File Copy

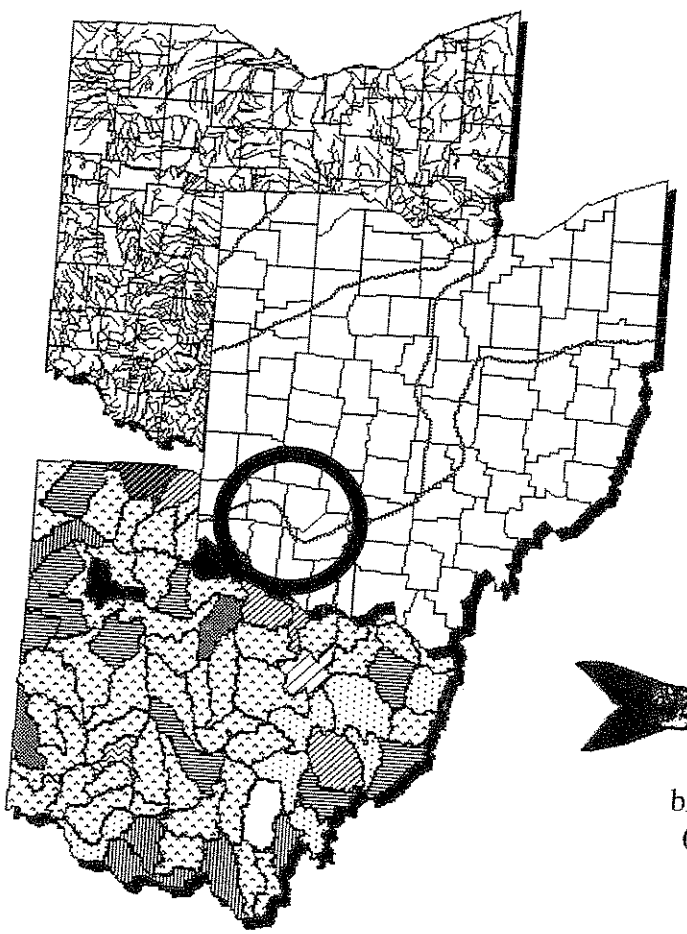
State of Ohio
Environmental Protection Agency

Ecological Assessment Unit
Monitoring and Assessment Section
Division of Surface Water

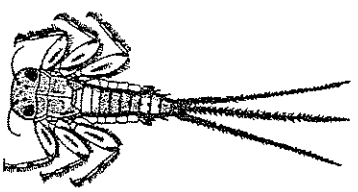
Biological and Water Quality Study of the Little Miami River and Selected Tributaries

Clark, Greene, Montgomery, Warren, Clermont, and Hamilton Counties (Ohio)

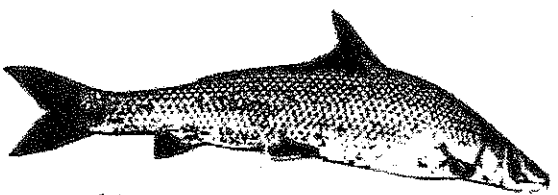
Volume 1



zebra mussel *(Dreissena polymorpha)*
(exotic introduced species)



mayfly nymph *(Stenonema sp.)*



blue sucker *(Cycleptus elongatus)*
(native Ohio Endangered species)

P.O. Box 1049, 1800 WaterMark Dr., Columbus, Ohio 43216-1049

Biological and Water Quality Study of the Little Miami River and Selected Tributaries

Clark, Greene, Montgomery, Warren,
Clermont, and Hamilton Counties (Ohio)

OEPA Technical Report MAS/1994-12-11

Volume I

State of Ohio Environmental Protection Agency
Division of Surface Water
Monitoring and Assessment Section
1685 Westbelt Drive
Columbus, Ohio 43228-3809
and
Nonpoint Source Program
1800 WaterMark Drive
Columbus, Ohio 43266-0149
and
Southwest District Office
401 East Fifth Street
Dayton, Ohio 45402-2911

TABLE OF CONTENTS

Volume I:

List of Tables

Volume II: Appendices

NOTICE TO USERS

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

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

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. 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. 1989b. 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. 1989c. 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. 1990. 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 report can be obtained by writing to:

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

ACKNOWLEDGEMENTS

The following persons are acknowledged for their significant contributions to this report.

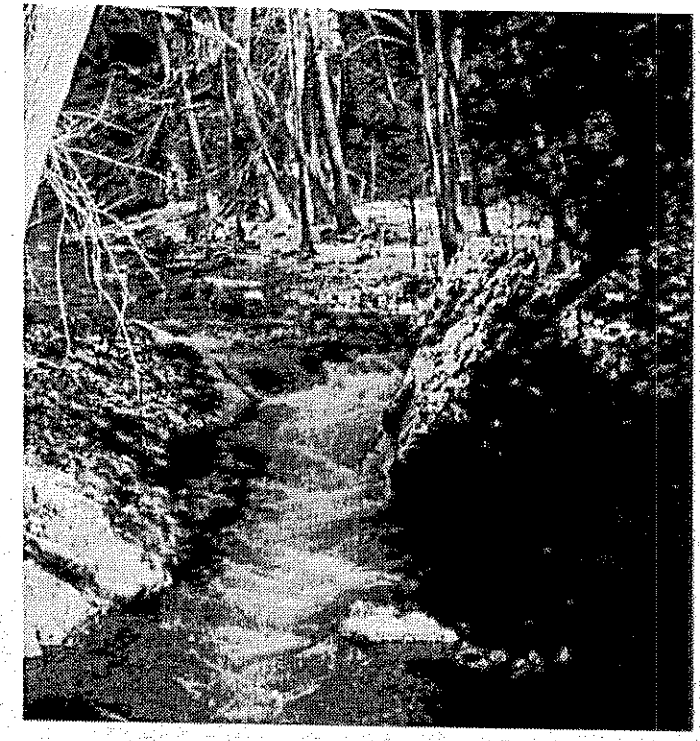
Report Coordinator, Plates, Introduction, and Summary - Randall E. Sanders
Study Area - Hugh Trimble
Pollutant Loadings - MaryAnne Mahr, Greg Buthker, and Diana Zimmerman
Sediment Quality - MaryAnne Mahr
Water Chemistry and Chemical Trend Assessment - Louise Snyder
Physical Habitat - Randall E. Sanders
Macroinvertebrate Assemblages - Mike Bolton
Fish Assemblages - Randall E. Sanders
Programming and Data Management - Charlie Staudt, Edward T. Rankin, and Dennis Mishne
Reviewers - Chris O. Yoder, Marc A. Smith, Jeff DeShon, Bruce Smith, Ron Ware, Mike Zimmerman

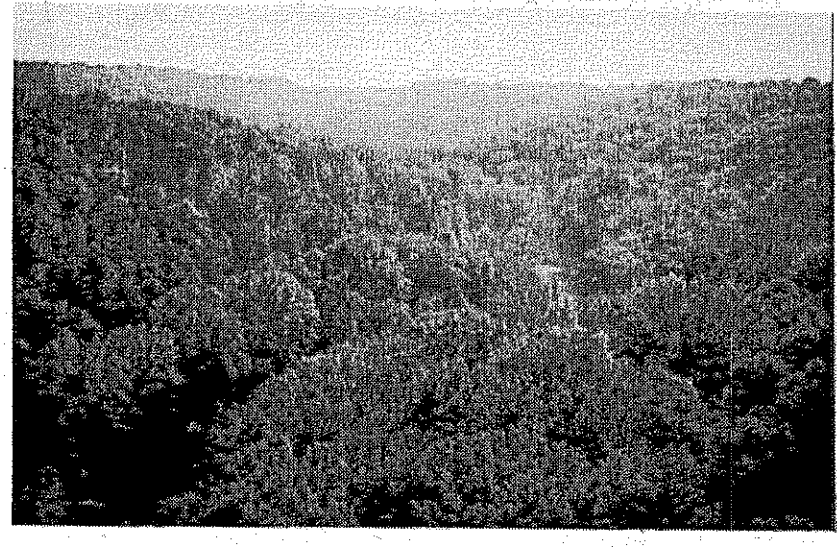
This evaluation and report would not have been possible without the assistance of the study team and numerous full and part time staff in the field and offices. The chemistry analyses (laboratory) were conducted by the Ohio EPA, Division of Environmental Services. Datasonde results were provided by the Water Quality Modeling Unit. The Ohio EPA also thanks and acknowledges the following property owners who permitted access to the sampling locations throughout the study area: D. Halder, Greene County Parks, the Beavercreek and Sugarcreek WWTPs, the City of Beavercreek, Montgomery County Eastern Regional WWTP, Xenia Glady Run WWTP and Xenia Water Department, the City of Waynesville, the City of Loveland, Hamilton Co. Parks, the City of Milford, the City of Indian Hill, Little Miami Incorporated, the Clermont Co. Fish and Game Club, and Shelter Cove Marina.

The following individuals are acknowledged for providing photos that appear in the color plates:

John Kopec and Stu Lewis - Ohio Department of Natural Resources, Division of Natural Areas and Preserves (Plate 1. Top Photos; Plate 2. Top and Bottom Right Photos; Plate 4. Top Left Photo; and Plate 12. Top Right Photo).
Dave Ross - Ohio Department of Natural Resources, Division of Wildlife (Plate 7. Bottom Left; and Plate 9. Top Left Photo).
Dr. Michael Hoggarth - Otterbein College (Plate 7. Bottom Right Photo).

All other photos were provided by Ohio EPA, Division of Surface Water staff.





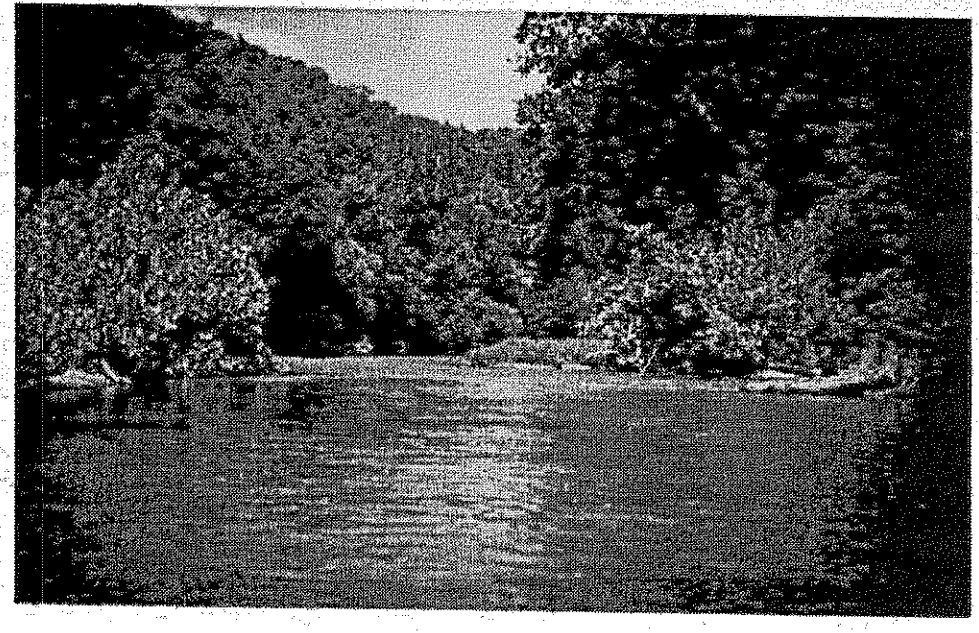


PLATE 1. WATER RESOURCE: Draining 1,757 square miles of glaciated southwest Ohio, the Little Miami River mainstem is the state's fourth largest Ohio River tributary. The river maintains a relatively steep gradient throughout it's 105.5 mile length and flows through several steep-sloped, forested gorges. The Little Miami River was the state's first designated national and state scenic river and contains some of Ohio's most beautiful and diverse riverine habitats. Two of the most scenic sections are located in the Clifton Gorge ***(Top Photos)*** and Fort Ancient ***(Bottom Photos)*** segments. The mainstem is the longest stream in Ohio designated Exceptional Warmwater Habitat.

