% of the catch between RMs 26.7 and 11.5.

- Positive attributes were observed between the Akron and NEORSD Southerly WWTPs, despite only fair to poor community performance. These included higher index values and some compositional improvements by RM 15.9 and the second highest cumulative number of species (31) at RM 11.5. Pollution sensitive and intermediate species were also present including northern hog sucker, shorthead redhorse, redside dace, river chub, smallmouth bass, greenside darter, fantail darter, rainbow darter, and log perch.

- Mean MIwb and IBI values from the NEORSD Southerly WWTP mixing zone (RM 10.5) were markedly lower than at the Akron WWTP and showed very poor to poor community performance. Avoidance of the effluent by most fish was evident during the July sampling which yielded only 29 individuals from four (4) species. Subsequent catches improved and contained 74 individuals (nine species) in August and 56 individuals (10 species) in September. The mixing zone had a distinctly different color (tea-like stain) than the Cuyahoga River. A single grass carp, a species previously unrecorded from the Cuyahoga River, was collected in the mixing zone during August.

- Fish assemblages also appeared impacted downstream from the NEORSD Southerly WWTP discharge where MIwb and IBI values declined to poor performance (except one fair MIwb value at RM 7.1) and the percent DELT anomalies increased. Downstream from the discharge, spotfin shiner and/or gizzard shad was numerically predominant at the five stations from RM

10.3-7.1 and common carp remained overwhelmingly predominant by weight.

- The incidence of DELT anomalies in the middle Cuyahoga River increased downstream from Kent to Cleveland. Mean percentages ranged from 0.20 - 0.92% between Kent and the gorge, reached 2.40% at Cuyahoga Street, and ranged from 0.90 - 1.90% between the Little Cuyahoga River and Boston. Between Tinkers Creek and the NEORSD Southerly WWTP, mean percentages ranged from 1.60 - 3.00%, and 2.90 - 6.70% between the WWTP and Harvard Avenue, immediately downstream Big Creek. The highest number of individual fish (42 from three samples) with one or more DELT anomalies occurred at RM 42.6, upstream from the Little Cuyahoga River. The highest consecutive mean percentages (5.7, 6.6, 4.2, and 6.7) occurred in the three-mile reach downstream from the NEORSD Southerly WWTP. The highest mean percent (6.7%) and percent by sample (10.6%) occurred upstream from Big Creek (RM 7.4) and the second highest (6.6%) occurred at RM 8.9.

- The failure to meet the biological biocriteria by one or both of the fish community indices between Munroe Falls and Harvard Avenue was attributable to water quality impacts as opposed to changes in the quality of physical habitat. QHEI values remained conducive for support of warmwater assemblages throughout the 47.5 middle river segment (mean QHEI = 74.2 for the 17 sampling locations between RM 54.6 and RM 7.1). Additionally, the middle Cuyahoga River supported a higher total number of fish species (55 between RM 54.6 and 7.1; 54 between RM 44.0 and 7.1) than the upper or lower mainstem (37 between 89.4 and 64.5; 18 between RM 5.8 and 1.4). This also suggests the current failure to meet the biocriteria is due to poor composition resulting from excessive pollutant loadings as opposed to the inability to recover from historical extirpation.

- Re-establishment of the fish community in the middle Cuyahoga River will likely be the result of fish migration from the high quality upper section, high quality tributaries (*i.e.,* Yellow Creek, Furnace Run), and Lake Erie. Species that have good populations in Lake Erie and were also encountered in the middle mainstem (with their 1991 distribution) included; alewife (RM 1.4), gizzard shad (RM 1.4 - 26.7), smallmouth buffalo (RM 7.1), shorthead redhorse (RM 11.5), emerald shiner (RM 1.4 - 11.5), spottail shiner (RM 5.8 - 10.3), goldfish (RM 3.3 - 26.7), white bass (RM 1.4 - 15.9, white perch (RM 1.4 - 15.9), and freshwater drum (RM 3.3 - 15.9).

Lower Cuyahoga River (Estuary and Navigation Channel [RM 5.8 - 1.4])

- Downstream from Harvard Avenue, fish community performance in the estuary and shipping channel remained poor (Table 22; Figure 49). The total number of fish species and MIwb values showed reductions compared to upstream which was partially due to a change in the physical habitat. The mean QHEI declined from 71.3 (RM 15.9 - 7.1) to 42.5 (RM 5.8 - 1.4) due to the estuarine type conditions and the extensive modifications for industrial and navigation uses. A total of 18 species and two hybrids were collected from the 4.4 mile segment (mean relative number = 330 fish/km; mean relative weight = 40.4 kg/km).

- Fish assemblages at the four estuary sites remained similar and contained 6.0 - 8.3 species (mean number per site) and only 8 - 12 cumulative species (all samples combined). Only five species and one hybrid (gizzard shad, common carp, emerald shiner, white bass, white perch, and common carp x goldfish hybrid) were collected at all four sampling locations. Three other species (white sucker, goldfish, and pumpkinseed) were collected at three of the four sites.

- Numerically, gizzard shad was overwhelmingly predominant throughout the estuary and represented 67 - 91% of the fish collected. Only two other species represented more than 10% of the catch at any one site (white perch, 19% at RM 1.4; common carp, 11% at RM 5.8). The predominant species in terms of biomass varied between common carp (12 - 84%), gizzard shad (8 - 46%), and carp x goldfish (0 - 50%).

- All IBI metrics scored "1" except percent tolerant fishes, DELT anomalies, and the relative number of fish (minus tolerant species). Longitudinally, the mean percentage of DELT anomalies in the estuary decreased slightly from 5.3% at RM 5.8 to 2.2% at RM 1.4.

- Based on electrofishing collections since 1984, the permanent fish community within the navigation channel is essentially comprised of six tolerant and moderately tolerant species; gizzard shad, emerald shiner, common carp, white perch, goldfish, and brown bullhead. Of these six the first four were routinely collected in the 1991 electrofishing samples. The brown bullhead was common in trap net samples collected for tumorigenic and biomarker analyses by the U.S. Fish and Wildlife Service and U.S. EPA. White bass, spottail shiner, and pumpkinseed sunfish were present in approximately one-half of the collections and an additional 19 species were collected sporadically in low numbers and are considered transients.

Tare Creek

- Tare Creek at RM 3.2 supported only a fair fish assemblage (IBI = 28) due to degraded physical habitat (QHEI = 39.5) and nutrient enrichment resulting from unrestricted livestock access. The fish community consisted of nine species, but had the highest relative number of fish (2775 per 0.3km) within the study area. Numerically, the community was predominated by bluntnose minnow (39%) followed by creek chub (16%), central stoneroller (12%), common shiner (12%), and johnny darter (11%). Negative attributes of the headwater assemblage (based on the IBI metrics that scored the minimum) included low numbers of headwater, sensitive, and darter species, and high percentages of tolerant species, omnivores, and pioneering species.

Little Cuyahoga River

- Fish community performance at the three sampling locations (RM 11.0 to 0.3) in the Little Cuyahoga River ranged from poor at RM 11.0 to fair/poor quality at RM 2.2 and 0.3. Longitudinally, from RM 11.0 to 0.3, mean MIwb scores remained very similar (5.8 - 6.0), while the IBI declined from 27 to 22 despite the higher quality habitat at RM 0.3.

- The low IBI scores at all three locations were the result of below expected values for nearly all of the metrics. Two metrics showed no change and scored the minimum (a "1") at all three locations (intolerant and darter species), five metrics showed positive changes (slight increases in the number of species and sucker species), and five metrics exhibited declines downstream (sunfish species, percentages of simple lithophils, top carnivores, insectivores and a slight increase in the percentage of DELT anomalies). Potential causes or sources of impairment include enrichment (nutrient and organic), CSOs/SSOs, spills, and urban runoff from the Akron area. Marshy, impounded conditions in the upper section of the river (immediately upstream from RM 11.0) may be a cause of poor performance upstream from Akron; some very low dissolved oxygen levels were recorded in these sections during an earlier survey in 1986. Other potential sources include undocumented releases from small industries in Akron authorized to discharge only non-contact cooling water.

- Totals of 19 fish species and one sunfish hybrid were collected from the 10.7 mile segment. The highest cumulative number of species (17 at RM 0.3) was collected downstream from the city of Akron and the Ohio canal near the confluence with the Cuyahoga River. Only nine and 11 species were collected at the upstream sites, respectively.

- Fish assemblages upstream from the city of Akron were predominated numerically by white sucker, yellow bullhead, and creek chub, and by weight by white suckers and common carp. Predominant species were similar downstream from Akron, but also included central stoneroller.

- The percentage of DELT anomalies by sample ranged from 0.0 - 1.7% at the three sampling locations. RM 0.3 had the highest incidence in July and a noticeable phenolic odor indicative of chemical pollutant loadings was noted during late August. This area was also noted for the presence of highly elevated EROD levels in white suckers (USEPA biomarkers; see page 125-127) and low to high fish tumorigenic potential associated with sediment PAHs (see page 114). Increased levels of fish tissue contamination from PCBs were observed in the Cuyahoga River immediately downstream from the confluence.

Tinkers Creek and Tributaries

- Fish community performance in Tinkers Creek ranged from fair to very poor (*i.e.,* IBI and MIwb values were well below biocriteria) despite overall good quality physical habitats and few exceedences of water quality criteria. The highest mean IBI value (30) occurred at RM 28.8 (the upstream most site) and the lowest value (17) was recorded at three locations (RM 10.5, 8.5, and 2.2). The greatest decline between sites (30 to 22) occurred in the headwaters over a distance of 0.5 miles (RM 28.8 to RM 28.3). Both sites were located in wetland areas and both were sampled only once during the 1991 survey (two sampling passes were conducted at all other Tinkers Creek stations). A specific reason for the difference in performance between the two sites is unknown. Downstream from RM 28.3 IBI values ranged from 17 to 22, indicative of poor and very poor performance (Table 22; Figure 50).

- The MIwb increased from 4.8 (very poor) at RM 21.9 to 6.4 (fair) downstream from the Twinsburg WWTP (RM 14.3). The increased MIwb was due to an increased density and biomass of moderately tolerant and intermediate fish species. The increases suggested one or more source(s) of nutrient and/or organic enrichment. This was followed by a decline to 4.5 (very poor) at RM 10.5. MIwb values then gradually increased to 6.9 (fair) by RM 0.2.

- With few exceptions, nearly half the IBI metrics from wading and headwater sites in Tinkers Creek scored the minimum of “1” during each sampling pass (Appendix D). Depending on sampling method, these scores related to low species richness, a lack of headwater, intolerant and sensitive species, and low numbers of darters, suckers and simple lithophilis. Conversly, percentages of omnivores and tolerant species were high, resulting in minimum scores.

- The failure to meet the MIwb and IBI biocriteria appears related to several influences including pollutant loadings from point and nonpoint sources, spills, and other undocumented pollutant releases. Although there is uncertainty about the cause of the larger declines, wetland influences, high TSS levels from nonpoint sources, landfill leachate, and upstream migration barriers posed by waterfalls are possibilities.

- Several waterfalls pose essentially permanent barriers to the upstream migration of fish. However, this does not seem a major reason for the poor performance of the fish community in the middle and upper reaches. Vestiges of a more balanced community are at least present in all segments; the elements of community recovery are available. The position and number of the barriers do, however, make the community more vulnerable to impacts, especially those that could nearly or completely eliminate the fauna.

- A total of 29 species and three hybrids were collected from Tinkers Creek in 1991. Surprisingly, the number of species (mean and cumulative) at each site showed little variation from the headwaters to the confluence with the Cuyahoga River. Mean numbers of species ranged from 9.0 to 13.5.

- In lower Tinkers Creek, the condition of the fish community was fair to poor despite the presence of good habitat quality and the lack of any physical barriers to fish migration (*i.e.*, waterfalls). This strongly suggests water quality was a primary factor influencing the fish. When compared to assemblages in the Cuyahoga River immediately downstream (RM 15.9), Tinkers Creek at the mouth (RM 0.2) supported a less diverse and more tolerant assemblage of fish. The Cuyahoga River site yielded an average of 22.7 species compared to a mean of 13.5 species at the mouth of Tinkers Creek. Also, the IBI metric for species richness (calibrated for drainage area) scored a "1" or "3" at RM 0.2 compared to scores of "3" and "5" (twice) downstream in the Cuyahoga River. This shows the Cuyahoga was performing much closer to ecoregional expectations regarding taxa richness than Tinkers Creek despite its known history of impairment.

- Three greenside darters were collected at RM 0.2 during August, but only one specimen was captured during September despite suitable habitat provided by an extensive riffle-run complex. Several pollution sensitive and intermediate species were captured in the Cuyahoga River but were absent from Tinkers Creek (*i.e.*, golden redhorse, black redhorse, rock bass, and smallmouth bass). This disparity between collections is also indicative of greater impacts to the fish community in Tinkers Creek than the adjacent Cuyahoga River.

- The percent DELT anomalies ranged from 0.0 - 4.1%. The highest mean percent (3.7%) occurred at RM 10.5 together with the lowest IBI and MIwb values. Individual samples at RMs 28.3 and 11.2 also had values greater than 3.0%.

Pond Brook, Beaver Meadow Run, and Hawthorn Creek

- The three tributaries of Tinkers Creek supported poor to fair fish assemblages. Pond Brook supported a poor quality fish assemblage at RM 3.6 and fair assemblages downstream at RM 3.4 and 1.4. Despite extensive channelization, IBI values at the two downstream sites were equal to or higher than the highest value from Tinkers Creek. Beaver Meadow Run and Hawthorn Creek supported only poor and fair assemblages, respectively, despite the presence of very good physical habitat.

Table 22. Fish community indices based on pulsed D.C. electrofishing samples at 48 locations sampled by Ohio EPA in the Cuyahoga River study area during July - September 1991. Sites sampled with wading methods denoted by a w; all other sites sampled with boat methods (VP = Very poor, P = Poor, MG = Marginally Good, G = Good, VG = Very Good, E = Exceptional).

Stream River Mile	Mean Number of Species	Cumulative Species	Mean Rel. No. (No./Km)[a]	Mean Rel. Wt. (Kg/Km)[a]	QHEI	Mean Modified Index of Well-Being	Mean Index of Biotic Integrity	Narrative Evaluation[b]
Cuyahoga River								
89.4[w]	20.0	20	466	39.5	47.0	6.4*	34[ns]	Fair-MG
87.2[w]	16.5	23	330	94.7	47.0	7.9*	31*	Fair
80.5	21.3	26	435	70.3	63.0	9.0	44	Good-VG
75.8[w]	19.0	23	451	25.0	70.5	8.7	38	Good
71.7	27.0	28	1279	82.5	79.0	10.1	50	Exceptional
67.5	22.3	29	659	104.7	66.0	8.9	51	Good-E
64.5	20.0	24	449	18.6	83.0	8.8	44	Good-VG
54.6	20.5	23	1017	17.2	72.5	8.8	40	Good
49.8	19.7	23	1127	147.1	74.0	8.7	35*	Good-Fair
44.0[w]	12.0	15	1699	8.3	84.0	6.9*	29*	Fair
42.6	23.0	33	1143	233.5	86.0	8.1*	33*	Fair
38.6	20.0	23	1008	58.5	76.5	6.9*	25*	Fair-Poor
37.4 (mix zone)	9.3	11	1843	61.4	65.0	7.0	29	Fair
37.2	15.3	18	708	32.1	79.5	6.9*	24*	Fair-Poor
35.3	13.7	17	713	46.6	81.0	6.5*	21*	Fair-Poor
26.7	15.7	21	833	43.1	73.0	7.0*	22*	Fair-Poor
15.9	22.7	29	628	118.8	73.0	7.3*	24*	Fair-Poor
11.5	20.0	31	481	119.3	71.5	6.6*	19*	Fair-Poor
10.5 (mix zone)	7.7	15	530	45.6	72.0	3.9	20	VP-Poor
10.3	14.7	24	297	74.1	69.0	6.1*	18*	Poor
8.9	16.3	27	298	132.9	75.5	5.8*	19*	Poor
8.3	14.7	22	247	101.0	72.5	5.9*	17*	Poor
7.4	12.7	17	282	72.5	63.0	6.3*	20*	Poor
7.1	13.3	20	328	63.1	73.5	6.9*	21*	Fair-Poor
5.8	8.3	12	196	73.3	55.5	5.0*	17*	Poor
Cuyahoga River Navigation Channel								
5.0	6.0	8	253	19.7	27.0	5.2*	21*	Poor
3.3	7.0	11	379	45.9	25.0	5.4*	19*	Poor
1.4	7.0	10	490	22.9	48.0	5.4*	20*	Poor
Tare Creek								
3.2[w]	9.0	9	2775	-	39.5	NA	28*	Fair

Table 22. (continued)

Stream River Mile	Mean Number of Species	Cumulative Species	Mean Rel. No. (No./Km)[a]	Mean Rel. Wt. (Kg/Km)[a]	QHEI	Mean Modified Index of Well-Being	Mean Index of Biotic Integrity	Narrative Evaluation[b]
Little Cuyahoga River								
11.0[w]	10.0	11	342	40.3	65.0	5.8*	27*	Poor
2.2[w]	8.0	9	492	6.0	64.0	5.9*	26*	Fair-P
0.3[w]	13.5	17	689	10.0	75.0	6.0*	22*	Fair-P
Tinkers Creek								
28.8[w]	10.0	10	327	-	67.0	NA	30*	Fair
28.3[w]	13.0	13	388	21.7	-	NA	22*	Poor
25.0[w]	8.5	10	195	6.4	77.5	NA	21*	Poor
21.9[w]	9.0	10	792	4.5	62.0	4.8*	18*	Poor
14.3[w]	13.5	15	1585	14.7	73.5	6.4*	22*	Fair-P
11.2[w]	13.5	16	461	24.2	79.0	4.7*	19*	Poor
10.5[w]	8.5	11	188	9.8	73.5	4.5*	17*	Poor-VP
8.5[w]	9.5	12	291	3.5	74.0	5.0*	17*	Poor-VP
7.2[w]	11.5	15	443	15.9	82.5	5.0*	21*	Poor
2.2[w]	11.5	14	621	6.2	60.5	5.7*	17*	Poor-VP
0.2[w]	13.5	17	541	8.5	76.5	6.9*	21*	Fair-P
Pond Brook								
3.6[w]	6.0	6	642	-	28.0	NA	22*	Poor
3.4[w]	11.0	11	210	14.0	33.5	NA	32*	Fair
1.4[w]	10.0	10	152	18.9	38.0	NA	30*	Fair
Beaver Meadow Run								
0.2[w]	10.0	10	614	8.2	80.0	NA	18*	Poor
Hawthorn Creek								
0.8[w]	9.0	9	1649	11.0	80.5	NA	28*	Fair
Miscelaneous Cuyahoga River Tributaries (see pages 164-171)								
Big Creek								
0.2[w]	9.0	9	261	--	71.0	NA	24*	Poor
Mill Creek								
0.2[w]	14.0	14	483	--	72.0	NA	22*	Poor
Fish Creek								
0.4[w]	17.0	17	446	--	70.5	NA	32*	Fair
Yellow Creek								
4.1[w]	13.0	13	1344	--	64.5	NA	36	Good
1.7[w]	19.0	19	1911	--	76.5	NA	38	Good

Table 22. (continued)

Stream River Mile	Mean Number of Species	Cumulative Species	Mean Rel. No. (No./Km)[a]	Mean Rel. Wt. (Kg/Km)[a]	QHEI	Mean Modified Index of Well-Being	Mean Index of Biotic Integrity	Narrative Evaluation[b]
North Fork Yellow Creek								
0.3[w]	13.0	13	3060	--	69.5	NA	42	Good
Furnace Run								
0.9[w]	14.0	14	2846	--	73.0	NA	46	V. Good
Brandywine Creek								
0.4[w]	12.0	12	2559	--	72.0	NA	30*	Fair

* Significant departure from applicable biological criterion (>4 IBI units or >0.5 MIwb units); underlined values are in the poor and very poor range.

ns Nonsignificant departure from biocriterion (<u><</u>4 IBI units or <u><</u> 0.5 MIwb units).

a Relative numbers and weights are based on a distance of 0.5 miles for boat method sampling and 0.3 miles for wading method sampling.

b Narrative evaluation is based on both MIwb and IBI scores.