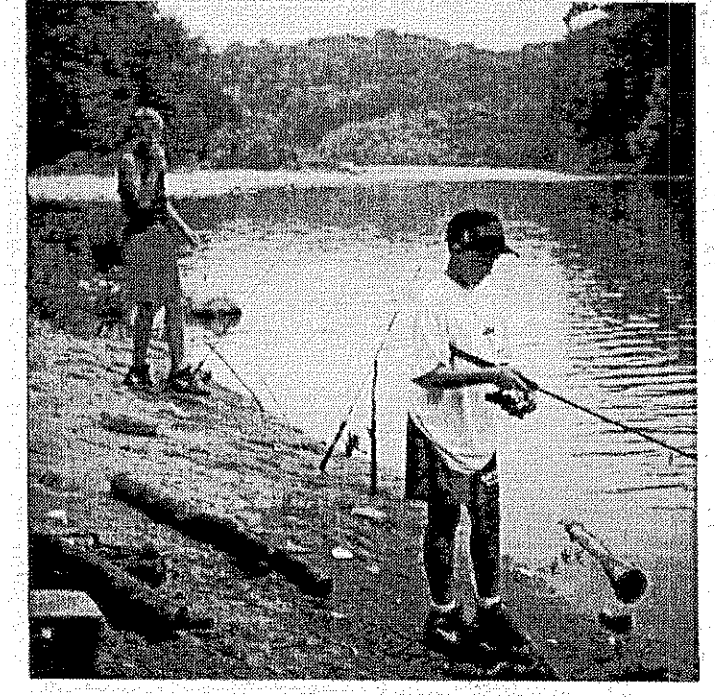
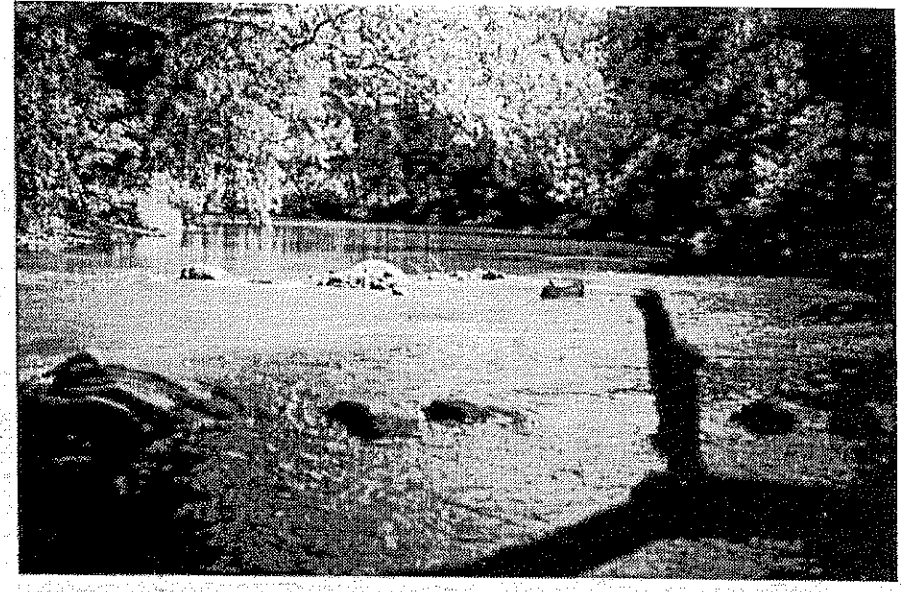
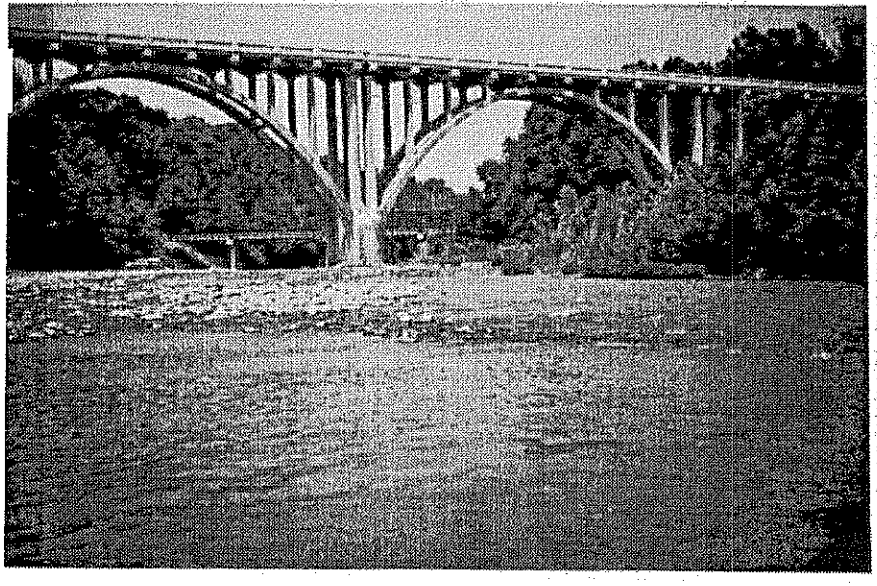


PLATE 2. RECREATIONAL USE: With seven canoe liveries located on the mainstem, the Little Miami River is one of Ohio's most popular canoeing streams ***(Top Left)***. The mainstem and large tributaries also support other recreational uses such as wading and swimming ***(Top Right)*** and sport fishing ***(Bottom Left)***. The floodplain contains a number of State, County, and City parks ***(Bottom Right)*** which provide public access to the mainstem.





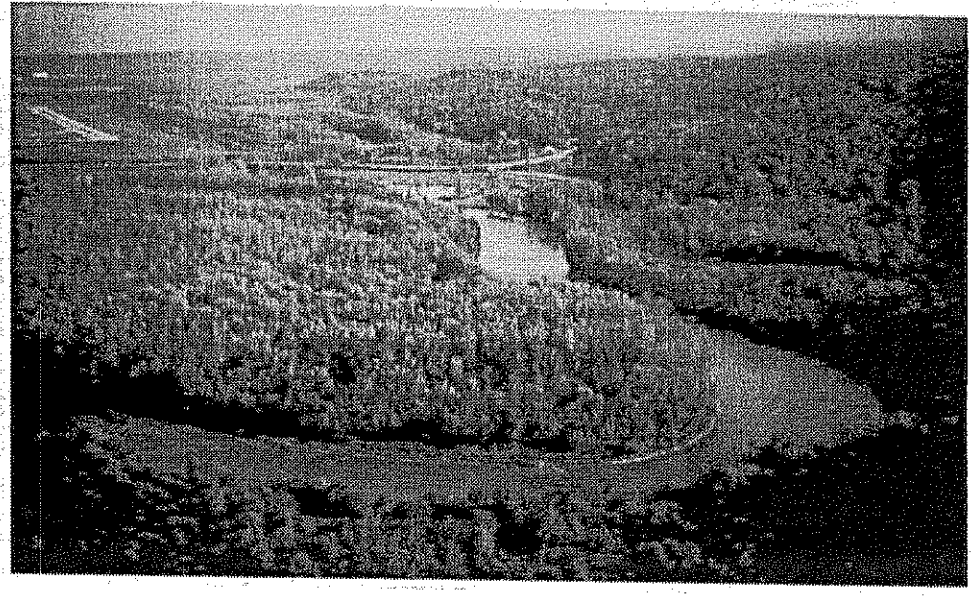


PLATE 3. MAINSTEM PHYSICAL HABITATS: Between South Charleston ***(Top Left)*** and Cincinnati ***(Bottom Right)***, the Little Miami River changes from a small, shallow headwater stream to a deeper large river. The quality of the stream habitat has been adversely impacted by agricultural practices within the headwaters, but improves downstream from Clifton and remains of good to exceptional quality to Cincinnati (RM 3.0). ***Top Right:*** View of the mainstem at Jacoby Road Reserve near Goes (RM 83.1) showing a well-defined riffle-run complex, pool, and streamside forests. ***Bottom Left:*** Mainstem view at Foster showing large river attributes comprised of extensive riffle-run complexes with limestone bedrock fragments and large pools. ***Bottom Right:*** Aerial view of the Little Miami River just upstream from its confluence with the Ohio River. The quality of habitat here has been markedly altered by impoundment from the Markland Dam on the Ohio River. This report recommends that the aquatic life use designation for this section of the river be changed to Warmwater Habitat (WWH) from the existing Exceptional Warmwater Habitat (EWH) designation because of the impounding effect of the Ohio River.



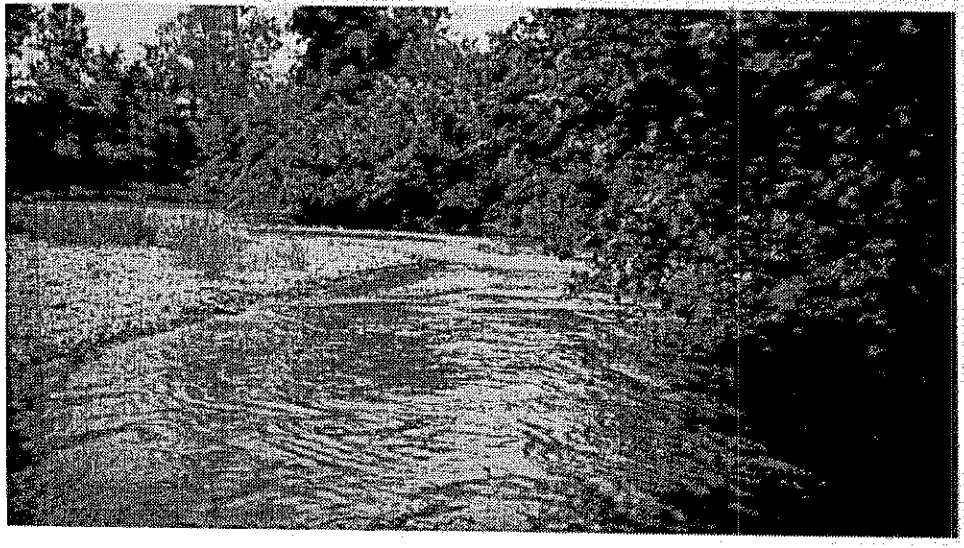
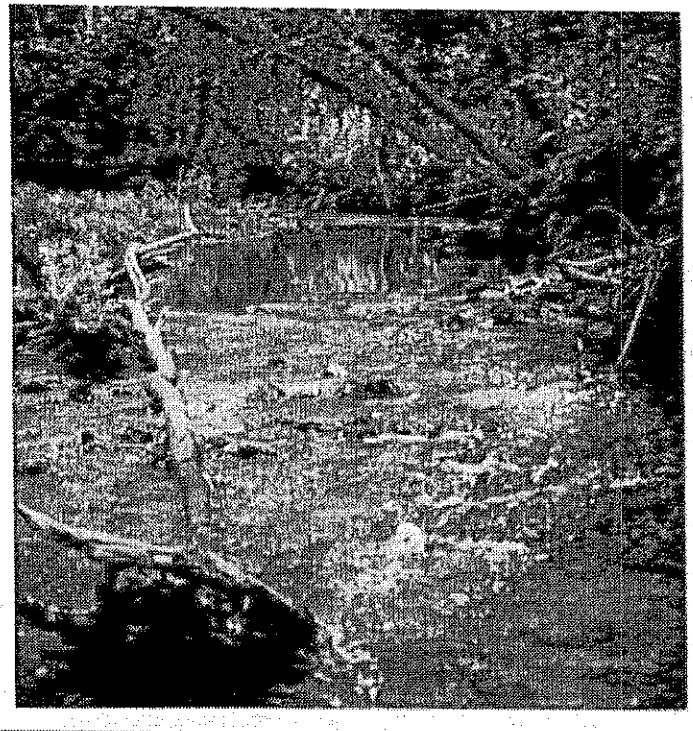
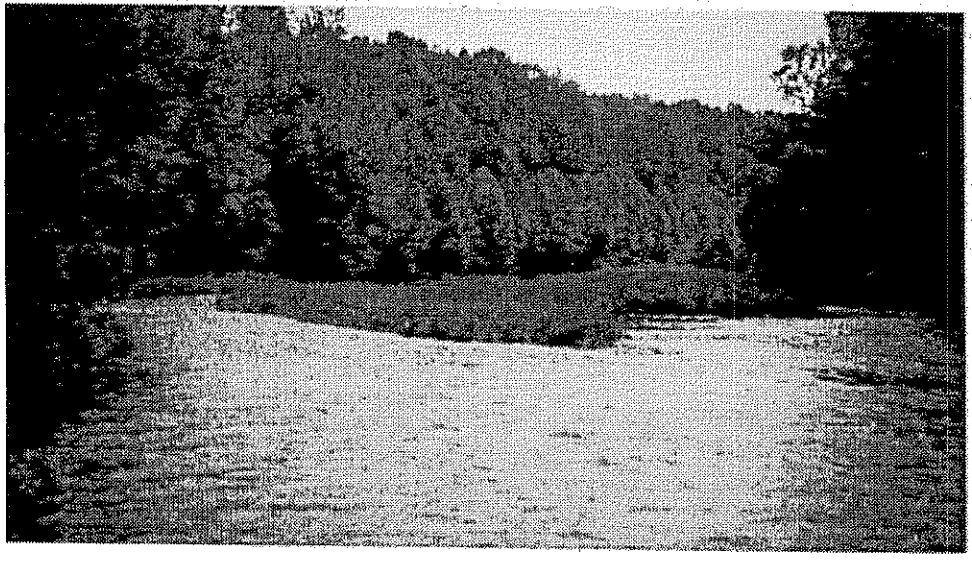



PLATE 4. EXCEPTIONAL WARMWATER HABITAT (EWH): Physical attributes indicative of an EWH stream in Ohio include: a predominantly rural watershed; natural and meandering stream channel; good quality streamside forests; clear water and silt-free substrates comprised of sand, gravel, cobble, and boulder size rocks; constricted low flow channels with vegetated islands and high flow channels; and pollution sensitive aquatic vegetation. ***Top Left:*** Aerial view (1982) of the meandering Little Miami River in Greene County near Trebein. Streamside forests protect and enhance water resources by providing shade, instream cover, and stable banks which result in narrower deeper channels, stable substrates, and clearer water. This view also shows encroachment by agricultural land uses resulting in severely eroding banks which further threaten EWH attainment by contributing excessive sediment loads which result in shifting substrates, increased levels of suspended solids, and wide shallow low flow channels with embedded substrates. Through time, property owners typically lose more acres than are initially gained by streambank encroachment. Bank stabilization techniques should be implemented to prevent further erosion coupled with land use set backs to prevent future problems. ***Top Right:*** Clear water and silt-free substrates in the Little Miami River near Trebein during 1993. ***Bottom Left:*** View of a deep, swift, narrow chute adjacent to a vegetated island located downstream from the Hamilton County MSD Polk Run WWTP. Small islands are common in high quality streams and increase the diversity of physical habitats. ***Bottom Right:*** Dense patches of water willow and lizard's tail, two pollution sensitive aquatic plants common within the Little Miami River stream channel.





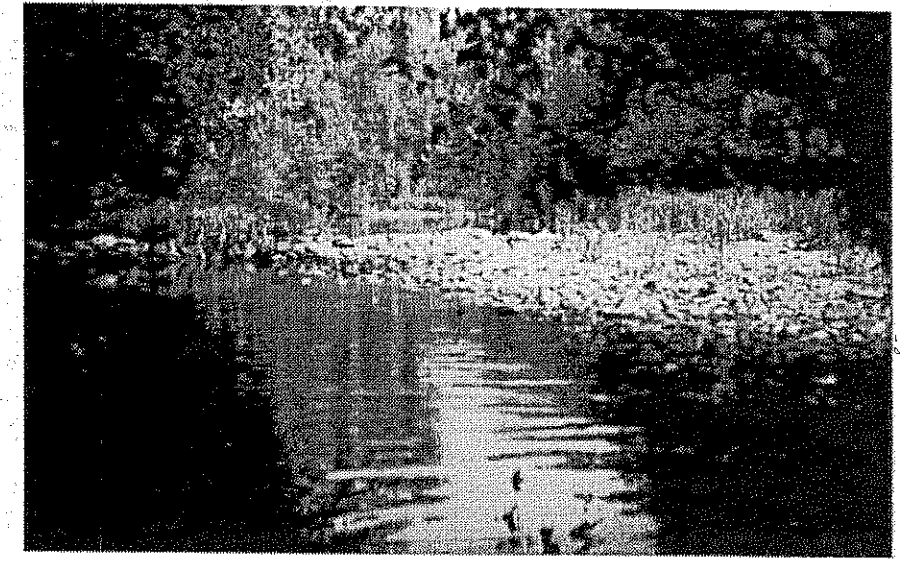
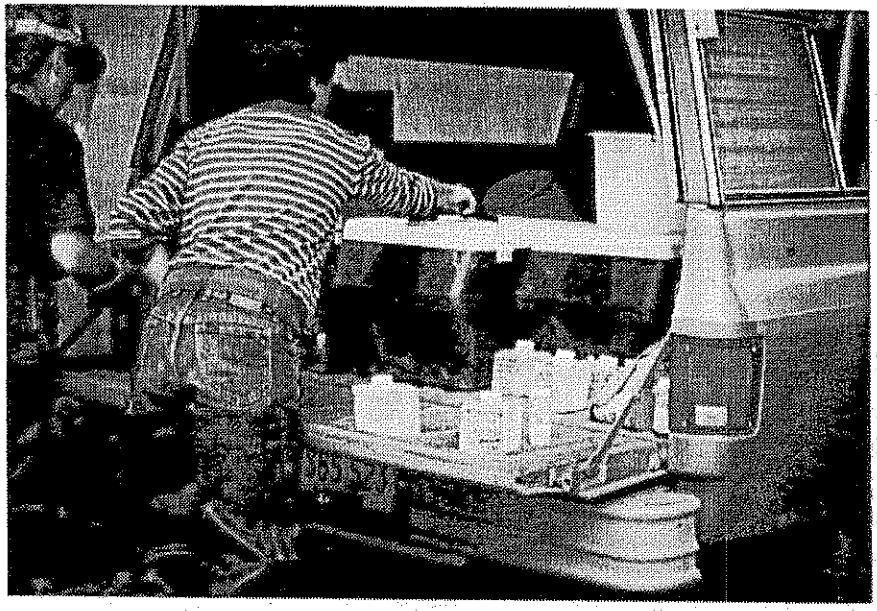
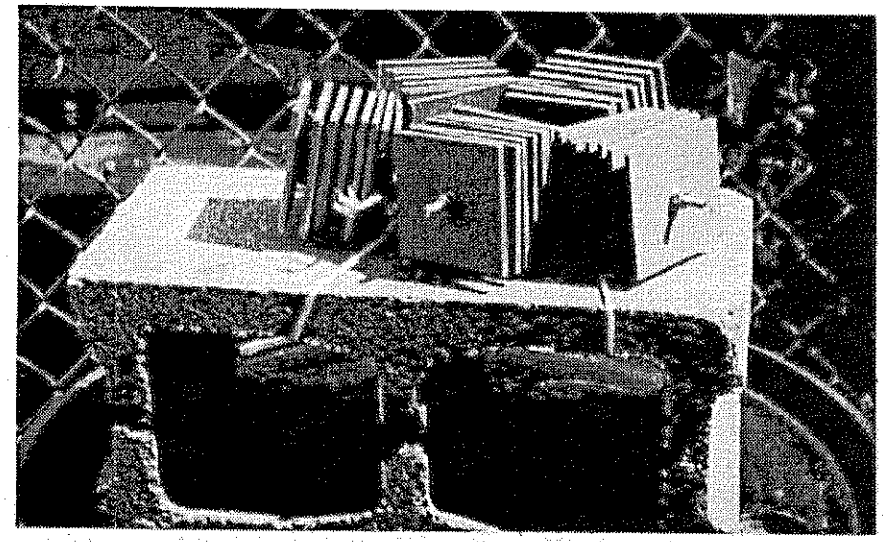


PLATE 5. TRIBUTARY PHYSICAL HABITATS: Most tributaries also contain good to exceptional quality physical habitats consisting of high-gradient riffle-run complexes, deep pools, and forested riparian corridors. ***Top Left:*** Yellow Springs Creek near the Yellow Springs WWTP. ***Top Right:*** View of Turtle Creek looking upstream towards Mason Road. Dense patches of water willow (shown in the middle of the channel) stabilize gravel bars and create narrow, swift-flowing, deeper aquatic habitats. This area has been recently impacted by reduced stream flows. ***Bottom Left:*** The East Fork of the Little Miami River downstream from Batavia. ***Bottom Right:*** Stonelick Creek upstream from the U.S. 50 bridge.