NA Headwater site; MIwb is not applicable.

w Wading methods used to sample site.

Ecoregion Biocriteria: Erie/Ontario Lake Plain (EOLP)

INDEX - Site Type	WWH[a]	EWH	MWH[b]
IBI - Headwaters	40	50	24
IBI - Wading	38	50	24
IBI - Boat	40	48	24
Mod. Miwb - Wading	7.9	9.4	5.8
Mod. Miwb - Boat	8.7	9.6	5.8

a For Lake Erie estuaries, Interim WWH boat criteria of MIwb = 7.5 and IBI = 32 apply.

b Modified Warmwater Habitat for channel modified areas.

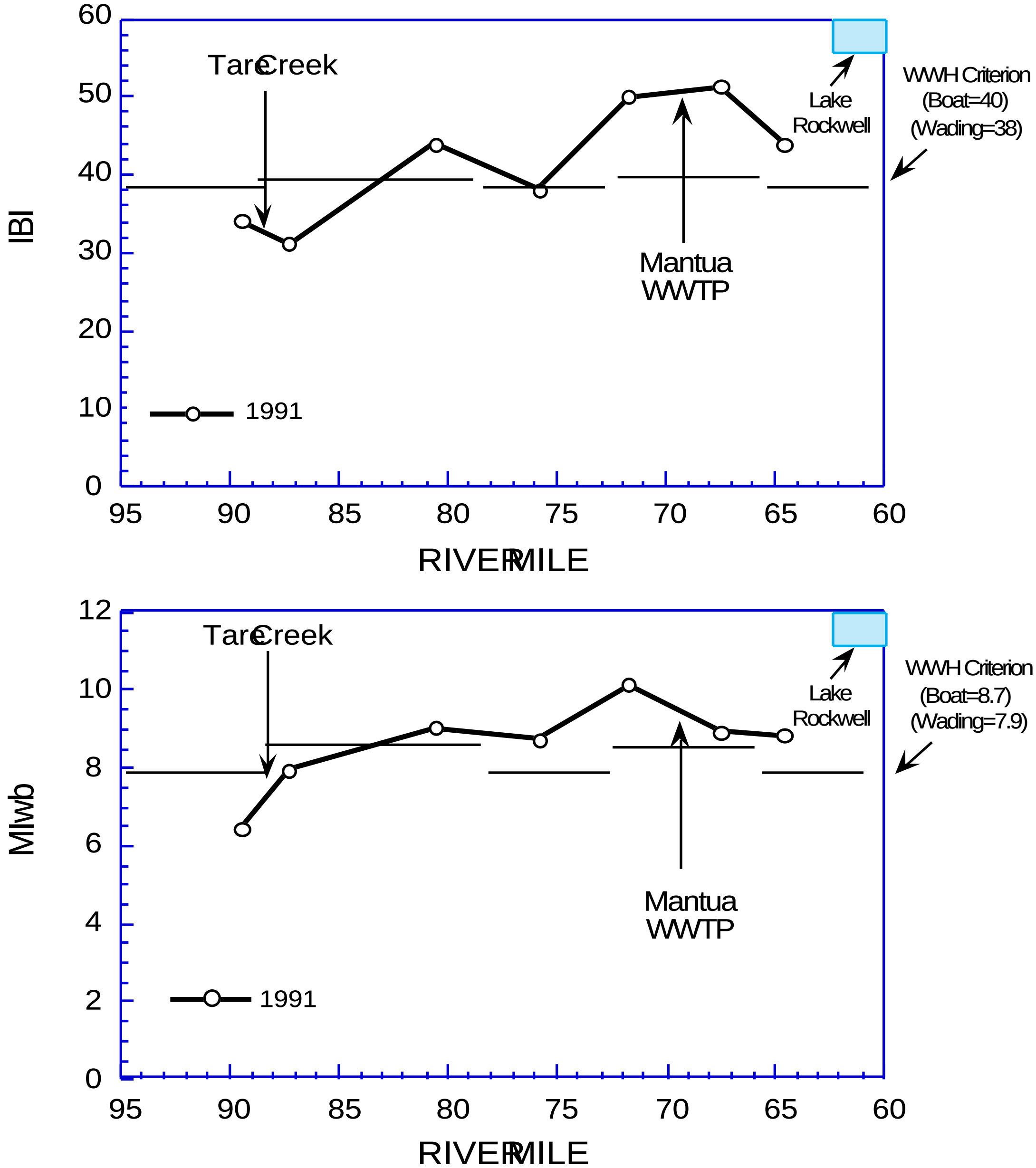


Figure 47. Longitudinal trend of the Index of Biotic Integrity (IBI; upper) and the Modified Index of Well-Being (MIwb; lower) in the upper Cuyahoga River during 1991. Note: Changes in WWH criteria depicted in graphs are related to differences in scoring between the boat and wading collection methods.

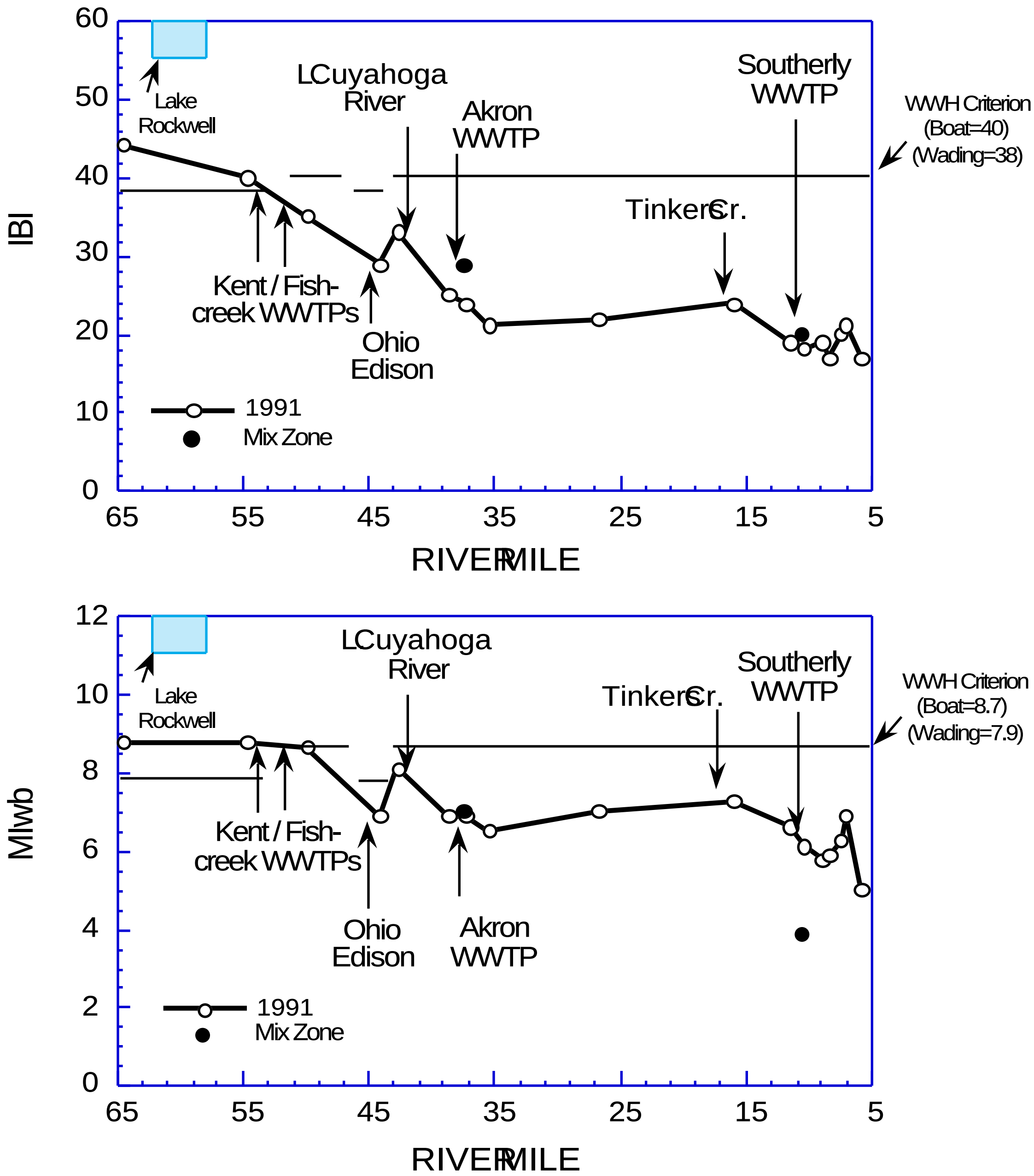
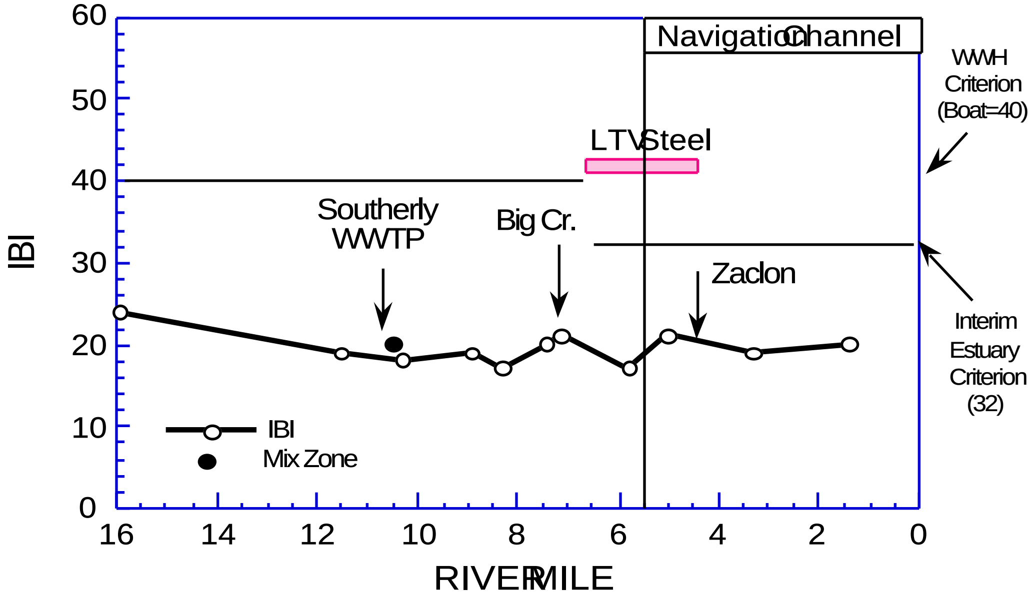


Figure 48. Longitudinal trend of the Index of Biotic Integrity (IBI; upper) and the Modified Index of Well-Being (MIwb; lower) in the middle Cuyahoga River during 1991. Note: Changes in WWH criteria depicted in graphs are related to differences in scoring between the boat and wading collection methods.



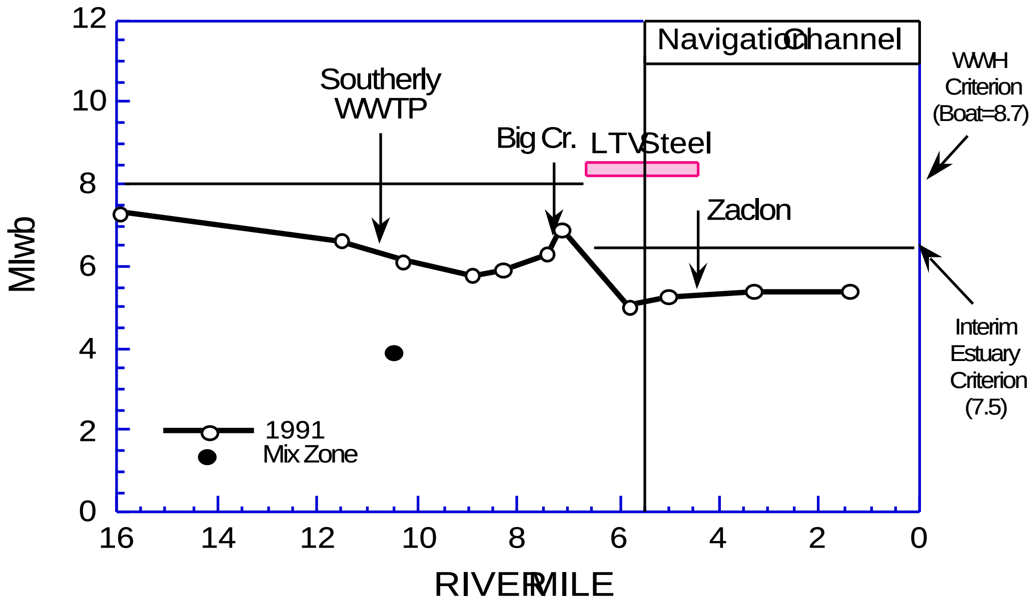


Figure 49. Longitudinal trend of the Index of Biotic Integrity (IBI; upper) and the Modified Index of Well-Being (MIwb; lower) in the lower Cuyahoga River during 1991. Note: Changes in WWH criteria depicted in graphs are related to differences in scoring between the boat and wading collection methods.

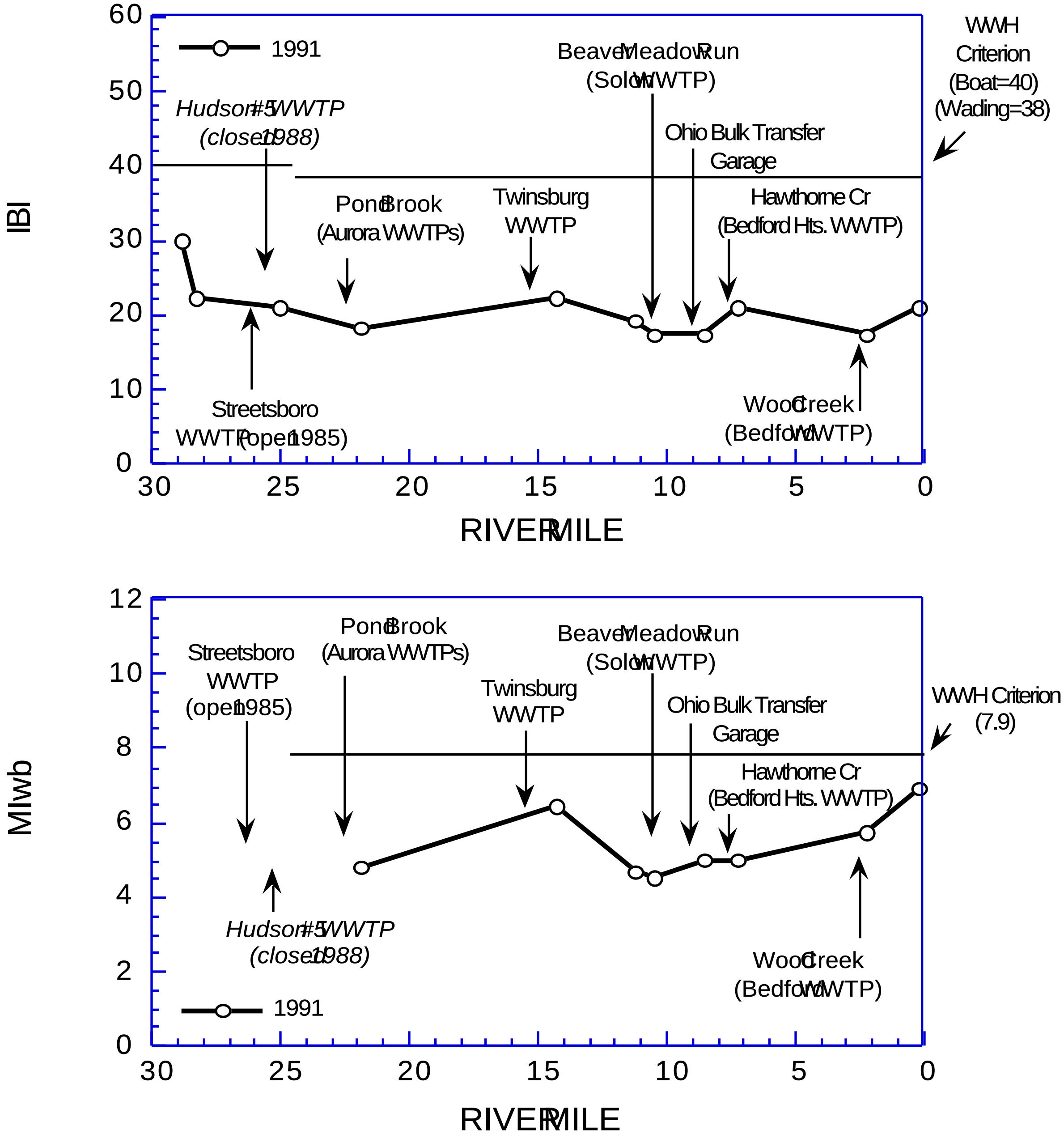


Figure 50. Longitudinal trend of the Index of Biotic Integrity (IBI; upper) and the Modified Index of Well-Being (MIwb; lower) in Tinkers Creek during 1991. Note: Changes in WWH criteria depicted in graphs are related to differences in scoring between the boat and wading collection methods.

Miscellaneous Cuyahoga River Tributaries:
Chemical and Biological Site Evaluations

Introduction

As part of the Cuyahoga River basin survey, biological and chemical sampling was conducted by the Northeast District Office (NEDO) near the mouths of selected mainstem tributaries. These included Fish Creek (RM 0.2), Brandywine Creek (RM 0.3), Furnace Run (RM 0.9), Mill Creek (RM 0.1), and Big Creek (RM 0.2). Excluding Fish Creek, one purpose of the surveys was to compare the 1991 results to previous (1984 or 1988) surveys near the same locations. Single chemical grab samples were collected under summer base flow conditions to detect potential exceedences of water quality criteria. No previous Ohio EPA biological data existed from Fish Creek so the sampling represented a baseline assessment.

Chemical/physical data from 1991 and biological data from 1990 and 1991 were also analyzed from the Yellow Creek watershed (RM 4.1, 1.7 and in the North Fork at RM 0.3). Samples were collected for trend analysis and to evaluate the proposed expansion of the Summit County #42 (Robinwood Hills) WWTP. No previous Ohio EPA biological data existed from the North Fork Yellow Creek.

Besides the above sampling, chemical data collected in 1990 and 1991 from five locations in Brandywine Creek was used to assess the influence of the Hudson WWTP following treatment upgrades between the two years. In response to concerns raised by the Cuyahoga River RAP process, additional grab water samples were also collected near landfills at three sites in the lower three miles of the Mill Creek basin.

A summary of water quality standards exceedences detected in chemical grab samples from the tributaries are included in Table 8. A summary of all chemical sampling results is included in Appendix A, Table 1. Macroinvertebrate and fish sampling results are included in Tables 21 and 22, and Appendices C and D, respectively. Physical habitat summary statistics and a matrix of warmwater and modified warmwater attributes are included in Table 20.

Fish Creek

Biological sampling was conducted at one location near the mouth (RM 0.4). A stream habitat evaluation (QHEI) was conducted at RM 1.3 in 1992 in the recently channelized portion of the upper mainstem. Fish Creek receives urban runoff from the cities of Kent in Portage County and Stow in Summit County. The Norton Company Ceramics Division discharges non-contact cooling water to an unnamed tributary that enters Fish Creek at RM 1.15 and is the only known point source discharge in the subbasin.

Biological Results

- A total of 16 species and 223 individual fish were collected from a 0.15 kilometer zone at RM 0.4. The most common species was creek chub (22%), followed by bluntnose minnow (15%) and white sucker (13%). The community was predominated by tolerant species (57%). There was also only one stoneroller minnow specimen, an algae eating fish often found in high numbers in many Cuyahoga River tributaries. The overall evaluation of the fish community was fair based on the IBI score of 32.

- A total of 30 macroinvertebrate taxa including six EPT taxa were collected during qualitative benthic sampling. Mayflies of the genus *Stenacron* and caddisflies were predominant while midges, isopods, and clams were common. The overall condition of the community was considered fair.

- The QHEI of 70.5 at RM 0.4 showed habitat quality near the mouth was sufficient to support warmwater communities. From the headwaters downstream to approximately RM 1.3, Fish Creek has been channelized to address surface flooding problems aggravated by the low gradient and numerous swamps and wetland areas. The QHEI score of 42 from the modified reach resulted from low habitat quality and a predominance of modified habitat attributes. The channel will be maintained in the future to alleviate flooding problems, making recovery of the channel unlikely. The modified warmwater habitat (MWH) designation is considered appropriate for the channelized section. Primary Contact is considered the appropriate recreational use based on the presence of large, deep pools in Fish Creek.

Yellow Creek

Study Area

Yellow Creek is a tributary of the Cuyahoga River with the confluence at RM 37.2. Yellow Creek is 10.3 miles in length and has a drainage area of 30.8 square miles. It has an average gradient of 44.3 feet/mile. Yellow Creek is designated as a Warmwater Habitat and for the Primary Contact Recreation use in the Ohio Water Quality Standards (OAC Chapter 3745-1). The North Fork of Yellow Creek empties into Yellow Creek at RM 4.64. It is 6.4 miles in length, has a drainage area of 9.8 square miles, and an average gradient of 54.2 feet/mile. The North Fork is also designated for the Warmwater Habitat and Primary Contact uses in the Ohio Water Quality Standards.

Given the relatively high stream gradient, there is a general lack of large, deep pool areas in Yellow Creek; however, the stream does offer excellent riffle/run type habitat. Groundwater springs were observed along the stream during summer base flow conditions. Combined WWTP flows average about 0.2 MGD in the Yellow Creek subbasin, which also are counted in the base flows. Riparian habitat in the basin remains largely undisturbed, thus providing shade, leaf litter, bank stability, and instream cover. These habitat attributes are important factors in the maintenance of balanced and diverse biological communities.

Land use in the Yellow Creek subbasin is mostly residential, natural forest, and light commercial. Most of the subbasin is located in Bath Township (Summit County), except the headwater areas located in Medina County. Summit County operates three WWTPs: Westmont Woods-Summit County #45 (0.100 MGD); Colony Hills-Summit County #26 (0.012 MGD); and Robinwood Hills-Summit County #42 (0.900 MGD). The Granger Lake WWTP in Medina County (0.800 MGD) discharges to a tributary that empties into Yellow Creek downstream from the Summit County #26 WWTP. Some small package type wastewater treatment plants serve the village of Ghent and the Bath Center area. Residential on-site septic tank systems are common in the Yellow Creek subbasin. Regional sanitary sewers have yet to be extended into Bath Township. The

NEORSD sanitary sewer system extends to the northern boundary of Bath Township along Everett Road, and the city of Akron sanitary sewer borders the southern boundary of the township along Medina Road (SR 18).

Survey Results

The North Fork Yellow Creek study area extended from upstream of the Summit County # 42 WWTP (RM 0.30) to the mouth at RM 0.01. Biological samples (electrofishing and qualitative kick-net for macroinvertebrates) were collected in 1991 at RM 0.30 to determine the appropriate aquatic life use designation. Summer flows were calculated to learn baseline conditions during the sampling period. In Yellow Creek, the study area extended from RM 5.7 (a 1988 sampling site) to 1.7 for chemical water quality analysis. Qualitative macroinvertebrate samples were collected at RMs 4.1 and 1.7 in 1991 and at RM 0.1 in 1988. Fish were collected at RMs 4.7 and 1.7 in both 1988 and 1991 and near the mouth (RM 0.1) in 1984.

Some information on historical chemical sampling conducted in the Yellow Creek basin by Ohio EPA on May 4, 1978 is available. Additional pre-1980 water chemistry and biological data for the Yellow Creek subbasin is found in the 1980 facility plan developed for the city of Akron (Burgess & Niple, 1980). The conclusion of the 1980 facility plan was that "Yellow Creek is relatively clean and suffers from seasonal or periodic pollution."

Chemical Water Quality

- The results of limited water quality sampling in Yellow Creek and the North Fork Yellow Creek below the Village of Ghent showed no exceedences of water quality criteria for the parameters analyzed.

Biological Communities

- The results from the 1988 and 1991 fish surveys at RMs 4.1 and 1.7 showed Yellow Creek met or exceeded WWH criteria (IBIs = 38-42) downstream from the village of Ghent. However, the IBI values are at the low end of the expected 38 ecoregion biocriterion for the wading site type (>20 sq.mi.). Calculation of IBI values using headwater scoring results in a significantly higher value than that obtained with wading type scoring. Yellow Creek sites were near the 20 sq.mi. drainage area limit which separates the wading and headwater IBI calculation methods. A lack of large deep pools due to geologic features suggests that the headwater scoring criterion may be more appropriate since the wading IBI may underestimate the fish community performance of this stream.

- Fish sampling results from 1988-91 show no significant changes between sampling years. IBIs at each site ranged from 38-42, all within the 4 IBI unit range of acceptable measurement variation established for the index. The most recent results do suggest improvement over 1984 conditions at RM 0.1 when the IBI of 34 and MIwb of 6.9 were in PARTIAL attainment of WWH criteria.

- The total number of fish species collected in Yellow Creek by Ohio EPA and Orr *et al.* (1980) between 1979 and 1991 are similar and slightly higher than the total number of species reported by Trautman (1981) before 1955 (22). Seven species reported by Trautman were not collected by Ohio EPA or Orr whereas five species were collected during the 1979-1991 period that were not reported by Trautman. Of special interest is the fact that Trautman *did not* report the presence of the intolerant river chub either from Yellow Creek below the confluence of the North Fork or from the North Fork. However, sampling in 1988 and 1991 showed good populations of this species at both localities. Trautman reported river chubs from Yellow Creek *above* the confluence of the North Fork, thus it is likely that the river chub population expanded downstream after 1955. This type of range expansion would not be expected if the lower sections of the Yellow Creek had been subjected to a significant decrease in water quality, siltation, or loss of instream habitat between 1955 and 1979.

- The results from the qualitative macroinvertebrate sampling suggests that Yellow Creek at RMs 4.1 and 1.7 has a diverse community of invertebrates. Both sites had the same number of qualitative EPT taxa (10), an ICI metric. The overall rating of the macroinvertebrates was good to very good which is consistent with the WWH use designation. The 1988 sample at RM 0.1 also received a very good evaluation.

North Fork of Yellow Creek

- The results from the biological and habitat evaluation of the North Fork of Yellow Creek showed FULL WWH attainment. The RM 0.3 location, upstream from the Summit County #42 WWTP, scored an IBI value of 42 and macroinvertebrates received a very good evaluation. The QHEI value of 69.5 shows physical habitat quality was adequate to support the WWH use designation.

Furnace Run

Chemical Water Quality

- The results of the limited water quality sampling showed no exceedences of water quality criteria for the parameters analyzed. Total phosphorus was below laboratory detection limits (<0.05 mg/l) and ammonia-N was 0.13 mg/l, well below the water quality criterion.

Biological Communities

- The 1991 fish data show a well-balanced community near the mouth with an IBI of 46. This was significantly improved from the IBI of 38 found in 1984; however, the 1984 sample location for fish was at RM 0.2, 0.7 miles downstream from the 1991 sample location. Different IBI values likely resulted from the use of the wading IBI for the 1984 RM 0.2 (drainage area >20 sq.mi) results. The headwater IBI was used for the 1991 RM 0.9 location data. It is also possible that subtle habitat differences resulted in the different IBI values between 1984 and 1991 since the RM 0.2 station lacked the large cobble-boulder substrate found at RM 0.9. The 1991 QHEI score of 73.0 indicated habitat conditions were adequate to support the WWH use designation.

- In both the 1984 and 1991 surveys the stoneroller minnow was the most common fish species collected. Because these fish feed on algae, their presence in large numbers suggests a certain degree of nutrient enrichment from upstream sources. Several small package type WWTPs discharge to the Furnace Run subbasin. In 1991, four intolerant species of fish were collected at RM 0.9 (river chub, rainbow darter, hog sucker, and redside dace). The IBI score of 46 recorded in 1991 reflects very good performance.

- The results of qualitative macroinvertebrate sampling in 1988 and 1991 showed exceptional community performance. Less taxa were collected in 1991 (32) than in 1988 (53), although this difference was due in large part to fewer chironomid taxa. The number of EPT taxa was 16 in 1988, and 13 in 1991, with no change in overall diversity of types.

Brandywine Creek

Grab water chemical samples were collected on July 24, 1991 at six locations throughout the Brandywine Creek subbasin to document potential impacts from the discharge of the village of Hudson WWTP. Previous sampling in 1990 immediately downstream from the Hudson WWTP showed very low dissolved oxygen, elevated ammonia-N, sewage sludge, and discolored and odorous water. The WWTP installed additional treatment capacity in late 1990, thus it was expected that the 1991 survey would show improved chemical water quality and biological performance. The Hudson WWTP will be tied into the NEORSD Cuyahoga Valley Interceptor (CVI) in 1995. This will require installation of five miles of force main and five miles of gravity sewers.

Chemical Water Quality

- The results of the chemical grab sampling revealed no exceedences of chemical water quality criteria downstream from the Hudson WWTP. Concentrations of dissolved oxygen and ammonia-N were greatly improved from samples collected in 1990, before the WWTP upgrade. During the 1990 survey, ammonia-N as high as 13.6 mg/l and dissolved oxygen as low as 0.7 mg/l was observed in Brandywine Creek downstream from the Hudson WWTP.

- Wasteload allocation (WLA) modeling conducted by Ohio EPA predicts excursions below the dissolved oxygen criterion (5.0 mg/l) in Brandywine Creek under low flow conditions, even with the increased level of treatment at the Hudson WWTP. D.O. concentrations did decline from 7.7 mg/l upstream from the WWTP to 5.8 mg/l downstream in 1991. The samples were collected under elevated summer stream flow conditions; it is possible that excursions below the D.O. criterion can occur under lower flows.

Biological Communities

- A total of 12 fish species were collected at RM 0.3. A predominance by stoneroller minnows (65% by numbers) was an indication of nutrient enriched conditions. There was little change in fish IBI scores between 1984 (IBI = 25) and 1991 (IBI = 28) at RM 0.3. Based on the wading IBI Brandywine Creek was not meeting the ecoregional potential for a WWH fish community.

- The results of the qualitative macroinvertebrate sampling indicated fair community performance and some indication of improvement since 1988. The number of EPT taxa in 1988 was two, whereas 5 EPT taxa were collected in 1991. Caddisflies were the predominant organisms in the riffle habitats; however, only two taxa were collected.

Mill Creek

Chemical Water Quality

- Besides sampling at the mouth of Mill Creek, chemical samples were also collected at three upstream locations. These stations were 1) the mouth of an unnamed tributary that enters Mill Creek at RM 0.4, 2) Mill Creek upstream from the tributary and downstream from the Warner

Hill and Harvard Refuse solid waste landfills (RM 0.45), and 3) Mill Creek upstream from the landfills but downstream from CSOs and SSOs (Warner Road, RM 2.9).

- The results of the water quality sampling in Mill Creek at RM 0.1 (Canal Road) showed an exceedence of the fecal coliform Secondary Contact Recreational criterion with a count of 97000/100 ml recorded on September 12, 1991. The source of the bacteria was traced to the unnamed tributary of Mill Creek (RM 0.4) which had a fecal coliform count of 760000/100 ml on the same date. This tributary had a strong odor of raw sewage and sewage sludge was observed in the stream sediments. The contamination was investigated by the Northeast Ohio Regional Sewer District (NEORSD) and traced to a blocked sanitary sewer that has since been remediated.

- Ammonia-N concentrations as high as 3.58 mg/l were observed which exceeded the WWH chronic criteria. A value of 2.86 mg/l was found above the unnamed tributary (RM 0.4) with upstream landfills as probable sources. Relatively low ammonia-N (0.06 mg/l) was found at the most upstream location at Warner Road (upstream from the landfills) but a fecal coliform exceedence was detected. No exceedences of heavy metals criteria were recorded in Mill Creek.

Biological Communities

- There was a significant increase in the number of fish species collected at RM 0.1 in 1991 as compared to 1984. In 1984, an average of 3.7 species were collected from three samples; in 1991, 12 species were collected in one sample. There was also a significant increase in the IBI between years (IBI = 13 in 1984; IBI = 24 in 1991). Although the fish community has improved since 1984, the 1991 data indicate that the fish community at the mouth of Mill Creek is still degraded and not near the IBI criterion of 40.

- Physical habitat conditions based on QHEI measurements at RM 0.1 (QHEI = 72) and reanalysis of 1984 habitat measurements indicated a predominance of warmwater habitat attributes at all sites. An exception was the most upstream location in 1984 that resulted from a localized landfill disturbance.

- Results of macroinvertebrate sampling in 1991 at RM 0.1 in Mill Creek yielded 22 taxa as compared to 14 taxa collected at the same site in 1984. The number of qualitative EPT taxa was four in 1991 and one in 1984. The invertebrate community appeared degraded both in the number of taxa and the number of individuals. Baetid mayflies were the predominant taxon found in the riffles and midges were common in both riffle and pool habitats. The overall narrative rating of the invertebrate community was fair to poor.

Big Creek

Chemical Water Quality

- The results of the limited water quality sampling indicated no exceedences of water quality criteria for the parameters analyzed. Total phosphorus was below laboratory detection limits and ammonia-N was 0.18 mg/l, well below the water quality criterion. An oily sheen was observed seeping into Big Creek from the old Research Oil property, just above the Jennings Road bridge. Additional sampling by Ohio EPA -DERR in 1991 showed the presence of PCB in the oily discharge. Corrective actions are presently underway.

Biological Communities

- There was a significant increase in the number of fish species collected at RM 0.2 in 1991 as compared to 1984. In 1984 an average of two species were collected from three samples; in 1991, 8 species were collected in one sample. Although the number of species increased, there was only a slight change in the IBI between years (IBI = 16 in 1984; IBI = 22 in 1991). Results of macroinvertebrate sampling indicated 16 taxa in 1991 as compared to six taxa collected at the same site in 1984. The number of qualitative EPT taxa was two in 1991, and zero in 1984, with the narrative rating of **poor** and **very poor**, respectively.

TREND ASSESSMENT

Chemical Water Quality Trends

Cuyahoga River Mainstem

Middle Cuyahoga River: 1954- 1991 (RM 54.7 to 7.4)

- Instream ammonia-N concentrations in the Cuyahoga River near the Akron and NEORSD Southerly WWTPs have decreased significantly over the past two decades (Figure 51). These decreases have occurred as improvements or additional wastewater treatment processes have come on-line. Ammonia levels at Lower Harvard Ave. (RM 7.1) show a strong decreasing trend following the instalation of de-nitrification facilities at NEORSD Southerly in 1988 (Figure 52).

- Average concentrations of dissolved oxygen in the middle Cuyahoga River have also shown significant improvement during the past decade. No D.O. violations were recorded by the USGS continuous monitor at the Independence gage (RM 13.2) from 1987 to 1991; before 1987, D.O. violations at Independence were common (Figure 53).

- Loadings of phosphorus, TKN, ammonia, COD, and BOD_5 from the Akron WWTP have declined steadily since the early 1980s (see Point Source Loadings Section) and resulted in dramatic improvements in water quality between Akron and Cleveland. Similar trends in loadings reductions have also occurred at the NEORSD Southerly WWTP. Sampling results from 1991 were compared to earlier chemical surveys in 1954 (for dissolved oxygen), 1965 (for fecal coliform bacteria and BOD_5) and 1965-67 for ammonia (Figure 54). In 1954, a 13 mile stretch of the river downstream from Akron and an additional 7-mile stretch in Cleveland was lacking oxygen. No sites in the survey exceeded the four mg/l daily minimum WWH criterion. In contrast, no 1991 D.O. violations were detected in instantaneous sampling outside the navigation channel in chemical grabs. Fecal coliform bacteria counts in 1967 were consistently orders of magnitude greater than Ohio's water quality criteria. Current fecal coliform counts in the river generally meet the criterion during low flow conditions. Ammonia in the 1960s was detected at levels sufficient to cause toxicity in aquatic life while in 1991, no ammonia exceedences of Ohio water quality criteria were detected between Akron and Cleveland. The dramatic improvement in the middle Cuyahoga River for each of these parameters has been closely correlated with wastewater treatment plant consolidations and improvements, particularly at the two largest municipal plants in Cleveland and Akron. More recently, improvements in wastewater collection systems have likely contributed to the improved conditions.

- During 1984 occasional water quality criteria exceedences for ammonia-N, iron, lead, zinc, and cadmium were detected in the middle section of the river from RM 42.6 to 5.0. The frequency of exceedences for these same parameters along with copper and D.O. increased in the navigation channel. During limited sampling conducted in 1988 in the lower section of the river, D.O., ammonia-N, iron, and zinc were the only parameters that exceeded WWH criteria. During more extensive sampling in 1990 and 1991, there were almost no measured chemical or physical water quality criteria exceedences from Lake Rockwell to Big Creek. Exceptions were some diel D.O. problems in the Ohio Edison dam pool and an occasional iron exceedence attributable to natural conditions.

Lower Cuyahoga River: 1975-1991 (RM 5.4 to 0.0)

- Ohio EPA has collected water quality data from the navigation channel at West Third Street (RM 3.2) from 1975 to the present. There are, however, significant data gaps in monitoring due to budget constraints. The reader should use caution when interpreting the results due to these data gaps, changing detection limits for some parameters, and small sample sizes in 1978, 1979, 1980, and 1988. Unlike the monitoring station at Independence, the long term monitoring station at West Third Street has not shown significant improvement in D.O. concentrations from 1975 to present (Figure 55). Results of an Ohio EPA model for the navigation channel show that channel morphology is the primary controller of dissolved oxygen concentrations. This may explain the lack of D.O. improvement while other water quality indicators such as ammonia and total-P (Figure 55) have improved since 1975.

- There also appears to be an improving trend for cyanide (Figure 56) and the heavy metals, cadmium, lead and copper (Figure 57) in the navigation channel. These improvements in water quality can be attributed to upgrades at the NEORSD Southerly WWTP, improvements in the sewer collection system, plant shutdowns and elimination of industrial discharges through tie-ins to sanitary sewers. Elimination of all coking operations in the Cuyahoga River watershed by 1993 should contribute to continued water quality improvements, especially for ammonia and cyanide.

Little Cuyahoga River: 1986 - 1991

- There appeared to be no significant change in dry weather water quality in the Little Cuyahoga River. Dry weather sampling during both 1991 and 1986 intensive surveys revealed no exceedences of the WWH chronic criteria between RM 2.2 (upstream from the Ohio Canal) and the mouth. However, rainfall and subsequent runoff event sampling in 1986 detected exceedences for total lead, cadmium, copper, zinc and fecal coliform within this same stretch. Several rainfall or runoff induced exceedences for metals were also detected in the Ohio Canal between RM 3.6 and the mouth. Septic sediments and sanitary wastes were evident in the Little Cuyahoga River during both intensive surveys, an indication of wet weather discharges. Also, extensive bacteriological sampling in the Akron area and CVNRA have shown the Little Cuyahoga River and Akron sewer system are major sources of bacterial contamination in the Cuyahoga River mainstem.

- Most Akron CSO and SSO overflow events occur within the Little Cuyahoga River subbasin. There had been no significant CSO remediation efforts in Akron before the 1991 survey but plans are currently being developed to address CSO problems in the service area. The city has been more aggressive in SSO identification and remediation. Bulkheading of SSOs was initiated in 1988 and all SSOs, except overflow #5, are scheduled for elimination by 1994. Overflow at #5 will occur only following a ten-year rain event.

- Ambient sampling in the Little Cuyahoga River basin was done by the city of Akron following rainfall events during 1989-92. Samples were collected from the Little Cuyahoga River at Otto Street (downstream from the Ohio Canal, CSOs and SSOs), the Ohio Canal at Lock #15 (downstream from sewer overflows) and the Ohio Canal at Cedar Street (upstream from all Akron overflows). Results showed a steady decline during this period in concentrations of total suspended solids (TSS) and five-day biochemical oxygen demand (BOD_5) in the Little Cuyahoga River and the Ohio Canal at lock 15 (see Figure 34). However, it is not certain if the declines in TSS and BOD_5 were related to sewer remediation efforts in Akron. The Ohio Canal at Cedar Street had consistently lower concentrations of TSS and BOD_5.