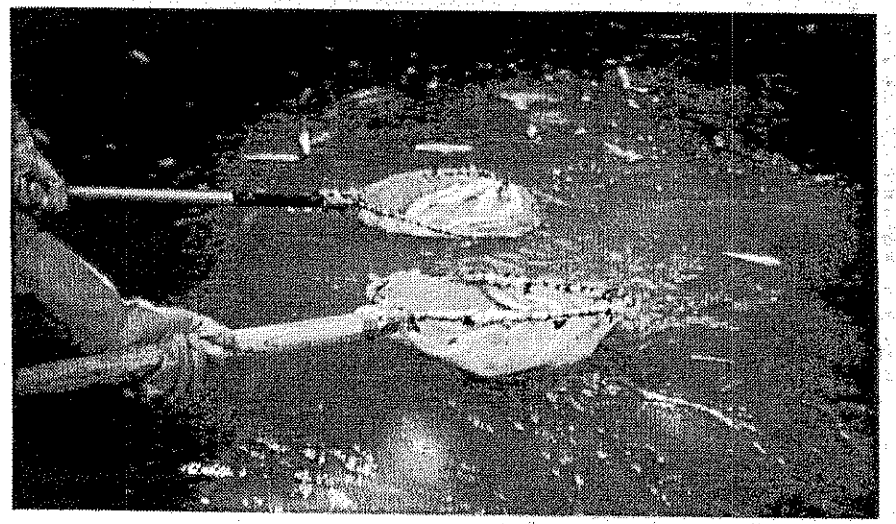
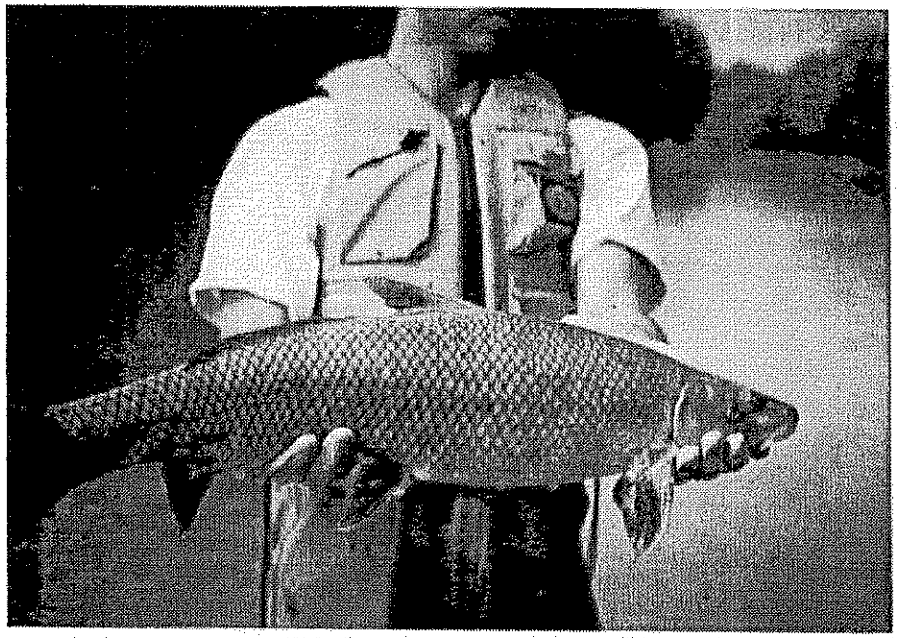
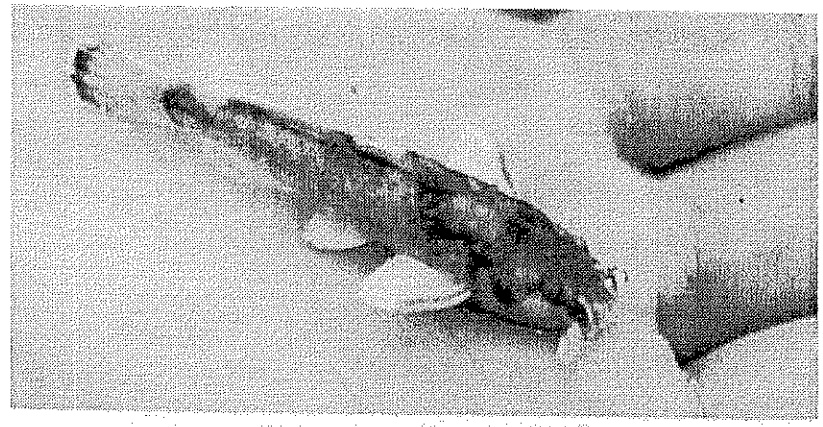
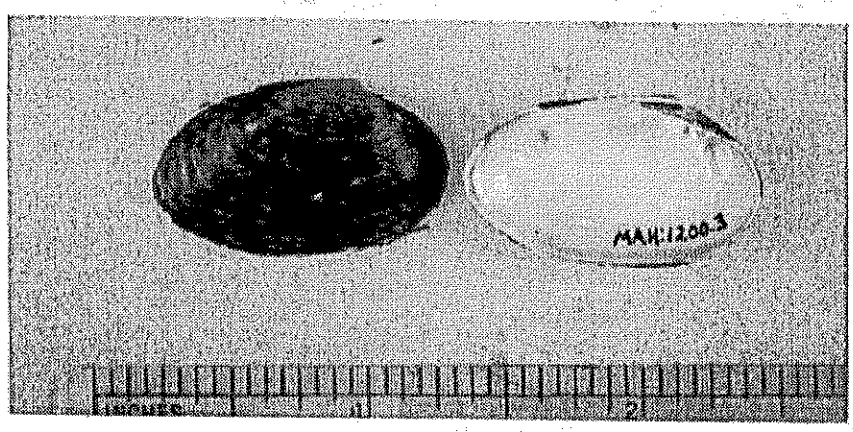


PLATE 6. DATA COLLECTION METHODS: Standardized collecting methods used by Ohio EPA personnel in the Little Miami River study area during 1993. ***Top Left:*** Preparation of water samples for chemical lab analyses. ***Top Right:*** Quantitative macroinvertebrate data was collected by submersing sets of five modified Hester-Dendy artificial substrate samplers for a six week colonization period between July 1 and September 30. Wading ***(Bottom Left)*** and boat ***(Bottom Right)*** electrofishing techniques were used to sample fish assemblages in different sizes of streams. Using this method, biologists can collect information about the fish community including diversity, quantitative relative abundance, biomass, and health data from the temporarily stunned fish before releasing them alive.







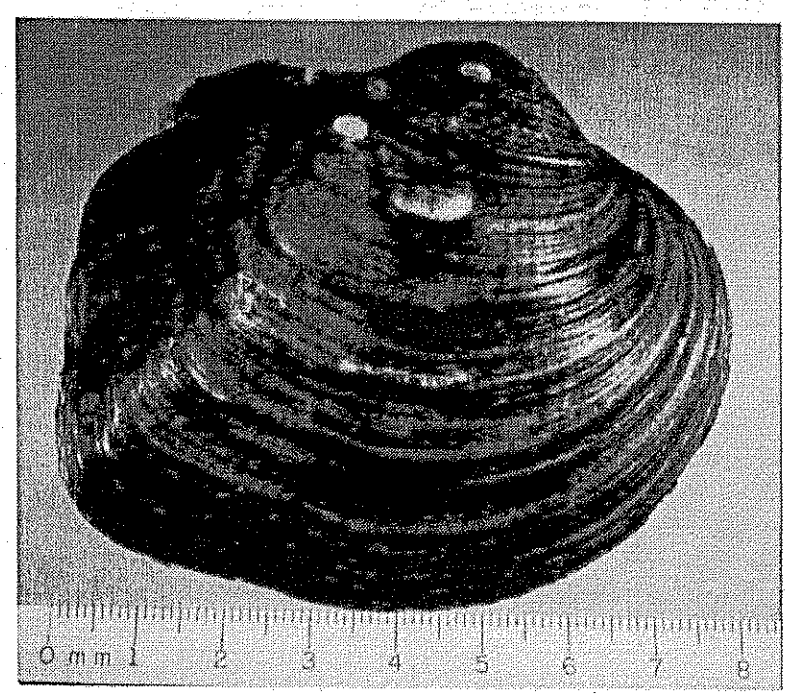
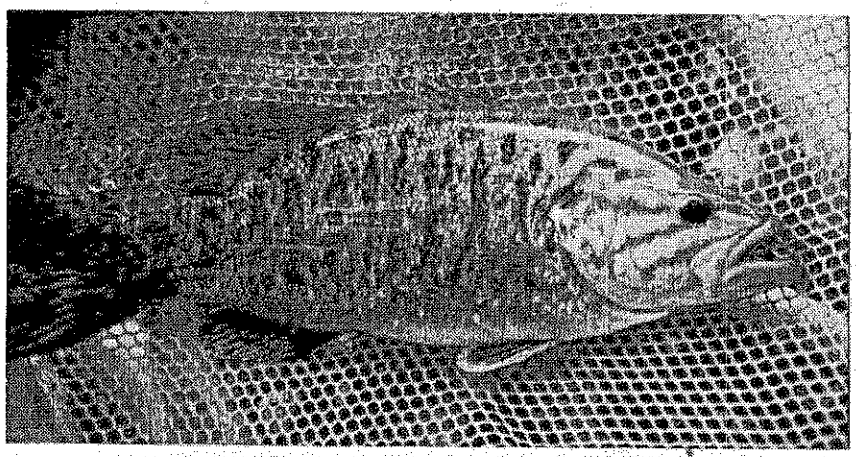
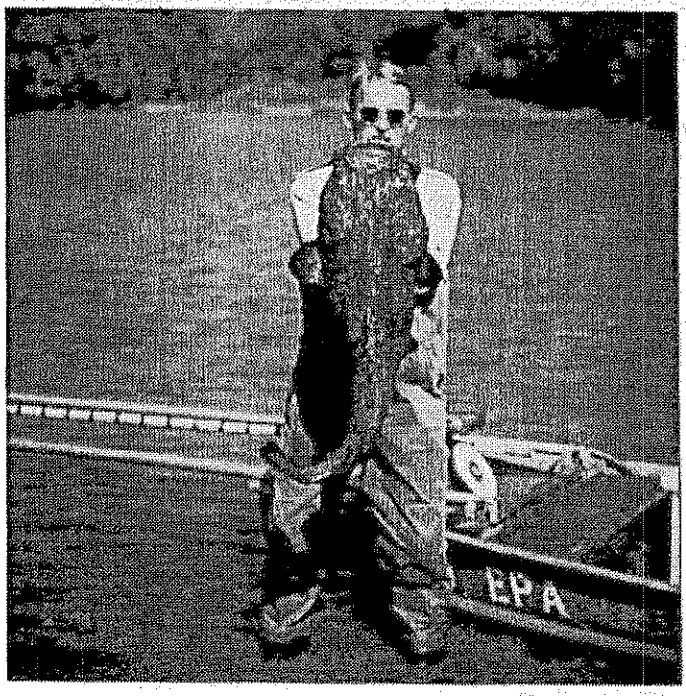


PLATE 7. BIOLOGICAL DIVERSITY/IMPERILED SPECIES: The Little Miami River watershed contains a high diversity of aquatic organisms, including six (6) Ohio endangered, two (2) threatened, and eight (8) special interest species. Eighty-seven (87) fish species and 349 taxa of aquatic macroinvertebrates have been recently collected from streams within the basin. ***Top Left:*** Blue suckers, one of Ohio's rarest and most endangered fish species, were discovered for the first time in the Little Miami River near Cincinnati during the 1993 Ohio EPA survey. ***Top Right:*** Mountain madtom, one of Ohio's smallest endangered catfishes, were also collected at four (4) sites in the lower Little Miami and East Fork mainstems. The Little Miami River, at Bass Island (RM 8.0), contains one of the largest populations of this species in the state. Most of the time, this species lives buried in gravelly riffles. ***Bottom Left:*** The rayed bean mussel (Ohio endangered) was collected at five (5) locations in the Little Miami and East Fork rivers (Hoggarth 1992). ***Bottom Right:*** The wartyback mussel, also endangered in Ohio, was reported by Hoggarth (1992) at two (2) locations in the lower Little Miami River (RM 23.9 and 8.0). Freshwater mussels have an unusual life cycle. Upon being released from a female clam, the larvae (called glochidia) drift and must attach to and successfully parasitize certain fish species in order to metamorphose into the adult mussel form.