Tinkers Creek and Tributaries 1984-1991.

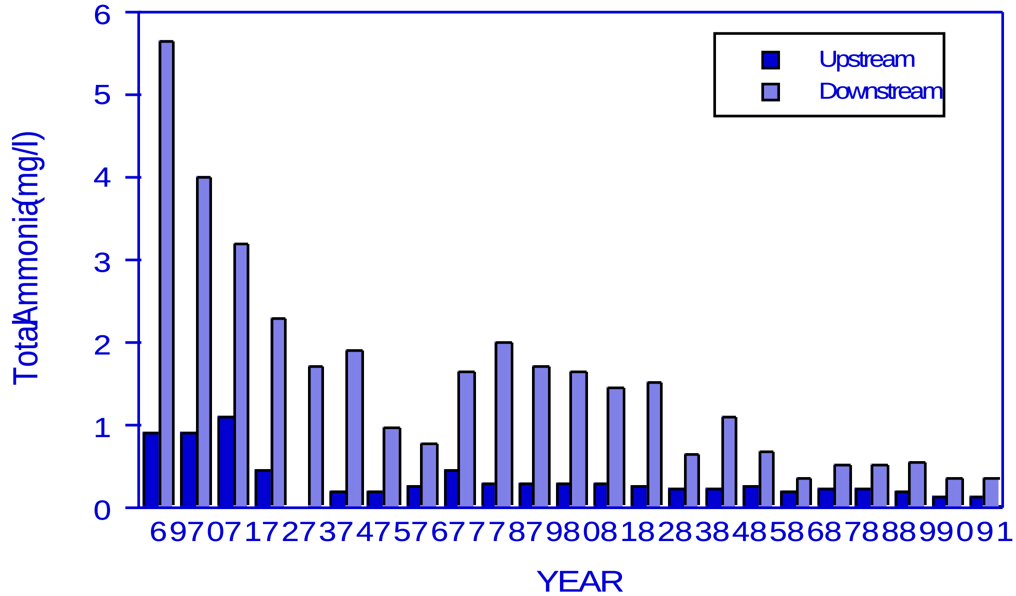
- Some significant trends were noted between the 1984 and 1991 Tinkers Creek chemical data. Concentrations of ammonia-N were significantly lower in 1991 at all 11 locations sampled in Tinkers Creek (Figure 58). Also, total phosphorus concentrations were lower at nine of 11 locations in 1991 as compared to 1984. These trends are most likely the result of increased levels of wastewater treatment from 1984 to 1991 (*i.e.*, nitrification, phosphorus removal), and the elimination of many on-site septic systems and small package type treatment plants. These sources have been connected to larger, regional sanitary sewers, especially in the Streetsboro, Hudson, and Aurora (i.e., headwater) areas.

- As observed in many Ohio rivers and streams, the reduction in ammonia-N was accompanied by a significant increase in nitrate+nitrite-N, a consequence of increased nitrification at the WWTPs (Figure 58).

- Concentrations of total copper in 1991 were below the 10 ug/l laboratory detection limit in 32 of 33 (97%) mainstem samples collected, and were significantly below the copper concentrations observed during the 1984 survey (Figure 59).

Pond Brook: 1984-1991.

- Improved chemical water quality was found in 1991 as compared to 1984 at RM 1.4 on Pond Brook. Improved parameters included higher dissolved oxygen, and lower ammonia and copper and were primarily attributed to closure of the old Geauga Lake WWTP and diversion of small WWTPs to the new Aurora Westerly plant in 1988.



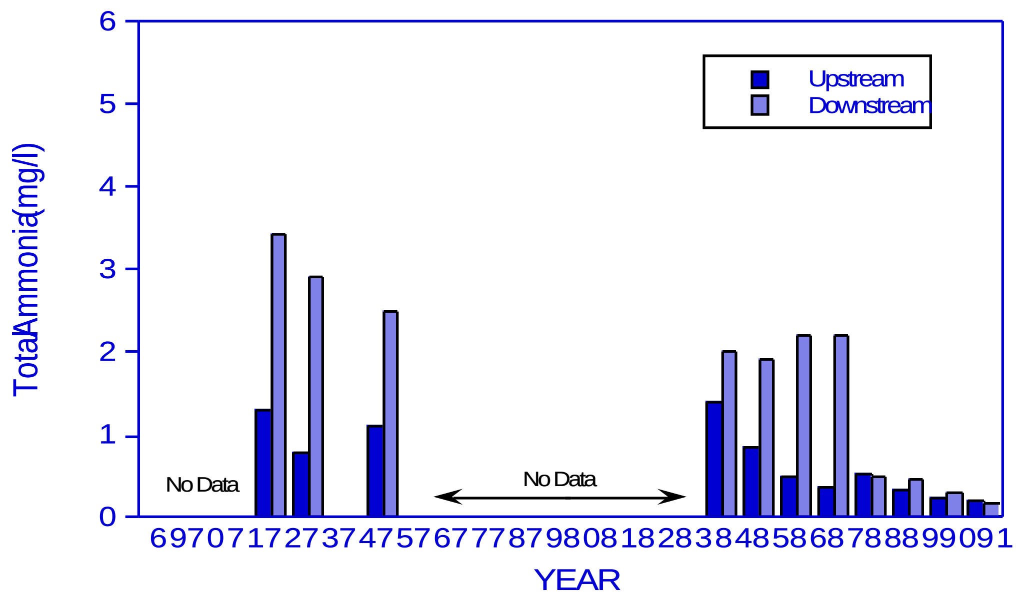


Figure 51. Historical trends of ammonia-N collected immediately upstream and downstream from the the Akron WWTP (upper) and NEORSD Southerly WWTP (lower) between 1969 and 1991. Akron samples were collected from RMs 37.47 and 35.31. NEORSD Southerly samples from were collected from RMs 10.95 and 9.95.

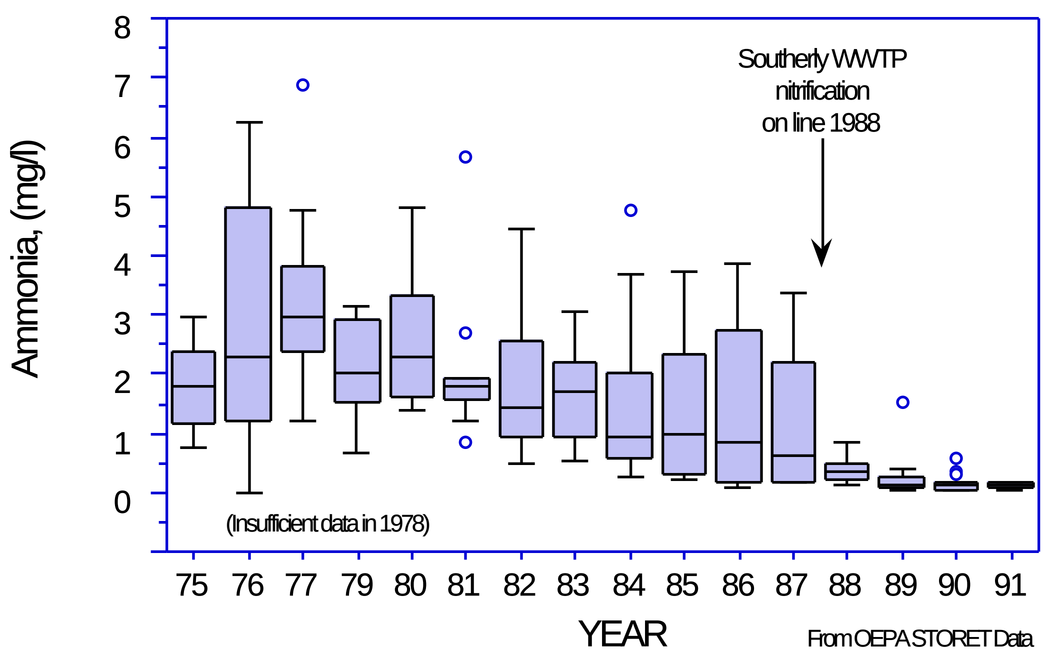


Figure 52. Box-and-whisker plot of ammonia-N concentrations at Lower Harvard Avenue (RM 7.1), 1975 - 1991.

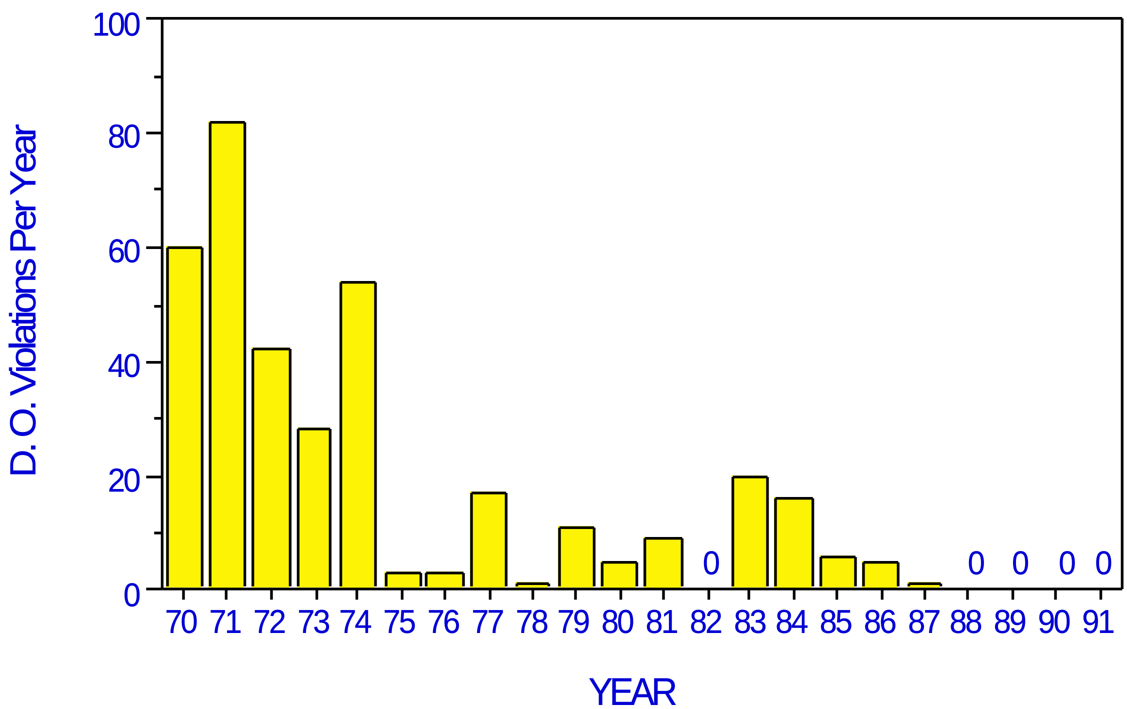


Figure 53. Numbers of dissolved oxygen (D.O.) violations of WWH criteria per year in the Cuyahoga River at Independence (RM 15.6), 1970-91.

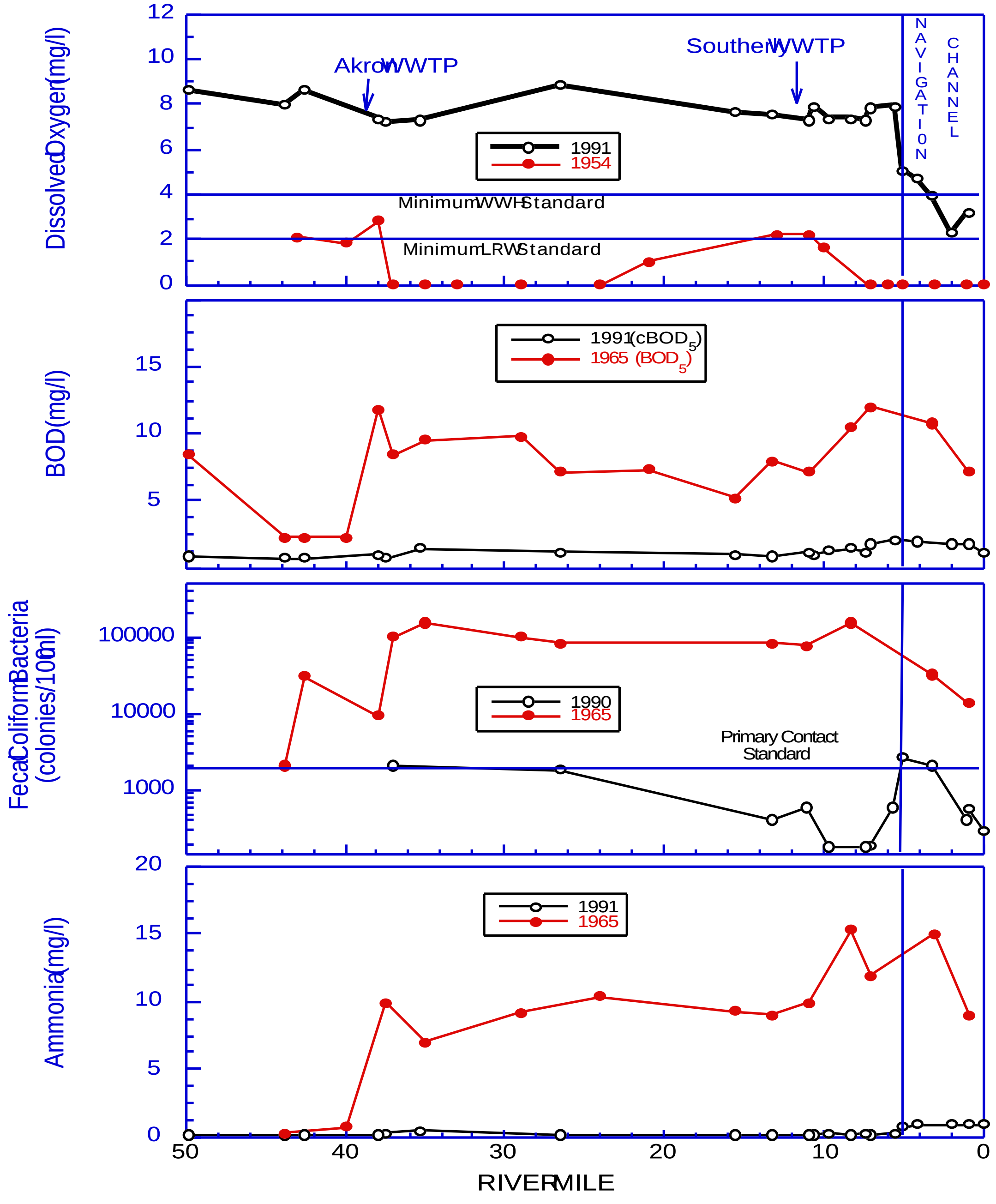


Figure 54. Historical trends of dissolved oxygen, BOD, fecal coliform, and ammonia in the Cuyahoga River mainstem between Munroe Falls and the mouth based on survey data from 1954 (D.O.) and 1965 through 1991.

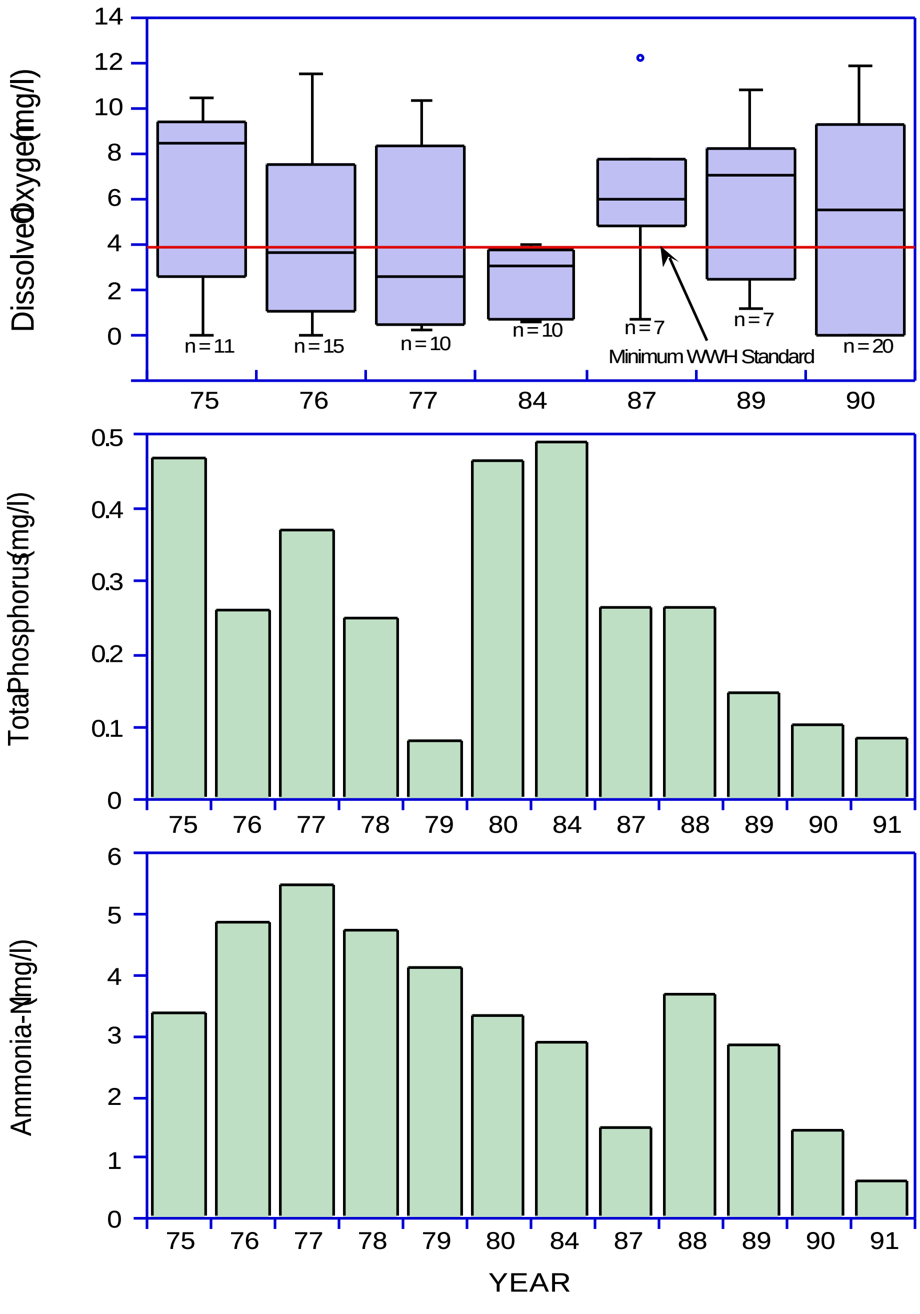


Figure 55. Historical trends of.dissolved oxygen (D.O.), phosphorus (Total-P), and ammonia-N from the Cuyahoga River navigation channel at West 3rd Street (RM 3.3) from 1975-91.

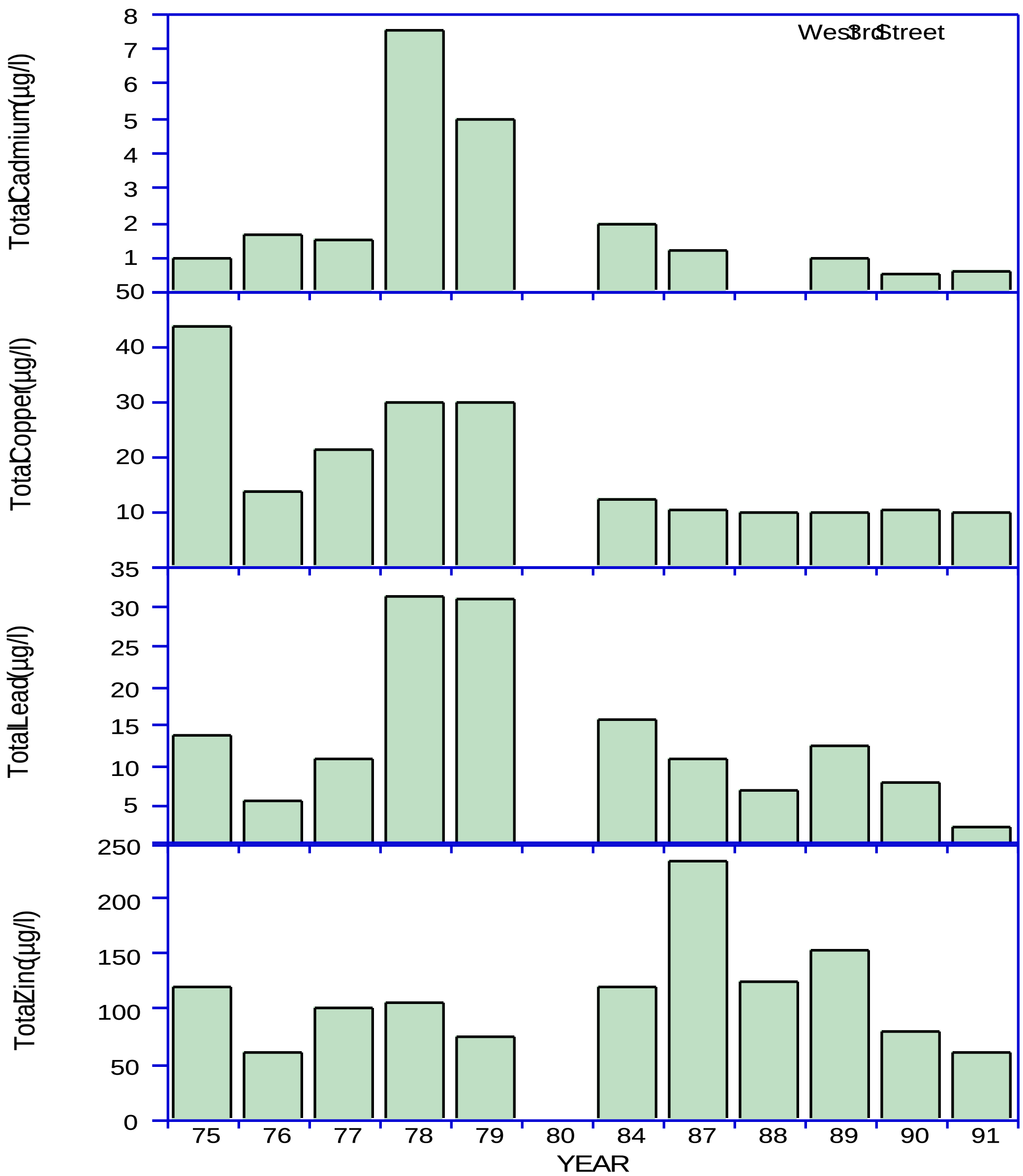


Figure 56. Historical trends of total cadmium (T-Cd), copper (T-Cu), Lead (T-Pb), and Zinc (T-Zn) from the Cuyahoga River navigation channel at West 3rd Street from 1975-91.

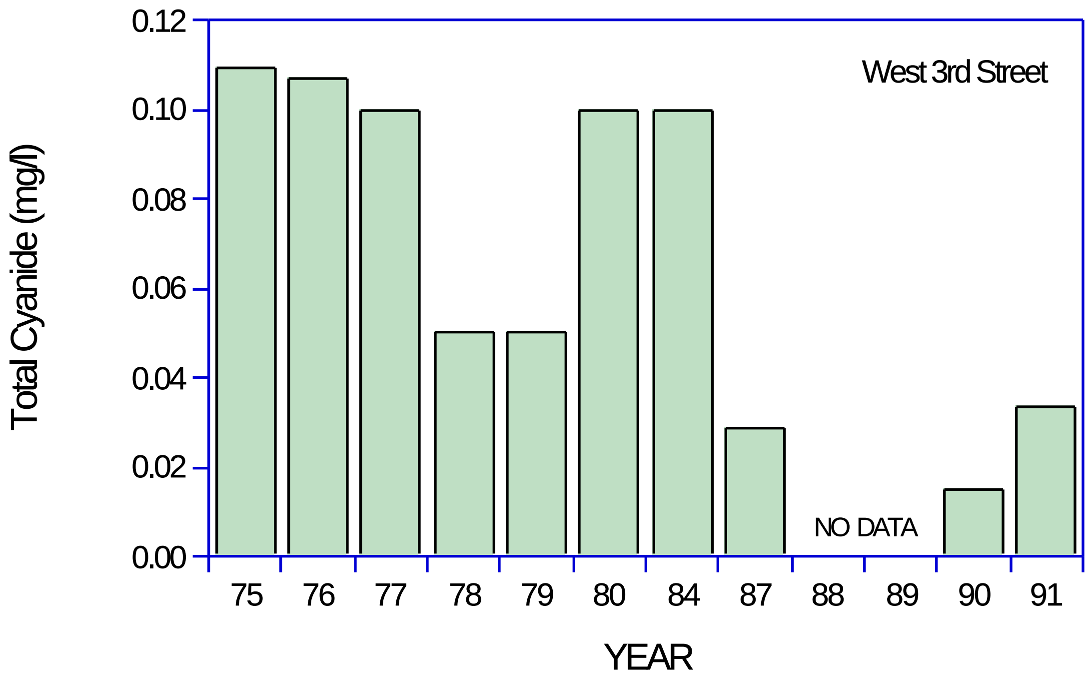


Figure 57. Historical trends of Total Cyanide (T-Cn) from the Cuyahoga River navigation channel at West 3rd Street from 1975-91

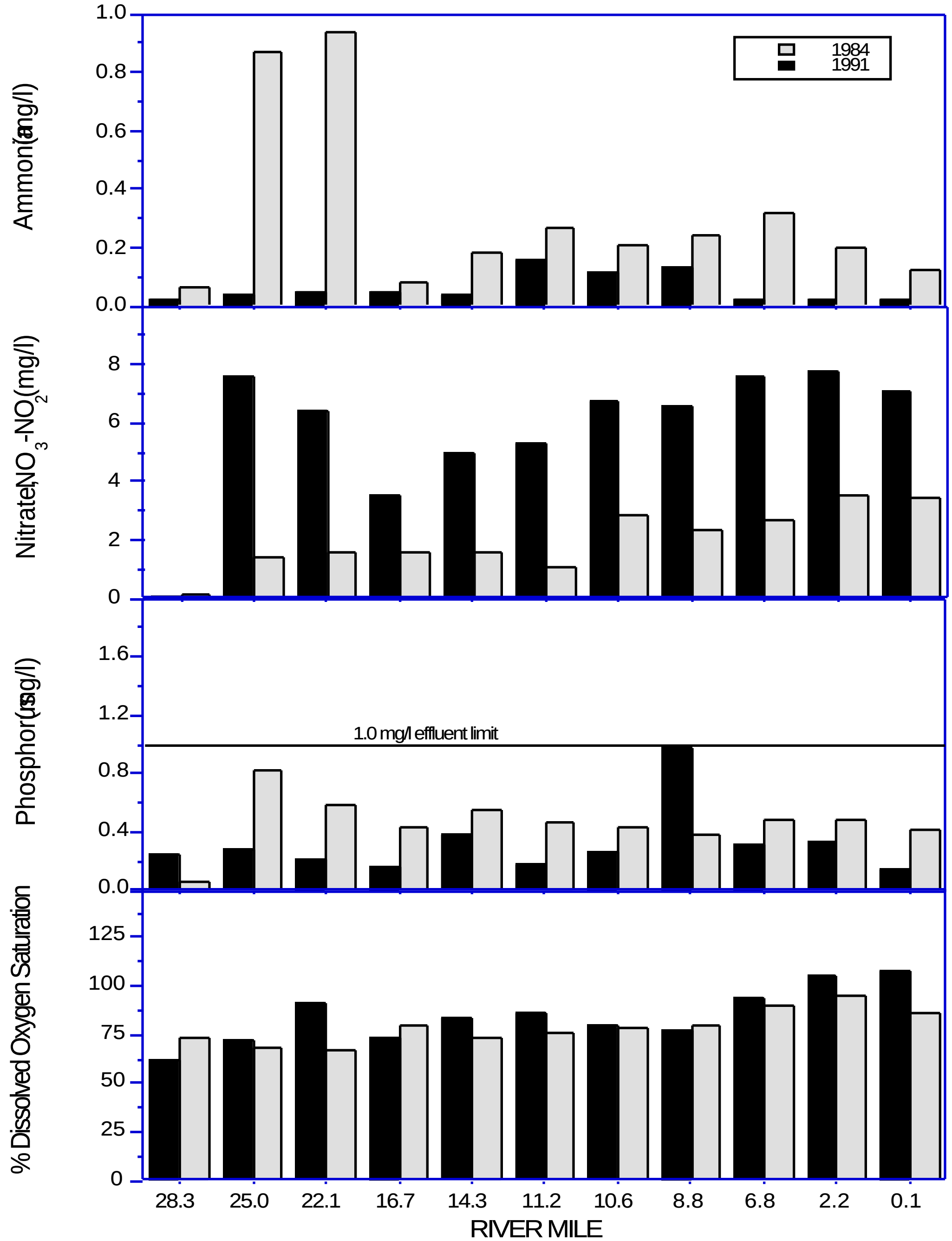


Figure 58. Longitudinal trend of mean ammonia-N, total nitrate+nitrite-N, phosphorus, and percent dissolved oxygen saturation in Tinkers Creek, 1984 and 1991.

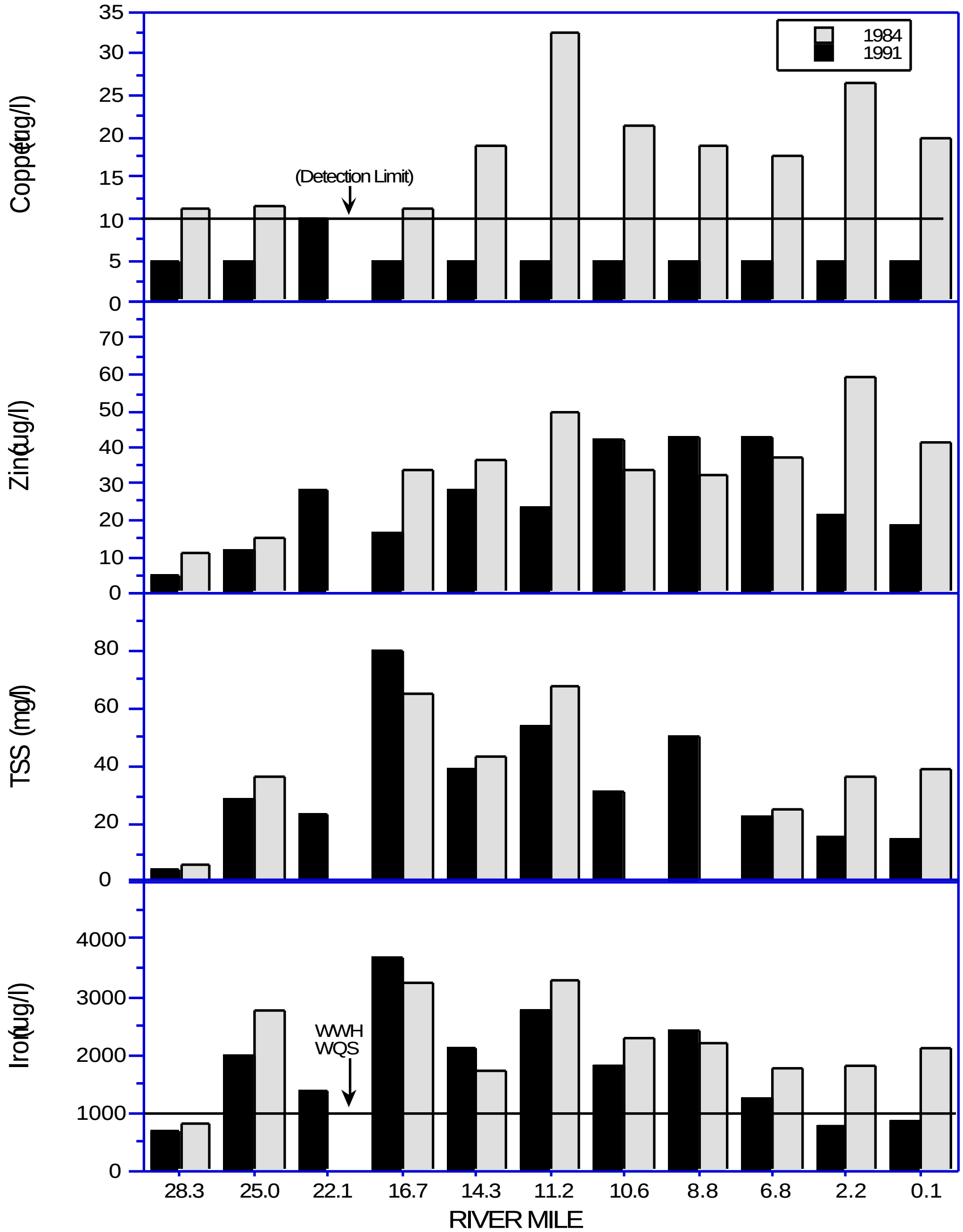


Figure 59. Longitudinal trend of mean copper, zinc, total suspended solids (TSS), and iron in Tinkers Creek, 1984 and 1991. Note: for copper and zinc concentrations reported as < detection limit (10 ug/l), a 5 ug/l value was used to calculate means.

Sediment Chemistry Trends: Cuyahoga River (1984 - 1991)

- Recent sampling conducted by the U.S. Army Corps of Engineers (U.S. ACE) in the upper section of the navigation channel between RM 5.6 and 5.48 showed that sediments now meet the criteria for open lake disposal. This is because of decreased concentrations of contaminants and an increased percentage of sand in the dredge spoil. Prior sampling found that sediments were highly contaminated and had to be placed in a Confined Disposal Facility (CDF). This improvement in sediment quality agrees with anecdotal information from the dredge operators who have said that "clean sands" are now the predominant sediments removed and the oils and foul smells in past sediments are now missing. Sediment from the remaining portions of the navigation channel must still be placed in a CDF.

- Copper concentrations in the sediments from RM 50.0 to 20.8 were slightly lower than the results reported in 1984 and 1986 by the U.S. ACE and in 1985 Ohio EPA samples. However, some earlier studies collected samples from dam pool sediments; a direct comparison to stream sediments may not be valid. Chromium concentrations are much lower in sediments near Shalersville (RM 63.26) in 1991 than in the 1985 Ohio EPA study.

Changes in Biological Community Performance: 1984 - 1991

Cuyahoga River Mainstem

Upper Cuyahoga River

- Biological results upstream from Lake Rockwell show fish and macroinvertebrate assemblages at RM 64.5 have remained stable and indicative of good to exceptional performance during the past seven years (Figure 60, Figure 61; upper plot). Rosyface shiner, a minnow species declining throughout Ohio due to pollution or habitat modification, was collected between RM 67.5 and 75.8 during the 1991 survey. This further suggests biological assemblages in the Cuyahoga River upstream from Lake Rockwell have remained stable. Trautman (1981) reports only one pre-1955 record for this species from the Cuyahoga River downstream from Kent near the Summit/Portage County line.

Middle Cuyahoga River

- In contrast to the segment upstream from Lake Rockwell, the quality of biological communities in the Cuyahoga River between Kent and Cleveland has shown considerable changes. Since 1984, results from most sampling locations downstream from Lake Rockwell improved in the quality of fish assemblages (*i.e.*, greater diversity and densities of fish, decreased percent occurrence of DELT anomalies). MIwb and IBI values in Kent (RM 54.6) improved from fair to good quality and met the WWH biocriteria (Figure 60). The mean percent DELT anomalies have decreased from 4.8% in 1984 to 0.6% in 1991.

- Fish assemblages in the Cuyahoga River between the Ohio Edison dam and the confluence of the Little Cuyahoga River have also improved, but remain only fair quality. This segment currently supports the highest cumulative number of fish species in the Cuyahoga River mainstem and was closer to achieving good quality in 1991 than during 1988. Species that appeared to be increasing include northern pike, northern hog sucker, greenside darter, largemouth bass, and walleye. The mean percentage of DELT anomalies during 1991 (2.4%), however, was higher than between 1985 and 1988 and nearly equal to the 1984 level (3.0%). The discovery and correction of sewage contamination within the segment (*i.e.,* CSO and SSO discharges and leaking sewer lines) has been an on-going problem. High levels of fecal coliform bacteria were identified in and downstream from Babb Run during the 1991 survey. A leaking sanitary sewer line was responsible for the contamination and this was corrected by the city of Cuyahoga Falls during October 1991. Some additional recovery is expected to occur within the segment with reduced loads from Babb Run and the discontinued discharge from the Ohio Edison power plant.

- Mainstem fish communities downstream from the confluence of the Little Cuyahoga River have also improved (*e.g.,* the 1991 MIwb and IBI values were the highest since 1984), but continued to show impacts at RM 38.6 during 1991. Compared to the fish assemblage upstream from the Little Cuyahoga River, notable changes included marked reductions in the numbers of sport and sensitive species, and increased numbers of white suckers. Percent DELT anomalies have remained low (0.9%) and the total cumulative number of species increased from 14 in 1988 to 23 in 1991. The 1991 biological response patterns suggested enrichment impacts.

- The Cuyahoga River was virtually without fish during 1984 some 10 miles downstream from the Akron WWTP, but has subsequently shown significant improvements. The most recent improvements found during the 1991 survey include the occurrence of several pollution sensitive and intermediate species (redside dace, rainbow darter, fantail darter, and greenside darter), increased numbers of northern hog sucker and central stoneroller, and decreased numbers of the tolerant white sucker. Percent DELT anomalies remained elevated (1.8%), but decreased considerably since 1986 (14.1%).

- The mainstem from upstream of Ira Road (RM 37.2) to Boston (RM 26.7) has also shown considerable improvement since 1984, but the number and relative abundance of pollution sensitive species captured at RM 37.2 declined during 1991. White suckers increased and were numerically predominant at RM 35.3 during 1991, but decreased and were replaced by bluntnose minnow and spotfin shiner at Boston (RM 26.7). The 1991 percent DELT anomalies increased slightly since 1988 at Boston, but decreased from 1.9% at RM 35.3 to 0.6% at RM 26.7 and were significantly lower than 1984 through 1987.

- Downstream from Boston and the confluence of Tinkers Creek, fish assemblages from the Cuyahoga River at Independence (RM 15.9) and Cuyahoga Heights (RM 11.5) remained impaired, but improved since 1984. A gradual recovery trend downstream from Akron was still evident, suggesting the continuation of upstream impacts. Additonal sources in Tinkers Creek and the Cleveland suburbs may also be contributing to the subpar performance within this segment. The mean numbers of species and cumulative numbers of species at Independence and Cuyahoga Heights more than tripled since 1984. Seven pollution sensitive species (golden redhorse, black redhorse, shorthead redhorse, northern hog sucker, sand shiner, and greenside darter) were collected from this reach in 1991 for the first time by Ohio EPA. Small white bass and white perch were also collected at both locations during 1991 and suggest successful reproduction by Lake Erie run fishes.

- Improvements downstream from the NEORSD Southerly WWTP were less marked than immediately upstream from the discharge. Although the number of cumulative species has continued to increase, most values (MIwb, IBI, mean number of species, and relative number) were lower in 1991 than in 1988.

- Macroinvertebrate community performance between Lake Rockwell and the Akron WWTP has not undergone substantial change since 1984 (Figure 61; upper plot). ICIs from comparable stations during each survey have generally fallen in the fair to good ranges. Slight, gradual declines in most values were observed at successive sites downstream from Kent as the river passed a series of WWTP discharges, impounded habitats, and CSOs and SSOs in the Akron and Cuyahoga Falls area. Performance immediately upstream from the Little Cuyahoga River (RM 42.8) declined from the marginally good to fair range since 1984. During a 1987 survey (not plotted), this site was severely degraded by raw sewage from a malfunctioning CSO. The 1991 results do show some improvement downstream from the Little Cuyahoga River at RM 39.7. The ICI of 32 was within non-significant departure from the WWH criterion (i.e., marginally good). Four previous surveys since 1984 have shown consistently fair quality between the Little Cuyahoga River and Akron WWTP.