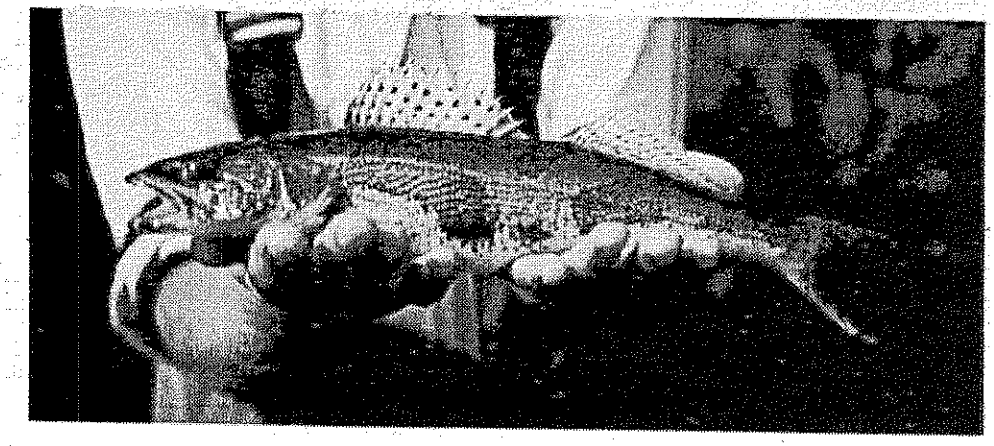
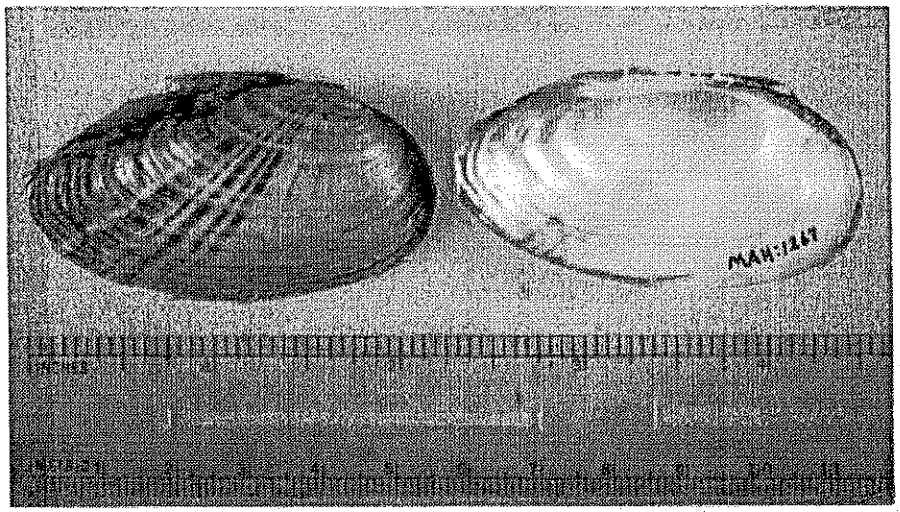
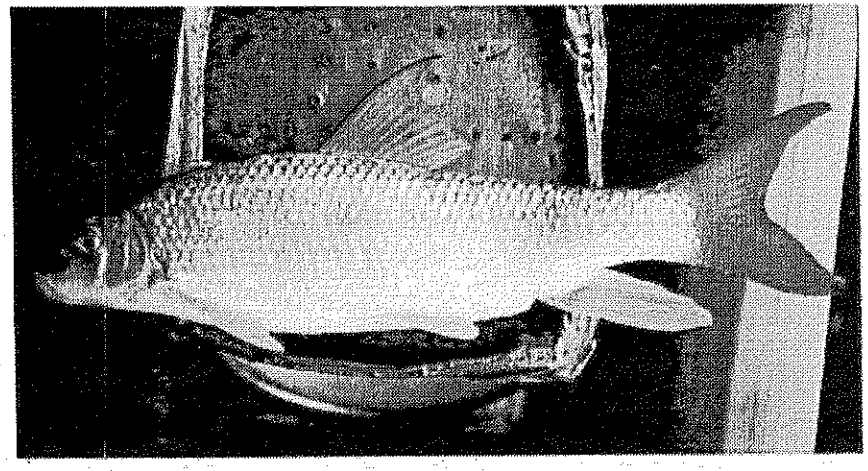
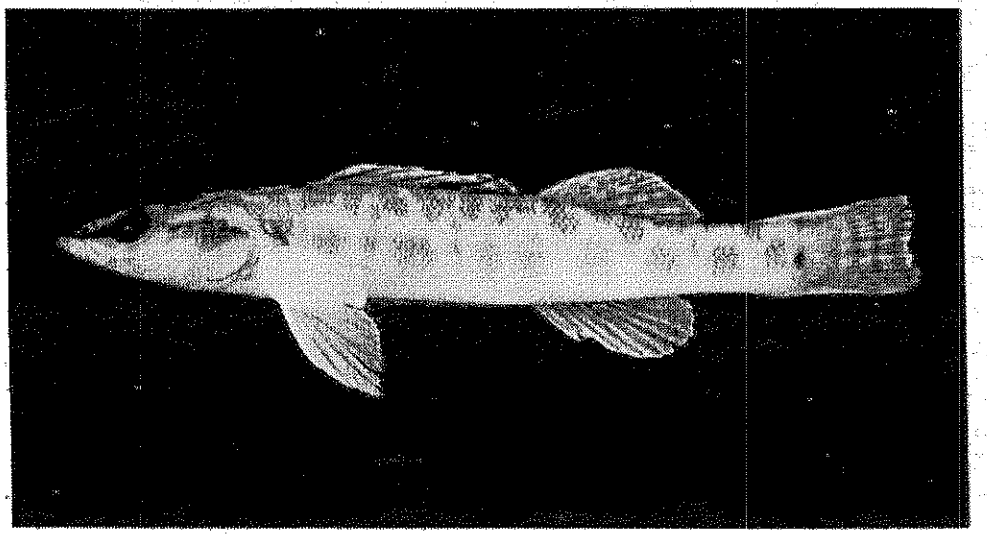


PLATE 8. GAME FISH: Four (4) of the sport species collected from the Little Miami River during the 1993 survey. ***Top Left:*** Smallmouth bass were collected at 30 of 31 locations between RMs 92.2 and 3.5. This popular species was most abundant near Goes, Foster, Branch Hill, and Milford, OH. Since 1983, the distribution of smallmouth bass has remained similar, but the mean relative abundance (number of fish collected per kilometer) has increased from 6.5 per km in 1983 to 13.4 per km in 1993. ***Top Right:*** Rock bass, a smaller sunfish species, were collected from 31 of 32 locations between RMs 102.1 and 8.0 and reached their greatest abundance in the upper half of the river between Goes and Trebein. The mean number of rock bass increased slightly from 4.3 fish per km in 1983 to 5.5 per km in 1993. ***Bottom Left:*** Flathead catfish, the largest fish species captured in the Little Miami River (view of 27.5 lb. specimen captured at Milford), were collected from 19 of 22 sampling locations between Waynesville and the Ohio River (RM 53.5 - 0.2). This species's catch rate increased from 0.5 per km in 1983 to 1.4 per km in 1993. ***Bottom Right:*** Since 1983, the distribution of sauger has expanded in the upper half of the mainstem. Sauger were collected from 24 of 28 locations between Alpha and the Ohio River (RM 74.5 - 0.2) during 1993. The mean catch rate increased slightly from 1.3 per km in 1983 to 2.5 per km in 1993.







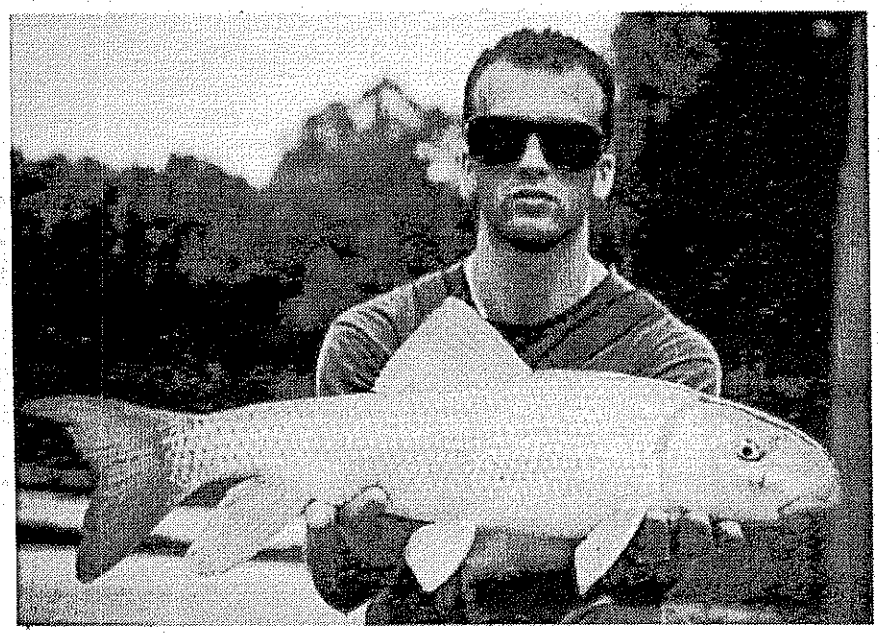
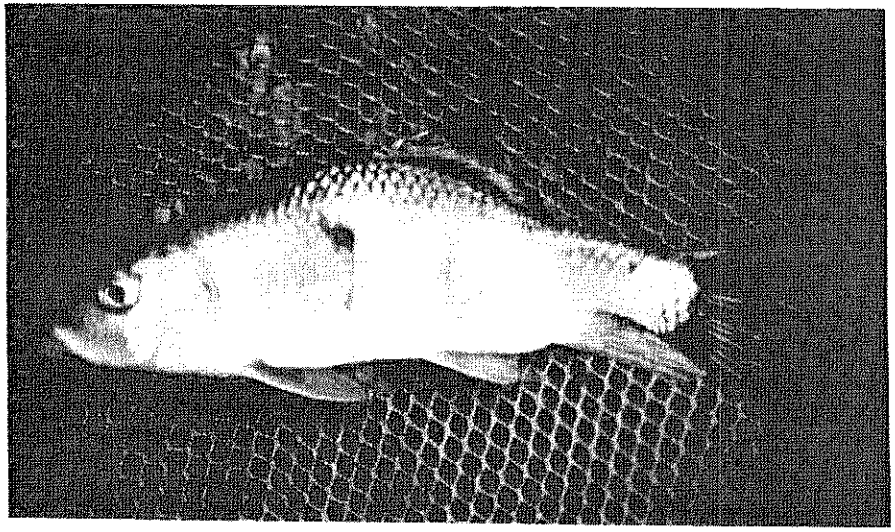
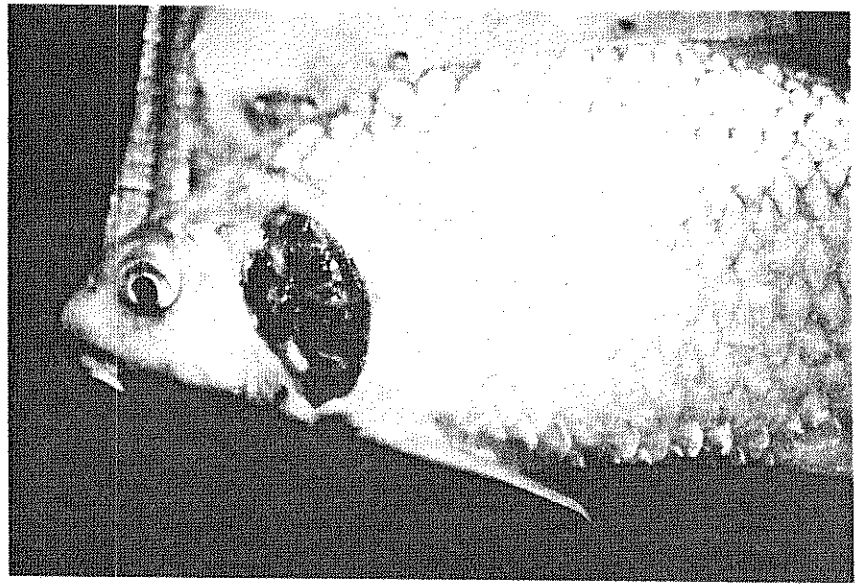
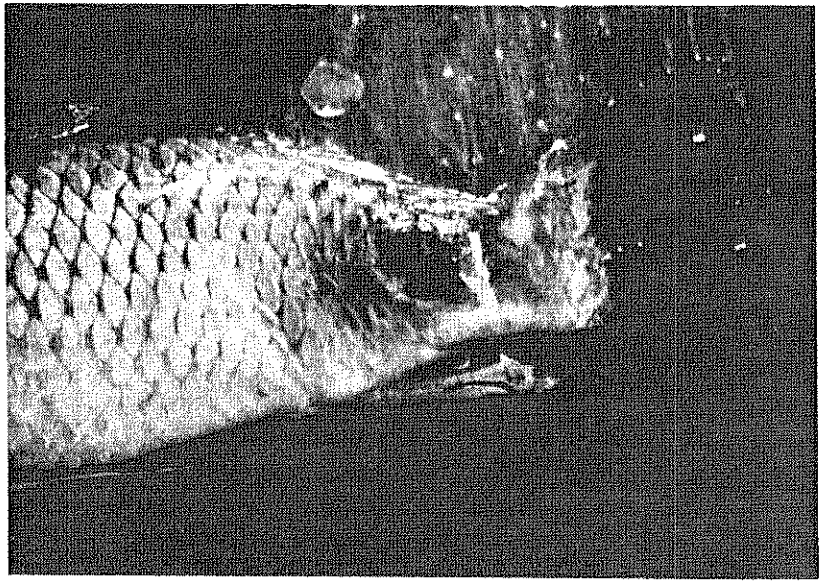