- Significant positive changes in macroinvertebrate performance has occurred downstream from the Akron WWTP since 1984 (Figure 61; upper plot). Long-term monitoring near Independence (RM 15.6/14.2) between 1976 and 1991 also showed significant improvement in the ICI in recent years. The trend is consistent with improved effluent quality and operations at the Akron WWTP, located approximately 22 miles upstream (Figure 62; upper plot). ICI scores at Independence were consistently in the poor or lower fair range from 1978 to 1980, but improved to the fair range in 1982 through 1984. Since 1986, scores have been within nonsignificant departure of the WWH ICI criterion and the highest quality communities (*i.e.*, ICI scores in the very good range) were observed in 1989 and 1991. The volume of bypassed wastewater at the Akron WWTP (Figure 62; lower plot) compared to ICI scores shows a strong inverse relationship with decreased pollutant loadings and increased community performance during the past decade.

- Similar monitoring at Ira Road at RM 35.3 (2.1 miles downstream from the Akron WWTP) has also shown an increasing trend, but not to the same degree as the Independence location (RM 15.6) (Figure 62; upper plot). Macroinvertebrates continued to reflect varying degrees of toxic impacts at Ira Road throughout most of the 1980s and did not reflect the more traditional non-toxic impacts until l991. The 1991 survey was also the first time the ICI met the WWH criterion this close to the Akron WWTP. Ohio EPA has frequently observed substantial recovery well downstream from pollution sources while communities in close proximity continued to reflect impairments (*e.g.*, the Scioto, Tuscarawas, Ottawa and Blanchard Rivers). This pattern has been especially common in areas historically affected by complex municipal/industrial type impacts such as those found in the middle Cuyahoga River. The continued lack of full attainment or only marginal attainment downstream from Akron suggests macroinvertebrate communities are still not performing to their full potential.

- In the Cleveland area, macroinvertebrate performance has also improved dramatically since 1984 (Figure 61; lower plot). At comparable locations downstream from the NEORSD

Southerly WWTP (RM 9.5-8.5) and Big Creek (RM 7.1) communities improved from the poor range in 1984 to the marginally good range in 1991. Better effluent quality from the Southerly WWTP and CSO/SSO remediation in the Cleveland area coupled with the improved conditions downstream from Akron are probably the major reasons for the positive trends in the mainstem. However, toxic response signatures observed downstream from the NEORSD plant in 1991 suggested possible chlorination impacts downstream from the discharge.

- Macroinvertebrates have also improved, to a lesser degree, in the estuary section of the mainstem between Big Creek and the navigation channel. The 1991 ICI of 26 at RM 5.8 exceeded the interim WWH criteria for Lake Erie River mouths; this represented an 8-12 point increase in the ICI since samples near the N&SS railroad bridge were first collected in 1987. Natural substrate communities in this section have not displayed a similar level of improvement. Oily sediments, particularly along the east side of the river, may be one reason for the lower quality communities found on the natural substrates.

- Since 1984, significant positive changes in both fish and macroinvertebrate community composition and response signatures have occurred downstream from Akron. Additional improvement was also documented between 1988 and 1991. The Area of Degradation Value (ADV) is a numerical value calculated for each biological index (IBI, MIwb and ICI) that quantifies the area an index falls below attainment criterion. Decreases in ADV scores are an indication of improving biological performance. Figure 63 shows the Total ADV trend between Akron and Cleveland and from the navigation channel since 1984. ADVs in the free-flowing sections from Akron to Cleveland show a nearly consistent declining trend, particularly for the ICI and MIwb. Substantial reductions were also noted in the ADVs that fell in the poor or very poor ranges of biological performance, particularly between Akron and Independence (*i.e.*, Akron to Hillside Road; RM 42.8-15.6).

  When the ADV is calculated per river mile, scores from 1984-88 between Akron and the Navigation Channel were reduced between 33.9% and 88.7% per index (Table 23; Figure 66, upper plot). Declines in ADVs and subsequent improvements were also noted between 1988 and 1991 when the ADV/mile exhibited additional decreases of 9.5% to 70.6%. The improved biological performance correlates to varying degrees with improvements in treatment at the Akron and Southerly WWTPs. These include reductions in bypasses, improvements in effluent quality, the apparent disappearance of acute effluent toxicity at Akron (based on bioassay testing), and on-going improvements in wastewater collection systems in the watershed.

Lower Cuyahoga River

- Fish assemblages within the Cuyahoga River navigation channel have made discernable improvements since 1984, but general community performance remains largely in the poor range. MIwb and IBI values consistently showed **very poor** performance in 1984 (Figure 64-65). Through 1991, both indexes showed a general increase with some values in the fair range and no values in the **very poor** range. The latter reflect a change from nearly 50% of navigation channel scores in the **very poor** range in 1988 and previous years.

- The incidence of DELT anomalies showed a dramatic decline between 1984 and 1987; values well in excess of 15-20% were found in 1984 compared to less than 10% in 1987. All samples in 1984 had some evidence of DELT anomalies. In 1988 and 1991, some samples had 0% DELT. Some additional decline in median values was observed through 1991 (Figure 65).

- Macroinvertebrates in the navigation channel has shown little improvement since samples were first collected by Ohio EPA in 1987 (Figure 58; lower plot).

- In contrast to the free-flowing portions of the mainstem, the navigation channel ADV statistics suggest minimal change since 1987, but significant improvements since 1984 (Table 23; Figure 65). Large portions of the navigation channel were devoid of fish in 1984. By 1987 the channel at least began to harbor a resident community, albeit of highly tolerant species. Some additional improvements were detected in 1988 and 1991 but fish communities have generally remained in a poor condition and have been consistently predominated by a half dozen very tolerant species. The much slower rate of recovery is particularly noticeable when compared to the more consistent declines in ADV scores observed elsewhere in the mainstem (Figure 66). Some additional improvements in biological and chemical water quality conditions would not be unexpected following additional reductions in pollutant loadings (*e.g.,* scheduled closure of the LTV coking oven #2, CSO/SSO remediatons). However, the existing channel morphology and concurrent low D.O. levels will likely severely limit any further improvements.

Cuyahoga River Tributaries

Little Cuyahoga River

- MIwb and IBI values at RM 11.0 and 2.2 (upstream from the Ohio Canal) increased slightly since 1986, but decreased slightly at RM 0.3. The improvement was greatest at RM 11.0 where the MIwb increased from the very poor range to the poor range (3.8 to 5.8) and at RM 2.2 where the MIwb increased from the poor to the fair range (4.8 to 5.9). The mean relative number of fish also increased at the sites by approximately 2-4X. Twenty (20) greenside darters and six northern hog suckers, two pollution sensitive species, were also collected at RM 2.2 in 1991 that were not found in 1986. A single hogsucker was also collected near the mouth at RM 0.3. In general, fish assemblages at RM 11.0 and RM 0.3 have retained a similar composition over the five-year period.

- Macroinvertebrate performance in the Little Cuyahoga River has also undergone little change since 1986. ICI values upstream from Akron were in the good range during both 1986 and 1991 (38 and 44, respectively at RM 11.0) and in the fair range downstream from Akron near the mouth (18 and 16, respectively). Artificial substrate samples were lost in 1991 at RM 3.8 but both the 1986 ICI value (12) and the 1991 narrative evaluation (based on qualitative data) was poor. While poor habitat quality may have had some influence on collections at RM 3.8, natural substrate samples from both surveys were similar and reflected degraded conditions.

- Biological communities reflected minimal improvement in the Little Cuyahoga River since 1986 and communities remained in **NON** attainment in 1991. Positive signs included the collection of northern hog suckers at RM 2.2 and 0.3 (one individual) and greenside darters upstream from the Ohio Canal at RM 2.2. These species had not been collected in these segments during previous surveys and may reflect a lessening of the more toxic conditions observed in 1986.

Tinkers Creek and Tributaries

- Since 1984, mean MIwb values have generally increased in the lower ten miles of Tinkers Creek primarily due to higher relative numbers of fish. In contrast, mean IBI values in 1991 were very similar to the 1984 values in the headwaters and the lower 8.5 miles of Tinkers Creek. However, scores were significantly lower in the middle section between RM 21.9 and RM 10.5 (Figure 64).

- Compositional changes between surveys reveal predominant species shifts from green sunfish, creek chub, and yellow bullhead in 1984 to bluntnose minnow, central stoneroller, spotfin shiner, and blacknose dace in 1991. Since 1984, the diversity of fish species in Tinkers Creek decreased moderately at RM 25.0, increased at RM 2.2, and remained similar at the remaining locations. Greenside darters were not collected in 1984, but were collected at RM 0.2 and 2.2 during 1991. Rainbow darters were collected in 1984 at RM 28.7, but not in 1991. Smallmouth bass were collected during both years, but in different reaches of Tinkers Creek. A young-of-the-year and one adult were collected at RM 25.0 and 25.4 during 1984; one large adult smallmouth bass was collected at RM 7.0 during 1991. The relative number of rock bass, which occur between RM 16.7 and 10.4, decreased slightly during 1991. Other species that are reinvading the adjacent Cuyahoga River mainstem are expected to move into Tinkers Creek as water quality improves.

- Macroinvertebrate communities have undergone significant improvement throughout most of Tinkers Creek since 1984 (Figure 65). The 1991 ICI values from the upper two-thirds of the mainstem (RM 28.8 to 10.3) were in the exceptional to marginally good ranges but in 1984 this same section was marginally good to poor. The largest improvement was found upstream from Pond Brook where the 1984 ICI increased from 20 at RM 24.5, to 54 in 1991 (RM 25.0). Improvement coincided with construction of the Streetsboro regional WWTP in 1985 and subsequent closure of the Hudson# 5 WWTP and several smaller plants in 1988.

- The lack of even a partial recovery in the fish community and outright decline in some reaches since 1984 is somewhat enigmatic compared to the improvement noted in the macroinvertebrate community and most chemical water quality parameters. One theory is that recovery in the middle and upper reaches has been prevented or at least deterred by several waterfalls on the mainstem that serve as permanent barriers to upstream migration and re-invasion to the degraded reaches. However, there are sufficient vestiges of a fish community present in these reaches to foster recovery to WWH levels of performance given sufficient time and environmental conditions. Evidently, recovery has been deterred by other factors such as nonpoint sources, spills, point sources, and other undocumented sources that continue to influence these segments. Future sampling should shed additional light on this situation. Meanwhile efforts should be directed at quantitatively documenting these other sources.

- The differences in macroinvertebrate and fish community trends since 1984 is reflected in the ADV statistics for Tinkers Creek. The ICI ADV dropped from 2,686 to 403 between surveys and reflected substantial improvement in the macroinvertebrates. In contrast, the IBI ADV actually increased from 3,000 to 4,300 indicating declining quality since 1984. Potential reasons for the declines are discussed in the above paragraph. The differences in responses do indicate the need for additional study in the basin.

Pond Brook

- IBI trends from two sites in Pond Brook show moderately improved fish assemblages since

1984. IBI values have increased from 12 to 22 at RM 3.6 and from 22 to 30 at RM 1.4. These changes have been due largely to reduced pollutant loadings from the closed Geauga Lake WWTP and suggest the stream performed near its biological potential given the habitat alterations.

- Macroinvertebrates ranged from a fair to poor condition during both the 1991 and 1984 sampling periods. Severe habitat limitations in the extensively channelized segments appeared to largely negate the influence of improved water quality conditions since 1984.

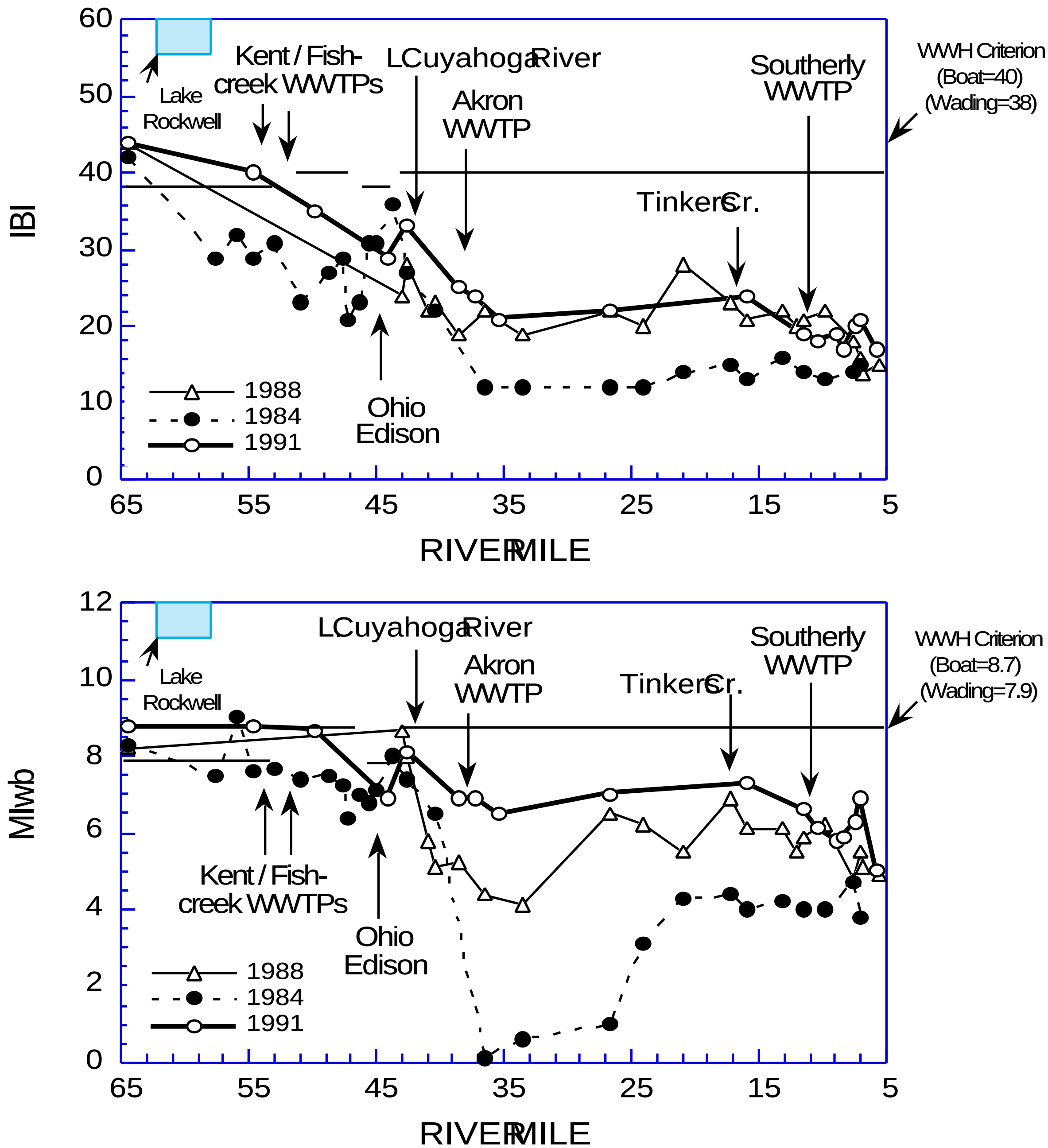
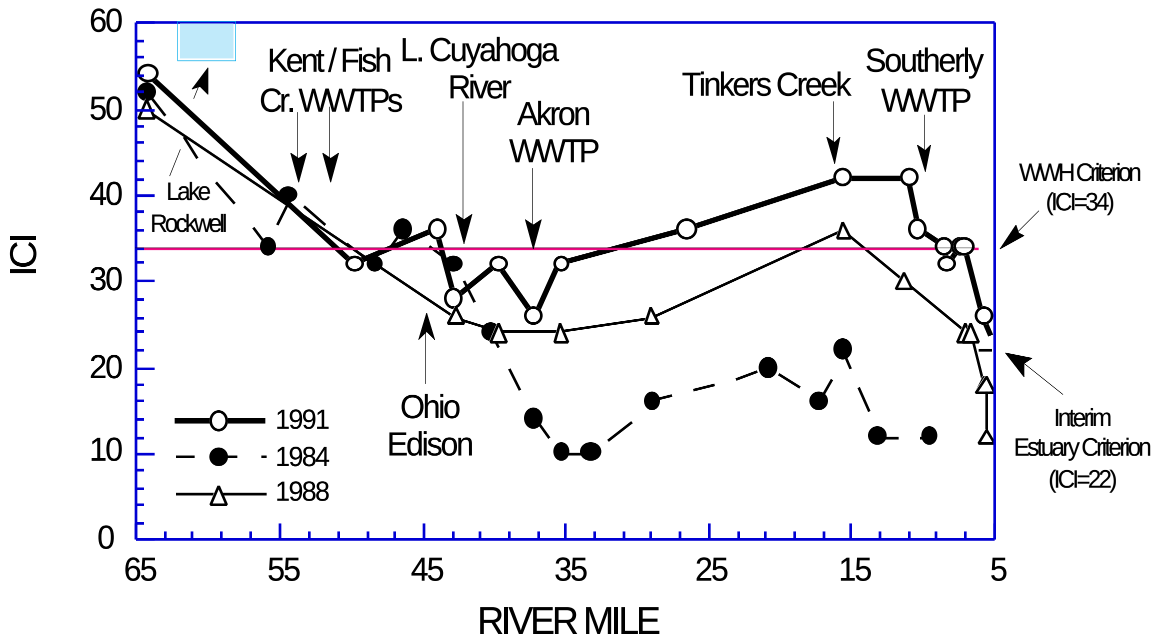


Figure 60. Longitudinal trend of the Index of Biotic Integrity (IBI) and the Modified Index of Well-Being (MIwb) in the middle Cuyahoga River during 1984, 1988, and 1991.



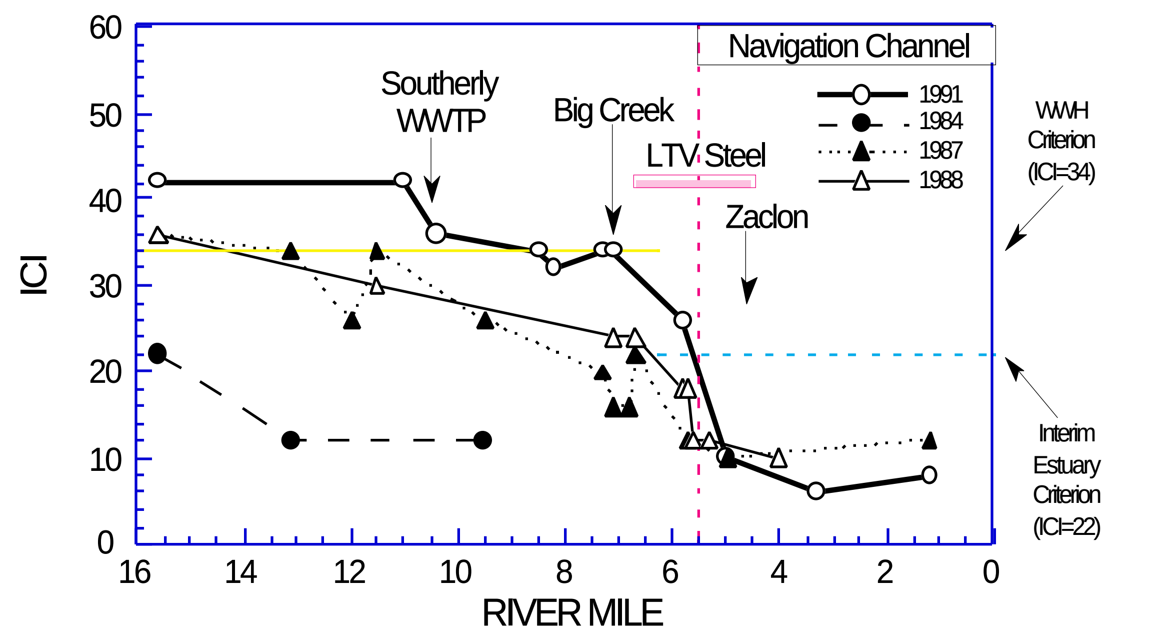


Figure 61. Longitudinal trends of the Invertebrate Community Index (ICI) in the middle and lower sections of the Cuyahoga River during 1984, 1987 (lower), 1988 and 1991.