PLATE 9. NONGAME SPECIES: Four (4) of the pollution sensitive species collected from the Little Miami River during 1993. ***Top Left:*** The rainbow mussel inhabits small to medium size streams with coarse sand or gravel bottoms (Cummings and Mayer 1992). Hoggarth (1992) reported the species in the Little Miami River at four (4) locations which fully attained EWH during 1993. ***Top Right:*** Shorthead redhorse, a signature species for the Little Miami River mainstem which inhabits the swiftest waters, were collected at 27 of 30 sampling locations between Goes and Lunken Airport (RM 83.1 - 3.5). This intolerant species was most abundant between Foster and Branch Hill (RM 27.9 - 21.4). The mean number of shorthead redhorse captured per km has increased from 10.3 to 28.1 in 1993. The species's maximum abundance increased from 42.0 per km in 1983 to 124.3 per km in 1993. The marked increase in the relative abundance of this sucker since 1983 is a positive sign for the mainstem. ***Bottom Right:*** River redhorse, a large special interest sucker species, were collected from eight (8) of 19 locations between Oregonia and Lunken Airport (RM 47.5 - 3.5). During 1983, it was collected only between RM 36.0 and 13.1. ***Bottom Left:*** The slenderhead darter, a small fish in the perch family, was not collected from the Little Miami River during 1983, but was captured at five (5) of 12 sampling locations between South Lebanon and Plainville (RM 32.9 - 8.3) during 1993.







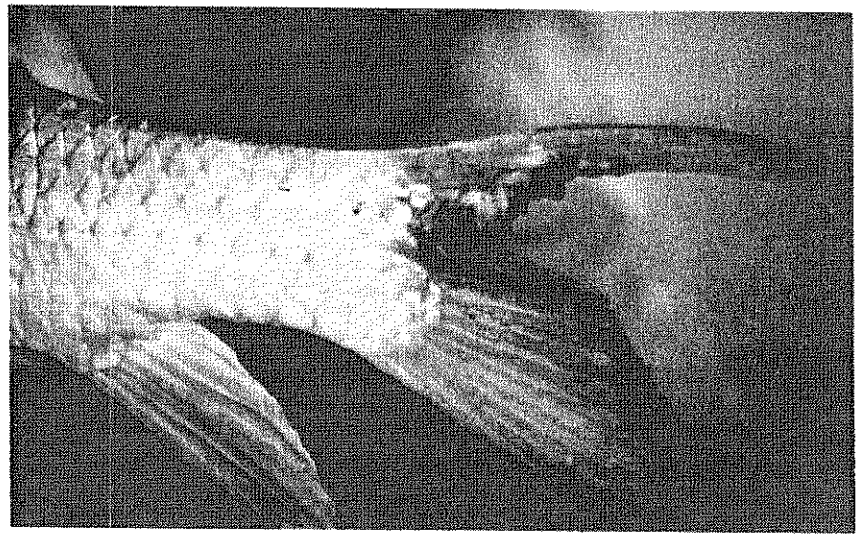
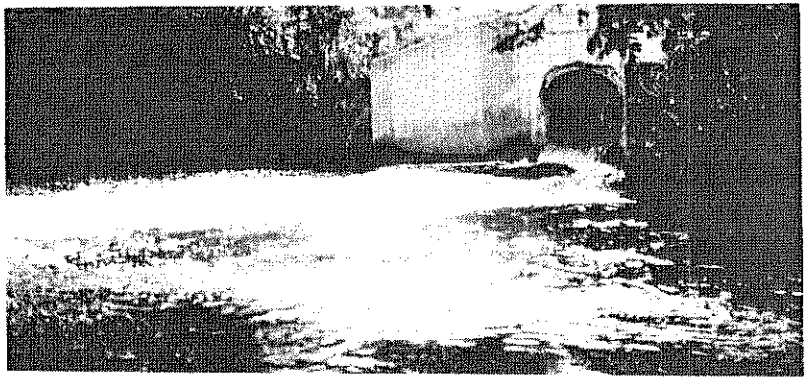
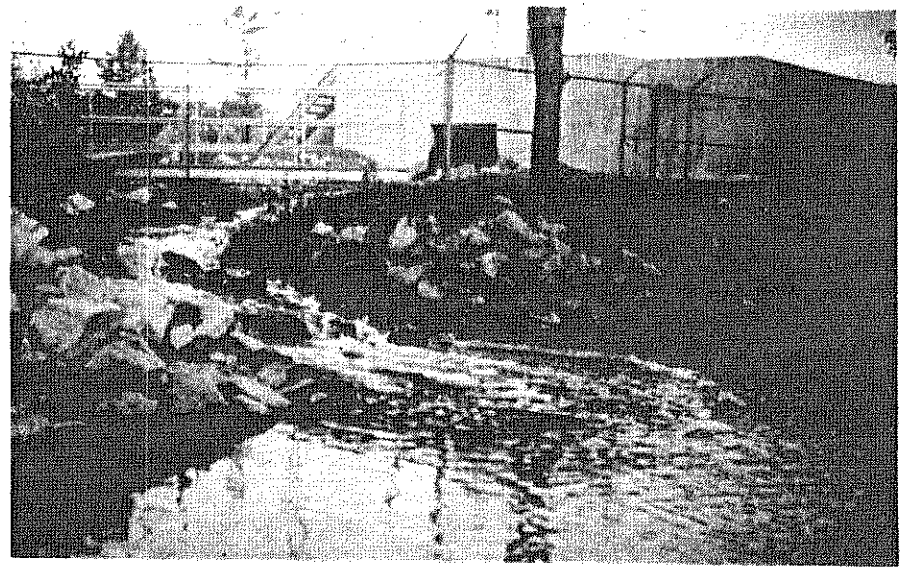
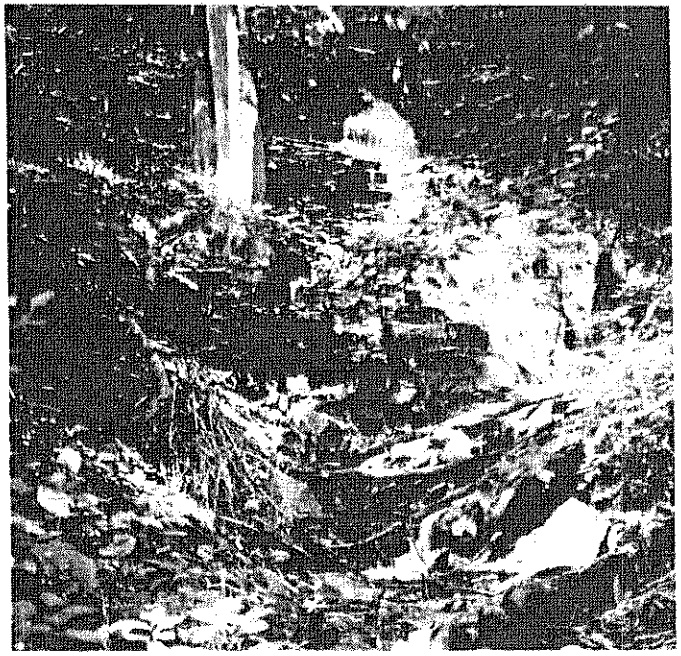


PLATE 10. EVIDENCE OF IMPACTS: Fish captured in the Little Miami River during 1993 with external deformity, erosion, lesion/ulcer, and tumor (DELT) anomalies. ***Top Left:*** A golden redhorse with a severe spinal deformity. ***Top Right:*** A quillback with a heavily eroded gill cover. ***Bottom Left:*** A common carp with a large lesion and deformed caudal peduncle. ***Bottom Right:*** A silver redhorse with heavy tumors and eroded caudal fin. These types of anomalies indicate sub-lethal stresses generally associated with marginal dissolved oxygen levels and/or chronic or acute toxic impacts. The highest incidence of DELT anomalies (6.0 - 11.7% of the fish captured) in the Little Miami River during 1993 occurred between Bellbrook and Waynesville.