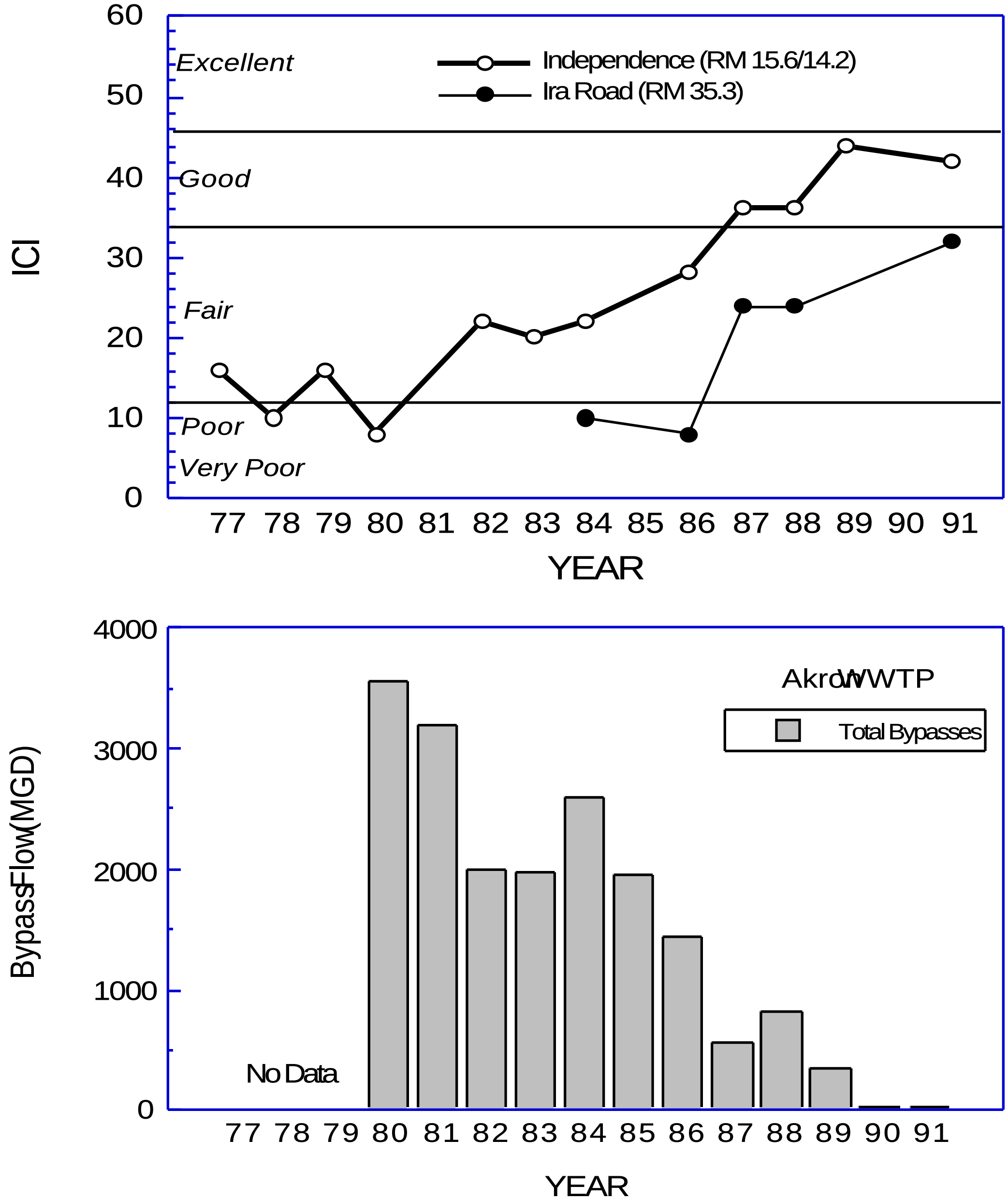


Figure 62. Historical trend of the Invertebrate Community Index (ICI) at Independence and Ira Road 1977-91 (upper plot), and histogram of total bypass flows from the Akron WWTP, 1980-91 (lower plot).

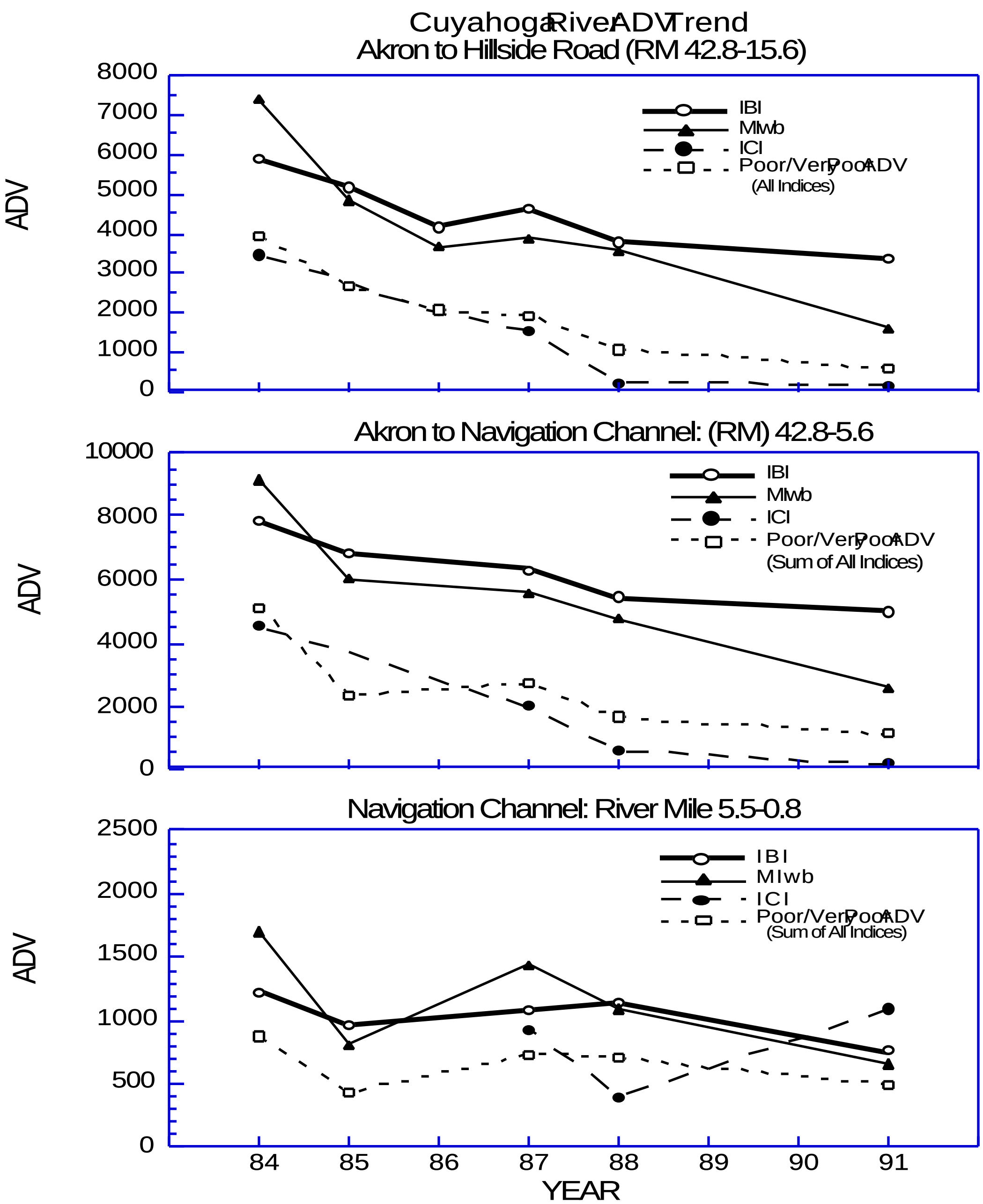


Figure 63. Area of Degradation Value (ADV) trend in three sections of the Cuyahoga River mainstem from RM 42.8 to 0.8, 1984 - 1991. Note: 1985 fish collections in the ship channel were limited to one sampling pass in October.

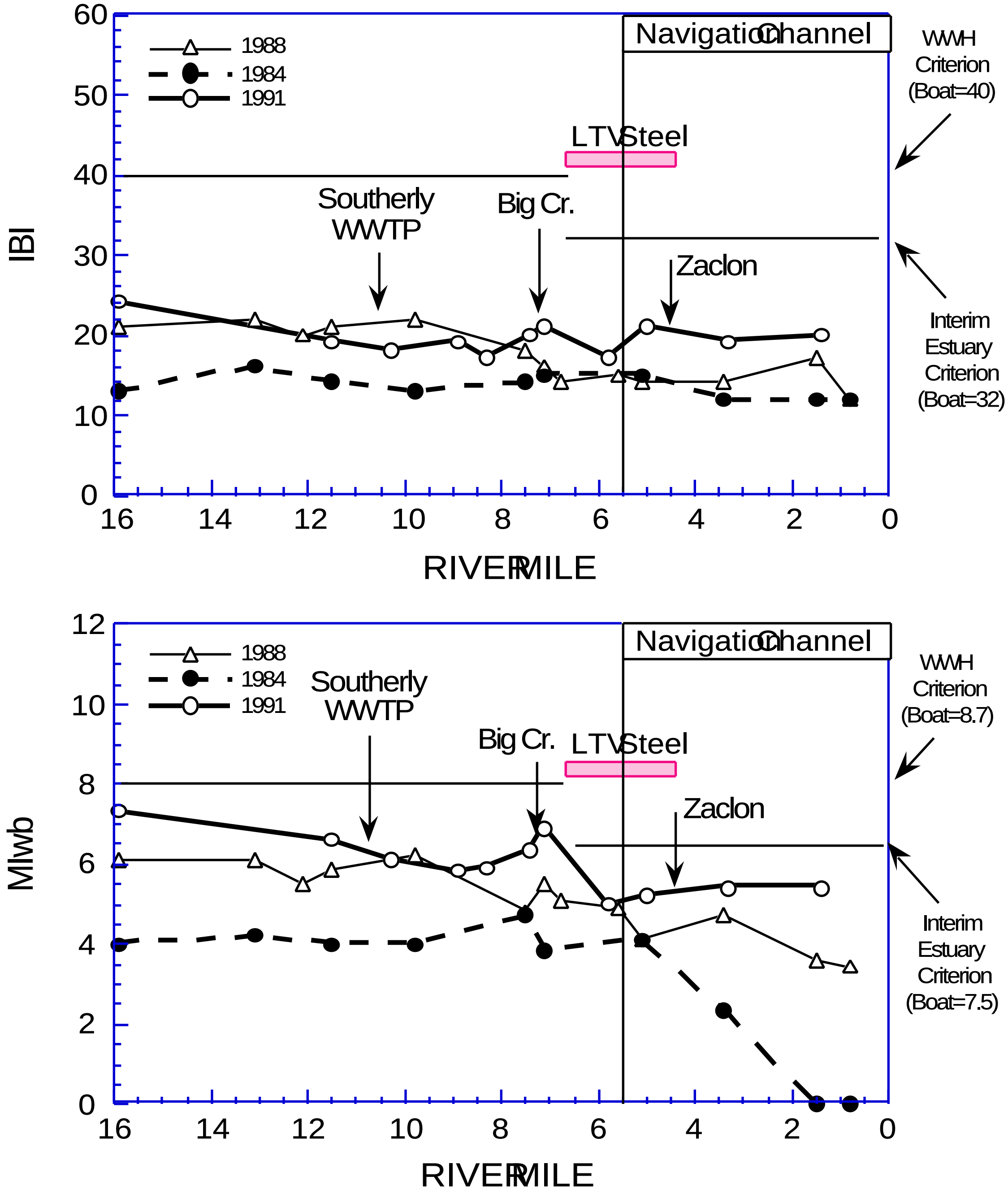


Figure 64. Longitudinal trend of the Index of Biotic Integrity (IBI) and the Modified Index of Well-Being (MIwb) in the lower Cuyahoga River during 1984, 1988, and 1991.

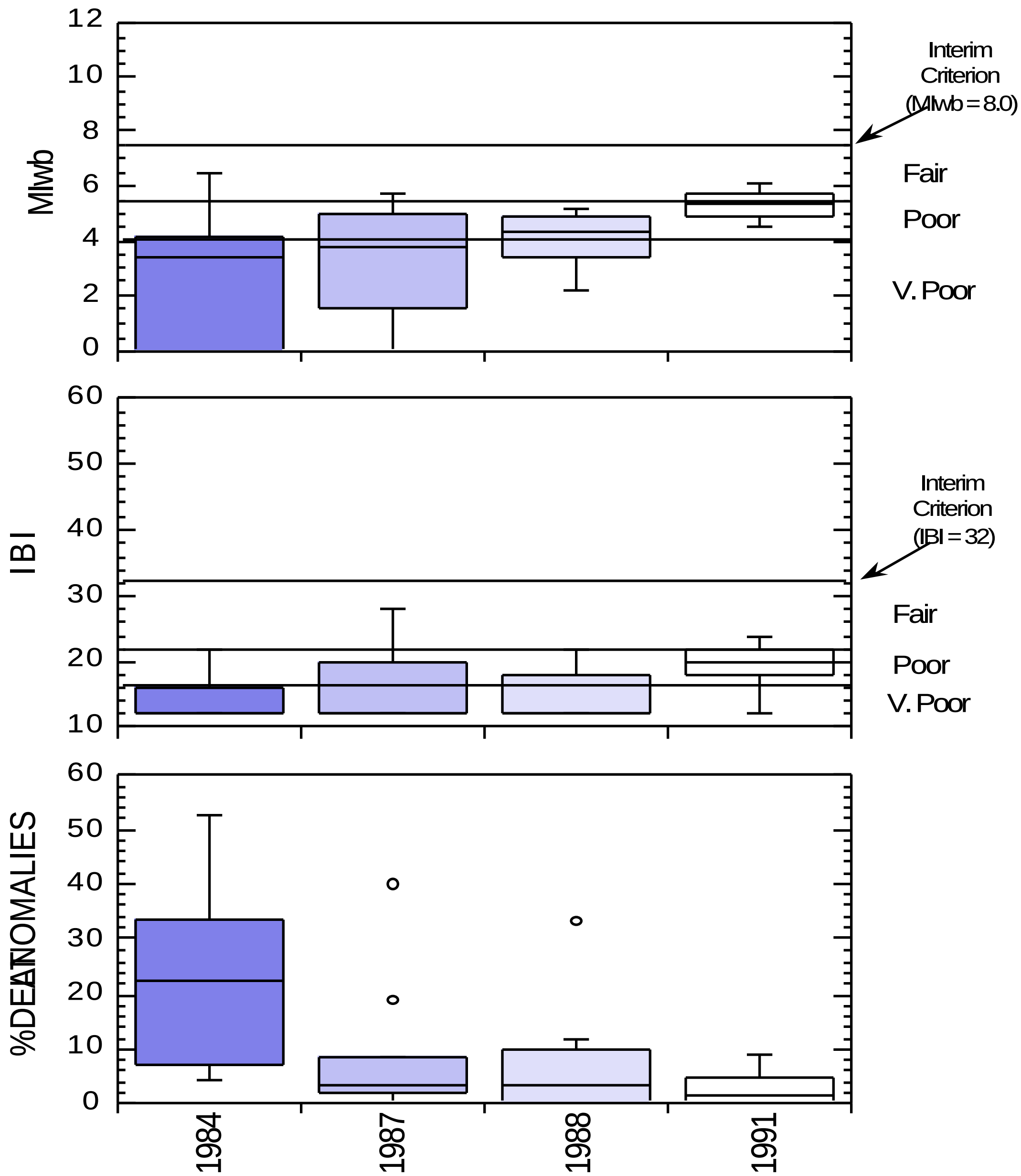


Figure 65. Box-and-whisker plots of the modified Index of Well-Being (MIwb; upper), the Index of Biotic Integrity (IBI; middle), and the %DELT anomalies (lower) at electrofishing sites in the Cuyahoga River navigation channel for the years 1984, 1987, 1988, and 1991.

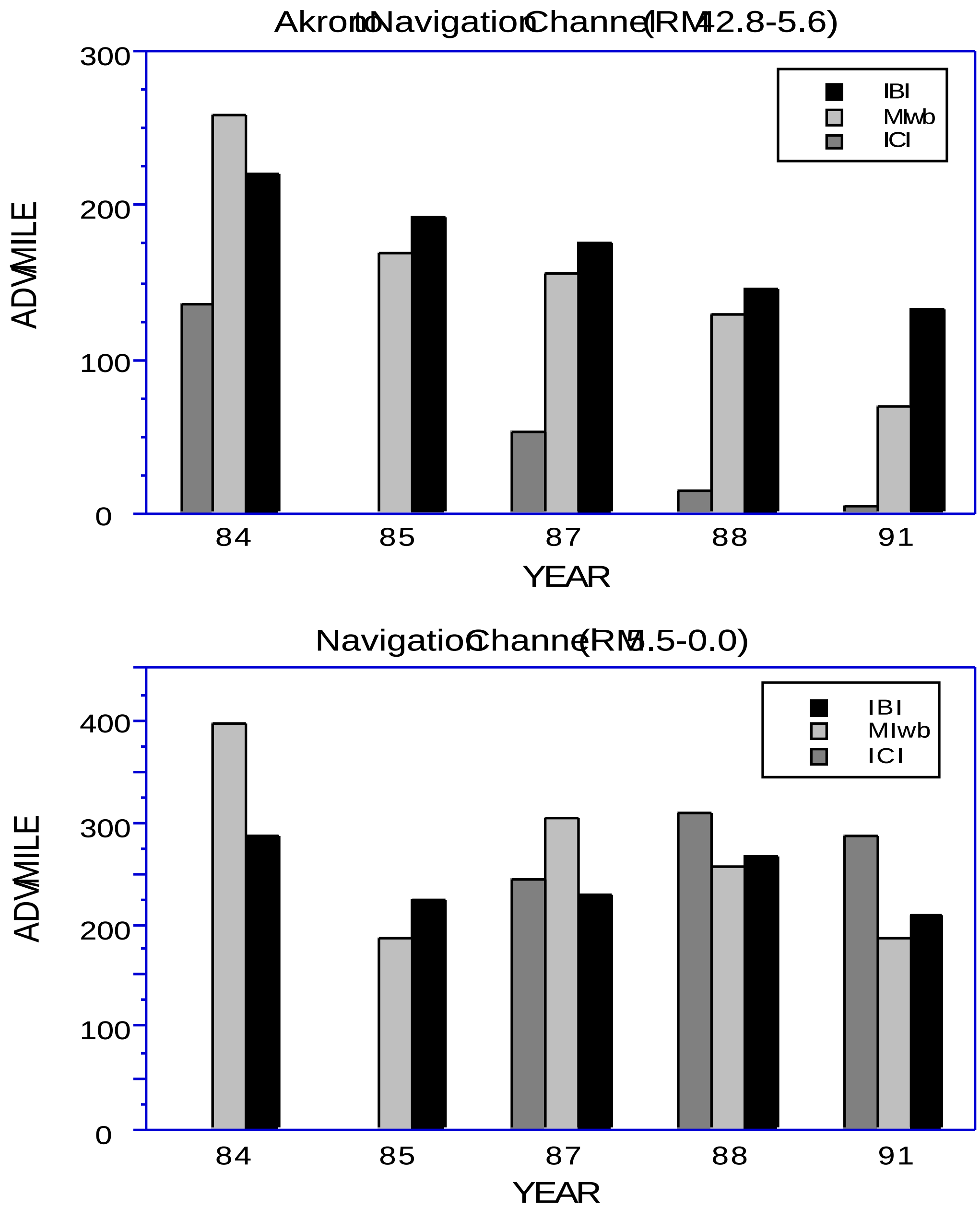


Figure 66. Area of Degradation (ADV) per mile trend for the Cuyahoga River between Akron and the Navigation Channel (upper plot) and the navigation channel (lower plot) RM 42.8 to 0.8, 1984 - 1991. Note: 1985 fish collections in the ship channel were limited to one sampling pass in October.