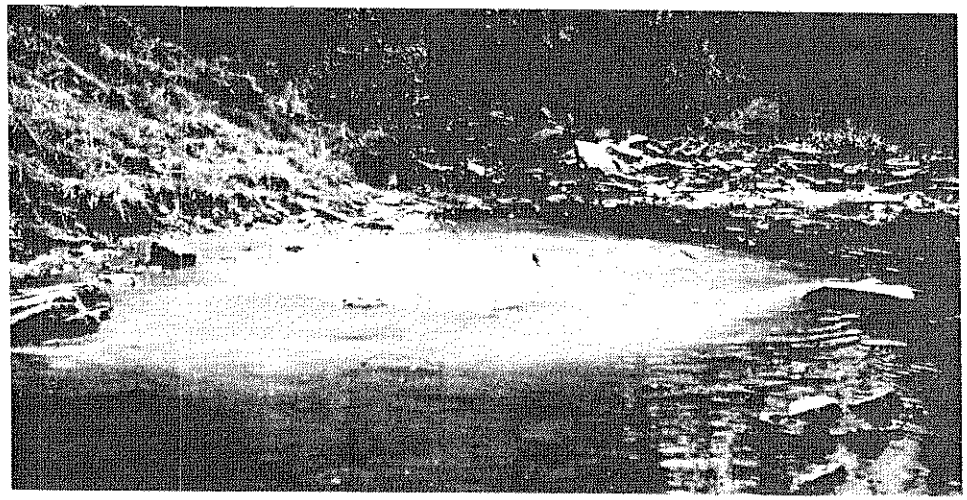
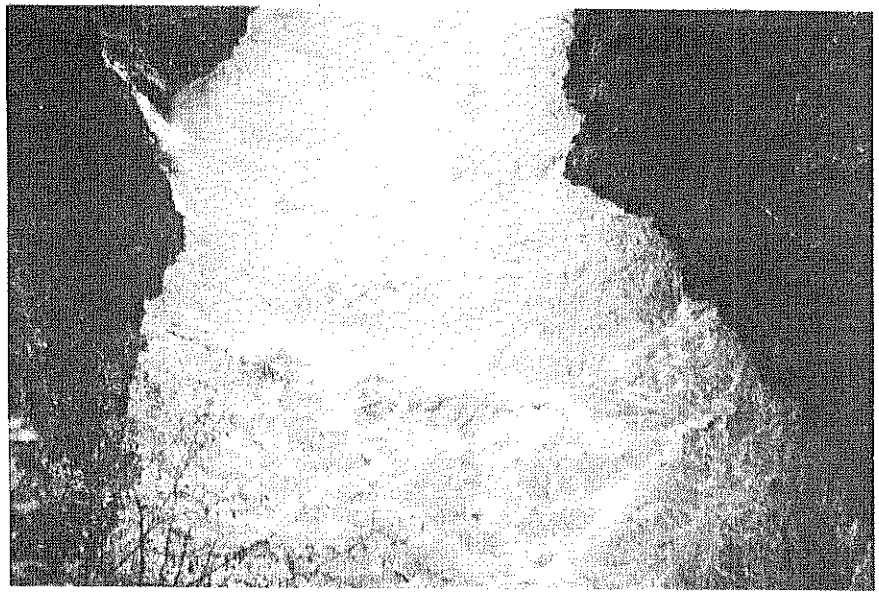
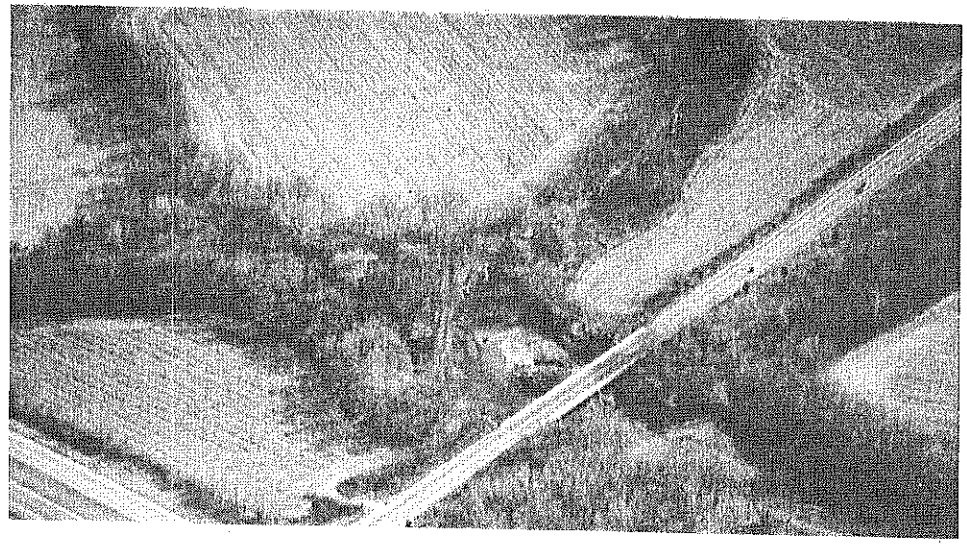
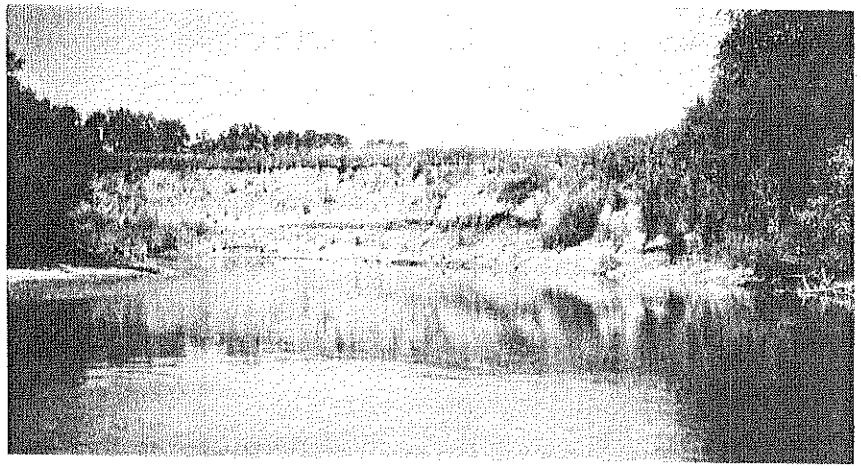


PLATE 11. POINT SOURCES OF POLLUTION: The Little Miami River watershed receives a cumulative total of more than 50 million gallons per day (MGD) of treated wastewater from permitted point source dischargers. The majority (99.2%) of effluent comes from municipal wastewater treatment plants (WWTPs) most of which have been upgraded during the last decade to meet state water quality standards. ***Top Left:*** The Montgomery County Eastern Regional WWTP discharges approximately 8.2 MGD to Little Beaver Creek, a tributary of Beaver Creek which also receives 4.3 MGD of treated effluent from the Greene County Beaver Creek WWTP ***(Top Right)*** before its confluence with the Little Miami River (RM 72.74). ***Bottom Left:*** The Yellow Springs WWTP discharges 0.8 MGD to Yellow Springs Creek through a cascading waterfall. Fish and macroinvertebrate communities attained Exceptional Warmwater Habitat biocriteria in Yellow Springs both upstream and downstream from the discharge. ***Bottom Right:*** Cincinnati Milacron, one of the few industries in the watershed, formerly had a similar type of cascading discharge, but now releases 0.08 MGD directly into Turtle Creek through a diffuser. During 1993, biological attainment of Warmwater Habitat criteria was FULL upstream, but only PARTIAL downstream from the discharge. The attainment status downstream from the industry was FULL from 1989 through 1992.







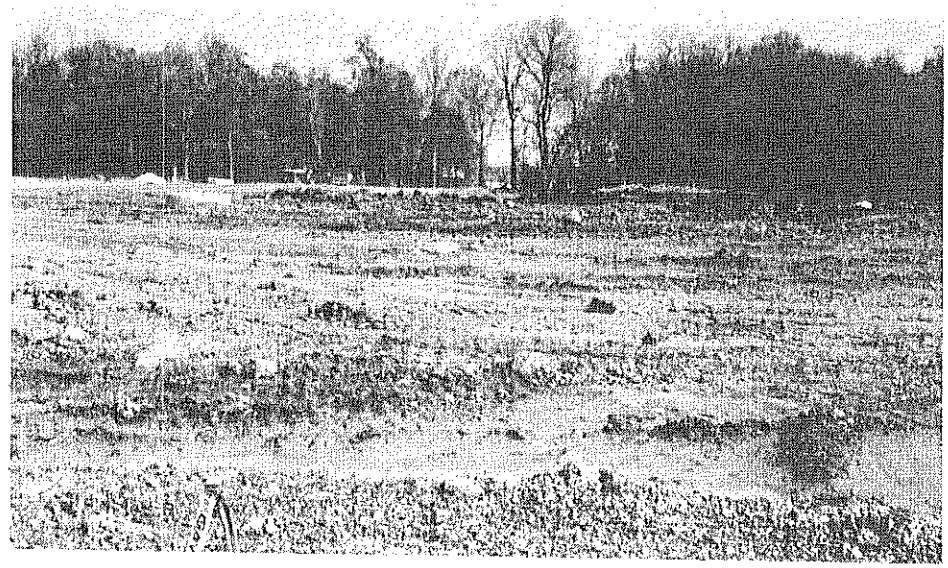
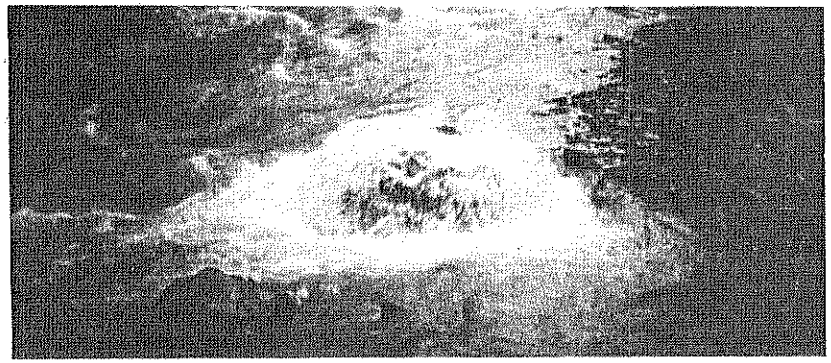
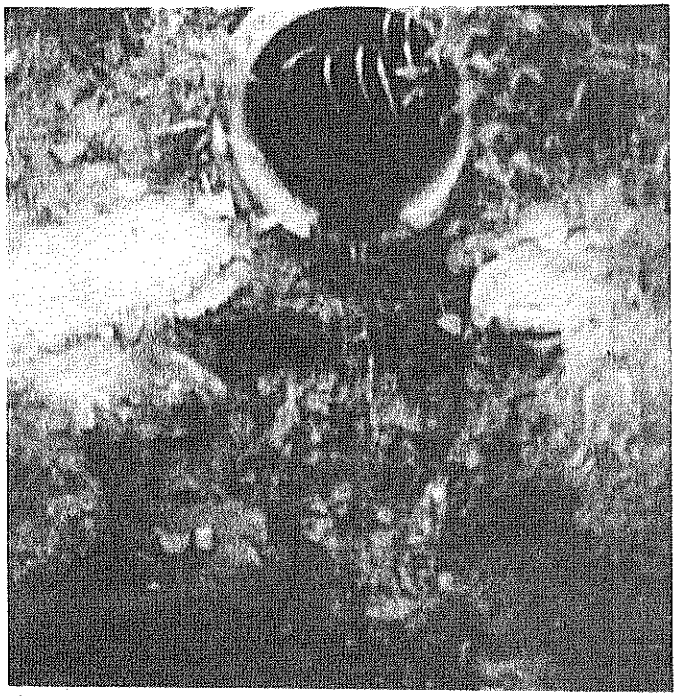


PLATE 12. NONPOINT SOURCES OF POLLUTION: High levels of sediment from soil erosion frequently enter the Little Miami River and tributaries through surfacewater runoff. Fluvial-sediment studies in Ohio (Hindall 1989) reports a mean annual suspended sediment discharge of 474,000 tons in the Little Miami River at Milford between 1977-1986. ***Top Left:*** Clifton Gorge view of the turbid Little Miami River during high flows. Three sources of excessive soil erosion are conventional row crop agriculture ***(Top Right)***, new construction sites ***(Bottom Right)***, and severely eroding banks ***(Bottom Left)*** which commonly occur subsequent to the removal of mature riparian vegetation. Streamside forests are a vital component of a healthy stream ecosystem. High suspended sediment loadings degrades both water quality and physical habitats, thus are not conducive to most pollution sensitive aquatic organisms. High turbidity levels can interfere with respiration, feeding, and reproduction. The retention of sediment within the low flow channel degrades substrate quality by embedding or burying preferred materials comprised of silt-free sand, gravel, and larger sized rocks. Surface runoff also contributes excessive nutrients, pesticides, and other chemicals. Streams with degraded physical habitats become more susceptible to the adverse effects of nonpoint source pollutants.