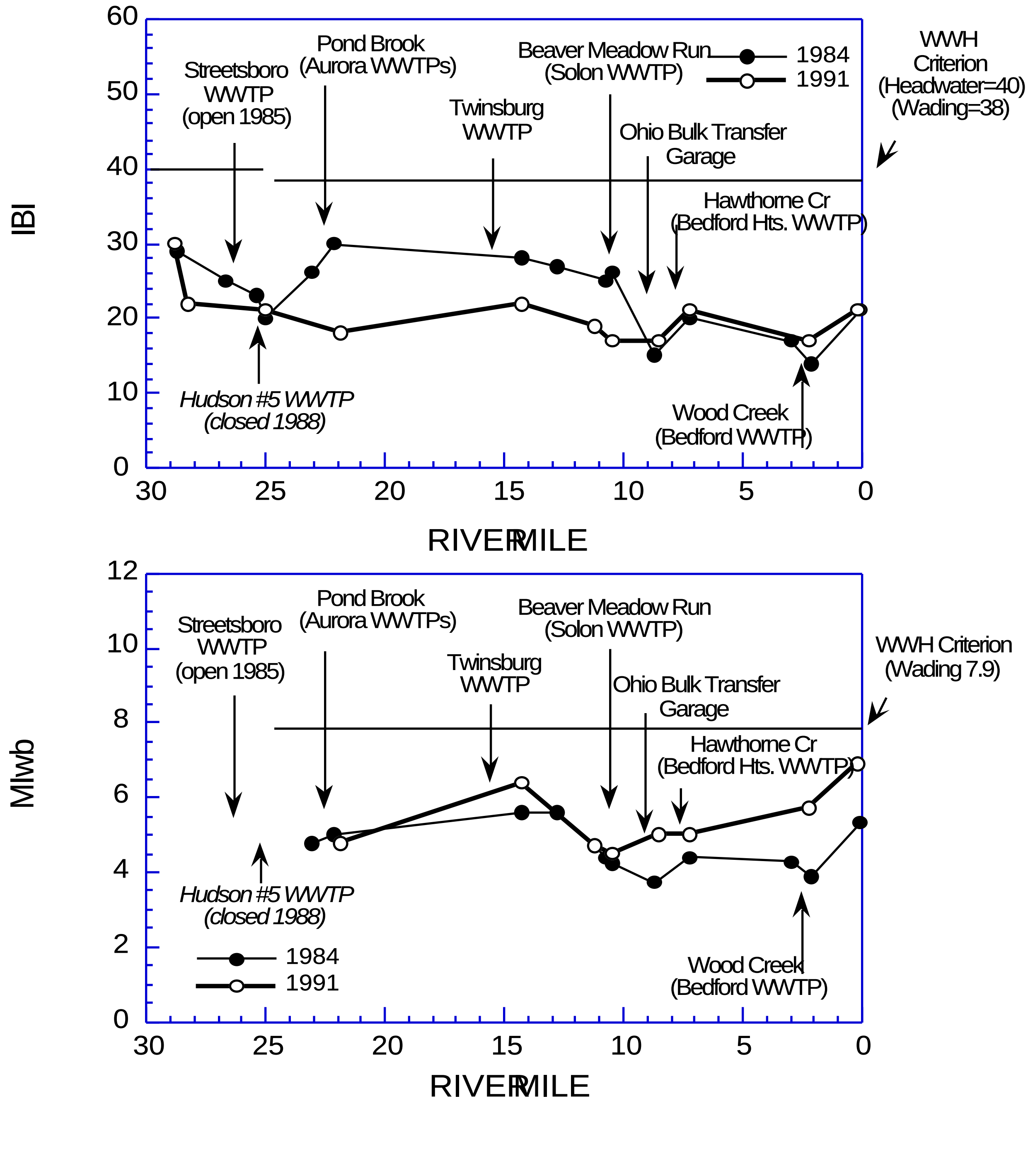


Figure 67. Longitudinal trend of the Index of Biotic Integrity (IBI) and the Modified Index of Well-Being (MIwb) in Tinkers Creek during 1984 and 1991.

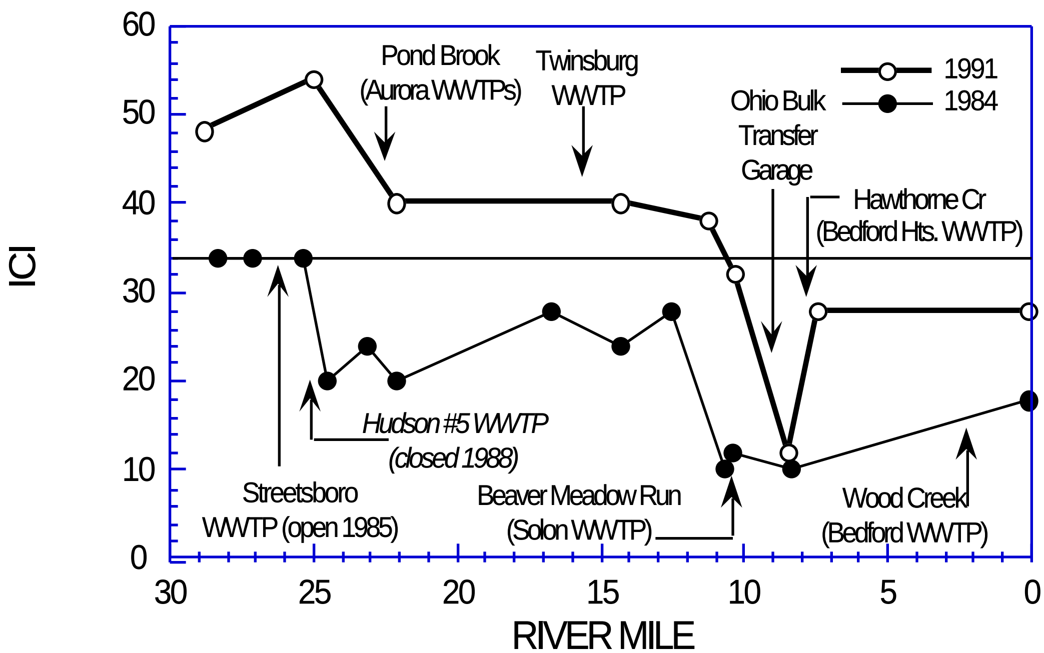


Figure 68. Longitudinal trend of the Invertebrate Community Index (ICI) in Tinkers Creek during 1984 and 1991.

Table 23. Area of Degradation (ADV) statistics for the Cuyahoga River mainstem study area, 1984-1991. Statistics were calculated using Erie/Ontario Lake Plain (EOLP) and interim Lake Erie river mouth ecoregional biocriteria for attainment of the warmwater habitat (WWH) aquatic life use designation as the background community performance.

	Biological Index Scores				ADV Statistics			Attainment Status (miles)			
Stream Index	Upper RM	Lower RM	Minimum	Maximum	**ADV**	ADV/ Mile	Poor/VP ADV	FULL	PARTIAL	**NON**	Poor/VP
Cuyahoga River- Ust. Lake Rockwell to Cuyahoga St. (RM 64.5-42.6)											
1984											
IBI			21	42	1224	55.9	54				
MIwb	64.5	42.6	6.4	9.0	550	25.1	0	1.7	10.5	9.8	4.7
ICI			8	52	52	2.4	803				
1991											
IBI			29	44	276	12.6	0				
MIwb	64.5	42.6	6.9	8.8	140	6.4	0	14.7	7.2	0.1	0.0
ICI			28	54	8	0.4	0				
Cuyahoga River- Cuyahoga St. to Hillside Road (RM 42.8-15.6)											
1984											
IBI			12	27	5890	193.7	2901				
MIwb	42.8	15.6	0.1	7.4	7355	275.5	978	0.0	0.9	26.4	26.4
ICI			10	32	3459	127.1	66				
1985											
IBI			15	30	5171	192.8	2203				
MIwb	42.6	15.9*	1.8	8.5	4810	180.1	445	0.0	0.6	26.7	26.2
ICI					NA						
1986											
IBI			16	26	4145	191.1	1686				
MIwb	42.8	15.6	3.5	7.4	3685	170.6	328	0.0	0.2	27.1	21.9
ICI			8	30	1990	73.2	48				
1987											
IBI			15	26	4638	173.7	1640				
MIwb	42.8	15.6	3.3	7.6	3875	145.1	145.1	0.0	0.0	27.3	27.1
ICI			12	36	1531	56.3	0				
1988											
IBI			19	28	3789	141.9	855				
MIwb	42.8	15.6	4.1	8.0	3530	132.2	213	0.0	0.0	27.3	23.6
ICI			26	36	219	8.1	0				
1991											
IBI			21	33	3365	126.0	570				
MIwb	42.8	15.6	6.5	8.1	1575	59	0	0.0	0.0	27.3	22.1
ICI			26	42	140	5.1	0				
Cuyahoga River- Cuyahoga St. to Navigation Channel (RM 42.8-5.6*)											
1984											
IBI			12	27	7848	221.1	3869				
MIwb	42.8	7.1	0.1	7.4	9185	258.7	1158	0.0	0.9	35.4	35.4
ICI			10	32	4527	135.9	66				

Table 22. (continued)

	Biological Index Scores				ADV Statistics			Attainment Status (miles)			
Stream Index	Upper RM .	Lower RM .	Mini-mum	Maxi-mum	**ADV**	ADV/ Mile .	Poor/VP ADV	FULL	PARTIAL	**NON**	Poor/VP
1985											
IBI			14	30	6845	192.8	2887				
MIwb	42.6	7.1	1.8	8.5	6035	170.0	521	0.0	0.6	35.7	35.2
ICI					NA						
1986*											
IBI			16	26	4145	137.3	1686				
MIwb	42.8	15.6	3.5	7.4	3685	122.0	328	0.0	0.2	27.6	21.9
ICI			8	30	2000	66.2	48				
1987											
IBI			15	26	6820	175.4	2259				
MIwb	42.8	5.7	3.2	7.6	5555	155.2	452	0.0	0.0	37.3	36.6
ICI			12	36	1955	52.7	0				
1988											
IBI			14	28	5408	146.2	1374				
MIwb	42.8	5.6	4.1	8.0	4780	129.2	262	0.0	0.0	37.3	36.6
ICI			12	36	570	15.3	0				
1991											
IBI			17	33	4985	132.3	1090				
MIwb	42.8	5.8	3.9	8.1	2550	68.9	26	0.0	0.0	37.3	32.1
ICI			26	42	168	4.5	0				
Cuyahoga River Navigation Channel (RM 5.5-0.8)											
1984											
IBI			12	15	1233	287	650				
MIwb	0.8	5.1	0.0	4.1	1700	395	235	0.0	0.0	5.3	5.3
ICI					NA						
1985											
IBI			12	22	962	224	379				
MIwb	0.8	5.1	3.9	6.5	805	187	58	0.0	0.0	5.3	5.3
ICI					NA						
1987											
IBI			14	18	1084	230	501				
MIwb	0.8	5.5	1.6	5.1	1435	303	186	0.0	0.0	5.3	5.3
ICI			10	12	931	245	49				
1988											
IBI			12	17	1145	266	562				
MIwb	0.8	5.3	3.4	4.7	1095	255	121	0.0	0.0	5.3	5.3
ICI			10	12	402	309	24				
1991											
IBI			19	21	756	210	239				
MIwb	1.2	5.0	5.2	5.4	670	186	47	0.0	0.0	4.9	4.9
ICI			6	10	1088	286	206				

***** The extent of the 1986 survey area (RM 42.8 - 15.6) was less than other surveys in this segment (RM 42.8 - 7.1/5.6 in 1984 and 1987 - 1991). This likely resulted in comparatively lower total ADV statistics for 1986.

REFERENCES

Antilla, P.W. and R.L. Tobin. 1978. Fluvial sediment in Ohio. Geol. Surv. Water Supply Pap. 2045. U.S. Govt. Printing Offc., Washington, D.C. 58 pp.

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. Battelle Press, Columbus, Ohio. pp. 93-102

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. Transactions of the American Fisheries Society, Vol.116: 79-86.

Baumann, P. C., M.J. Mac and J.C. Harshberger. 1991. Tumor Frequencies in Walleye and Brown Bullhead and Sediment Contaminants in Tributaries to the Laurentian Great Lakes. Personal Communication, Unpublished Manuscript. U.S. Fish and Wildlife Service, Columbus, Ohio. 27 pp.

Brown, Paula S. 1988. Analysis of unimpacted stream data for the state of Ohio. Division of Water Quality Monitoring and Assessment, Water Quality Modeling Section. Columbus, Ohio. 75 pp.

Burgess and Niple, 1980. Facilities Plan for the City of Akron. Appendix F.

Cuyahoga River Community Planning Organization, June 1992. Cuyahoga River Remedial Action Plan Stage One Report, Appendix C: Toxics Consumption Reports. Cleveland, Ohio. Unpublished.

DeGraeve, G.M., D.O. McIntyre, D.J. McCauley, W.H. Clement, M.A. Lewis, and N.G. Reichenbach. Final report on a field and laboratory site-specific evaluation of cadmium, copper and zinc for the Cuyahoga River in the vicinity of the Northeast Ohio Sewer District's Southerly effluent discharge. Battelle Columbus Division. 26 pp.

Estenik, John F., 1988. Fish Tissue Organic Chemical Evaluation, Cuyahoga River. Ohio EPA Water Quality Monitoring and Assessment. Columbus, Ohio. Unpublished. 15 pp.

Fabacher, D.L., C.J. Schmitt, J.M. Besser, and M.J. Mac. 1988. Chemical Characterization and Mutagenic Properties Polycyclic Aromatic Compounds in Sediment from Tributaries of the Great Lakes. Environ. Toxicol. Chem. 7:529-543.

Farr, Leonard J., 1988. PCB's in Lake Erie Fish. Personal Communication. U.S. Food and Drug Administration. Cincinnati, Ohio. 3 pp.

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

Foran, Jeffery A. and David Vanderploeg. 1989. Consumption Advisories for Sport Fish in The Great Lakes Basin: Jurisdictional Inconsistencies. Journal Great Lakes Research. 15(3): 476-485.

Great Lakes Sport Fish Advisory Task Force. September 1993. Protocol for a uniform Great Lakes sport fish consumption advisory. Model advisory. Unpublished.

Gallant, A.L., T.R. Whittier, D.P. Larsen, J.M. Omernik, and R.M. Hughes. 1989. Regionalization as a tool for managing environmental resources. EPA/600/3-89/060. 152 pp.

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.
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. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Env. Mgmt. 5(1): 55-68.
Karr, J.R., K.D. Fausch, P.L. Angermier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Ill. Nat. Hist. Surv. Spec. Publ. 5. 28 pp.
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.
Long, E.B. 1992. Transport of water, phosphorus and sediment in the upper Cuyahoga watershed. Volume 92, No. 2. April Program Abstracts. The Ohio Journal of Science.
Matisoff, G., C.J. Khourey, J.F. Hall, A.W. Varnes, and W.H. Strain. The nature and source of arsenic in northeastern Ohio ground water. Vol. 20, No. 4. Ground Water. July-August, 1982.
Ohio Department of Natural Resources. 1985. Principal streams and their drainage area. Division of Water. Ohio Department of Natural Resources. Columbus, Ohio.
___ 1960. Gazetteer of Ohio streams. Ohio Dept. Natural Resources, Division of Water, Ohio Water Plan Inventory Report No. 12.
___ 1989a. Ohio EPA manual of surveillance methods and quality assurance practices, updated edition. Division of Environmental Services, Columbus, Ohio.
Ohio Environmental Protection Agency. 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.
___ 1989a. Addendum to biological criteria for the protection of aquatic life: Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.
___ 1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Planning and Assessment, Columbus, Ohio.
___ 1989c. Ohio EPA policy for implementing chemical specific water quality based effluent limits and whole effluent toxicity controls in NPDES permits. Divisions of Water Pollution Control and Water Quality Planning and Assessment, Columbus, Ohio.
___ 1989d. Fish Tissue Analytical Data. Unpublished. Ohio EPA, Twinsburg, Ohio. 140 pp.
___ 1990. Ohio water resource inventory - 1990 305b report. Volume II. Edward T. Rankin, editor. Division of Water Quality Planning and Assessment, Surface Water Section,

Columbus, Ohio.
___ 1991. Calculation and uses of the Area of Degradation Value (ADV). Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.
___ 1992. Ohio water resource inventory- 1992 305b report. Edward T Rankin, editor. Division of Surface Water. Draft in Progess.
___ 1993. Cuyahoga River ship channel water quality modeling analysis. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.
Omernik, J. M. 1988. Ecoregions of the conterminous United States. Ann. Assoc. Amer. Geogr. 77(1): 118-125.
___ and A.L. Gallant. 1988. Ecoregions of the upper midwest states. EPA/600/3-88/037. U. S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon. 56 pp.
Orr et al. 1980 (Unpublished Report for the Cuyahoga Valley National Recreation Area: A Survey of the Rare and Endsangered Amphibians and Reptiles of the Cuyahoga River Tributaries in the CVNRA).
Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning and Assessment, Columbus, Ohio.
Schmitt, Christopher J., Jim L. Zajicek and Michael A. Ribick. 1985. National Pesticide Monitoring Program: Residues of Organochlorine Chemicals in Freshwater Fish, 1980-1981. Archives of Environmental Contamination and Toxicology. 14: 225-260.
Simpson, K.W. 1980. Abnormalities in tracheal gills of aquatic insects collected from streams receiving chlorinated or crude oil wastes. Freshwater biology 10:581-583.
Stalling, David L. and Christopher J. Schmitt. 190. Adducted Deoxyribonucleosides in DNA from Blood and Liver of Brown Bullheads (Ictalurus nebulosus) from Lake Erie at Cleveland, Ohio. Currently in Press. U.S. Fish and Wildlife Service. 29 pp.
Studen, Greg *et. al.* Cuyahoga River Remedial Action Plan Stage One Report Commitee Review Draft, Appendix C., November 1991
Trautman, M. B. 1981 The fishes of Ohio with illustrated keys. Ohio State Univ. Press, Columbus. 782 p
Tuckerman, Steve. 1989. Cuyahoga RAP Fish Tissue Collection Protocols. Unpublished. Ohio EPA. Twinsburg, Ohio. 19 pp.
United States. EPA. 1987. Biomonitoring to achieve control of toxic effluents. U.S. EPA Office of Research and Development, Duluth, MN. EPA/625/8-87/013.
___ 1989. Assessing Human Health Risks From Chemically Contaminated Fish and Shellfish: A Guidance Manual. U.S. EPA Office of Water Regulations and Standards, Washington, D.C.. EPA-503/8-89-002. 136 pp.
___ 1989. Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A). U.S. EPA Office of Emergency and Remedial Response, Washington, D.C.. EPA/540/1-89/002. 136 pp.
___ 1990. Ohio EPA's use of biological survey information. Water Quality Program Highlights. Assessment and Watershed Protection Division. 4 pp.
U.S. Army Corps of Engineers. 1981. Third interim preliminary feasibility report on erosion and sedimentation. Volume 1, Main Report. Buffalo District.
U.S. Department of the Interior-Geological Survey. 1981. Low flow characteristics of Ohio streams. Open-File Report 81-1195.
___ 1990. Water resources data for Ohio. Volume 2. St. Lawerence Basin. Water-Data Report

OH-090-2.

___ 1991. Water resources data for Ohio. Volume 2. St. Lawerence Basin. Water-Data Report OH-091-2.

___ 1993. Water resources data for Ohio. Volume 2. St. Lawerence Basin. Water-Data Report OH-093-2.

Warwick, W.F., J. Fitchko, P.M. McKee, D.R. Hart, and A.J. Burt. 1987. The incidence of deformities in *Chironomus* spp. from Por Hope Harbour, Lake Ontario. J. Great Lakes Res. 13 (1): 88-92. International Assoc. for Great Lakes Research.

Warwick, W.F. 1988. Morphological deformities in Chironomidae (Diptera) larvae as biological indicators of toxic stress. Offprints from: Toxic Contaminants and Ecosystem Health; a Great Lakes Focus. Marlene S. Evans, editor. John Wiley and Sons Inc.

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

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

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