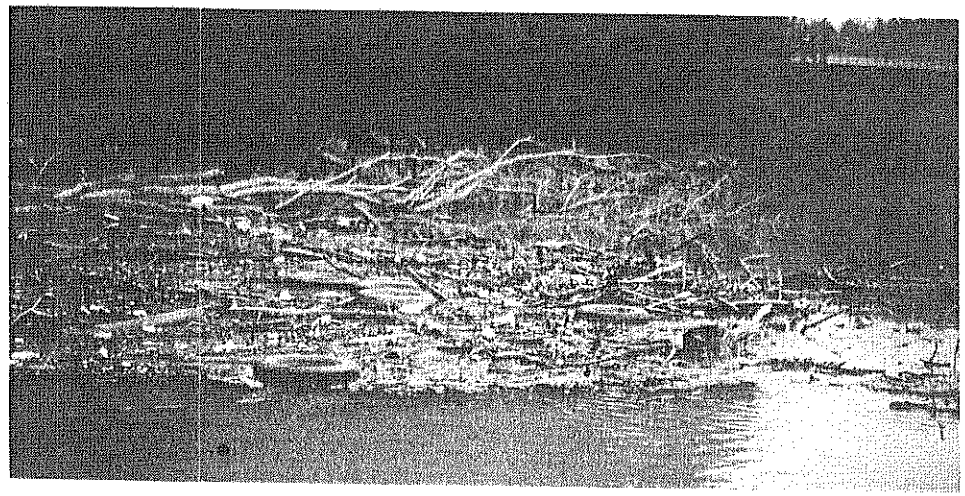
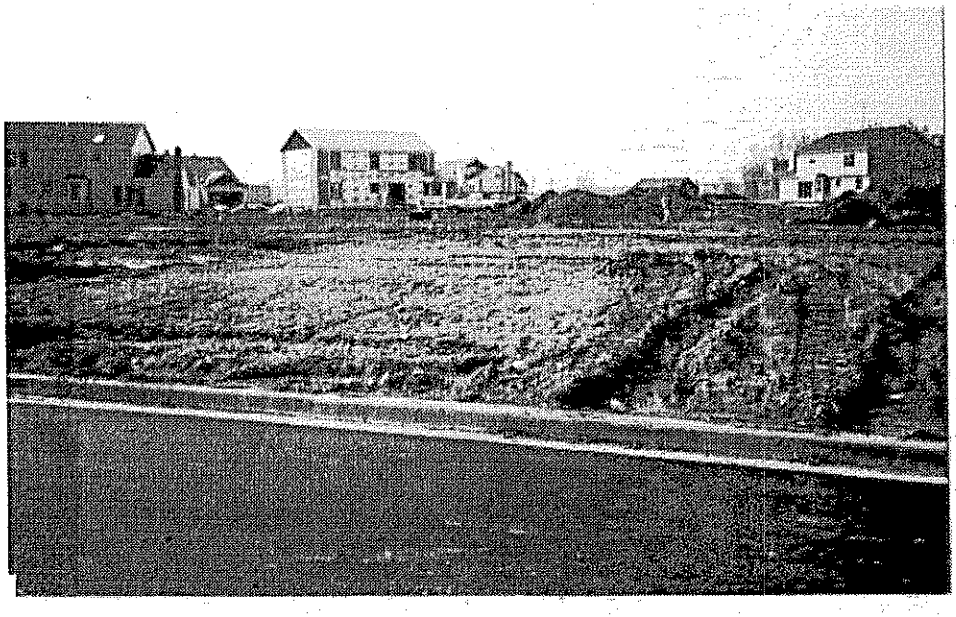
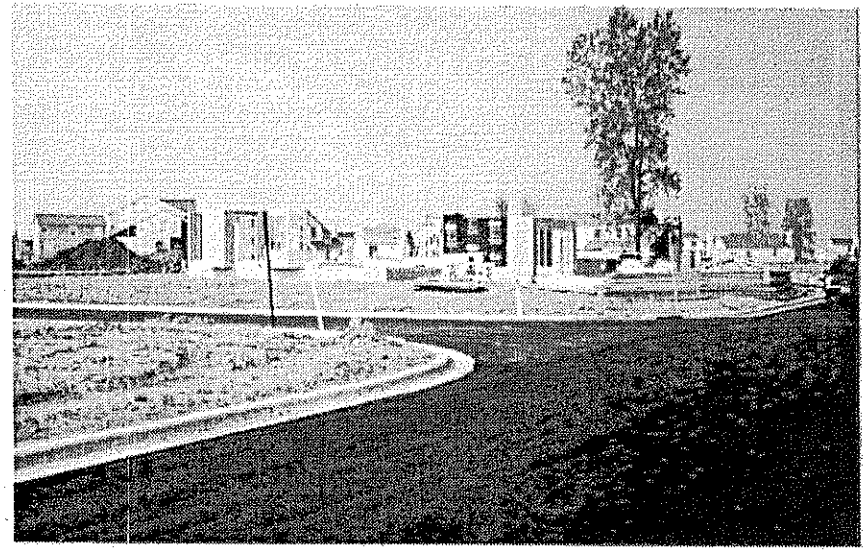


PLATE 13. ADDITIONAL WATERSHED THREATS: Human influences within the watershed increase as the Little Miami River flows into and through the greater Cincinnati metropolitan area. While most upstream sections of the Little Miami River have demonstrated improved aquatic life use attainment since 1983, the lower 19 miles has shown no significant change with some indications of deterioration. ***Top Right:*** Physical habitats and water quality within Sycamore Creek and its tributaries have been negatively impacted by the construction of gravity fed sewer lines, sanitary sewer overflows, and urban runoff from a predominantly suburban watershed. Sycamore Creek was in **NON** attainment of WWH upstream from the WWTP during 1993. ***Top Left:*** A 1990 view of an unauthorized release from a separate sanitary overflow in Raiders Run, a tributary to Sycamore Creek. New sewer lines with sealed man holes have been installed to prevent future releases. Between 1983 and 1993, more than 1500 spills (and other unauthorized releases) and 58,590 dead fish were reported throughout the Little Miami River watershed. ***Bottom Left:*** View of a small, dry-weather combined sewer overflow (CSO) discharge to the Little Miami River downstream from Beechmont Avenue (RM 3.5), the area inhabited by blue suckers. Forty-eight (48) of the 53 CSOs identified by the Hamilton County Metropolitan Sewer District (MSD) discharge to the Duck Creek subbasin which enters the mainstem upstream from Beechmont Avenue. Data collected by the MSD during October 1993 through February 1994 reveals 13 of the structures overflowed a total of 295 times and discharged approximately 232.2 million gallons. Sediments in the Little Miami River at RM 3.5 had some of the highest pollutant concentrations within the study area. ***Bottom Right:*** Flotsam (urban trash and debris from stormwater runoff and CSO discharges) was most common near Kellog Avenue (RM 1.6) in the backwaters of the Ohio River.





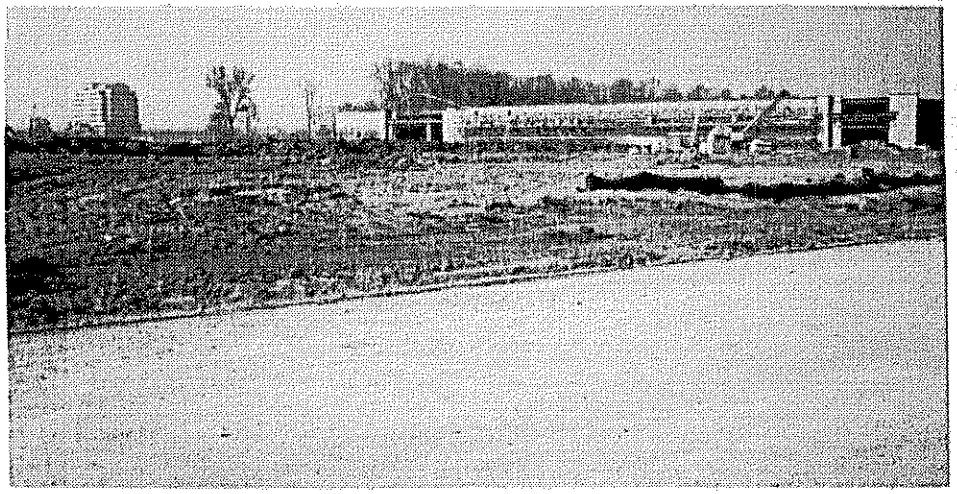


PLATE 14. SUBURBAN WATERSHED MODIFICATIONS: Residential ***(Top Photos)*** and commercial ***(Bottom Photos)*** developments replacing rural land use. FULL attainment of the EWH use designation by the Little Miami and East Fork rivers is threatened by new residential and commercial development within the watersheds. Portions of each stream presently are not in FULL attainment due in part to the effects (*i.e.*, sedimentation, runoff rates, nutrient enrichment) of suburban development. Without adequate controls to minimize runoff and protect headwater stream habitats, the ability to restore the mainstem to the designated EWH use will be seriously limited. A secondary result of the recent developments are requests by most WWTPs for larger discharge volumes to accommodate new sewer connections. Over the next decade, the total volume of treated wastewater discharged by WWTPs throughout the watershed is expected to increase causing stream flows to become increasingly effluent dominated. Other adverse changes include drainage pattern changes created by the conversion of headwater streams to channelized ditches, drainage of wetlands, and increased amounts of impervious surfaces (pavement and roofs) which contribute to a higher rate of runoff and less groundwater recharge.

Biological and Water Quality Study of the Little Miami River and Selected Tributaries

Clark, Greene, Montgomery, Warren, Clermont, and Hamilton Counties (Ohio)

State of Ohio Environmental Protection Agency
Division of Surface Water
1800 WaterMark Drive
Columbus, Ohio 43216-3669

INTRODUCTION

The Little Miami River is 105.5 miles long and contains the longest Exceptional Warmwater Habitat (EWH) segment of any stream or river in Ohio. The watershed occupies 1,757 square miles of land area, includes 133 named streams, and was principally formed by three glacial events (Krolczyk 1960, Cross 1967, Goldthwait 1979). The Little Miami River flows through several steep-sloped, forested gorges and contains some of Ohio's most scenic and diverse riverine habitats (Plate 1). Sections of the mainstem became Ohio's first state and national designated scenic river in 1969 and 1973, respectively (J. Kopec pers. comm.). Land use within the basin is predominately agricultural, but suburban land uses (*i.e.,* residential and commercial development) are rapidly increasing. The mainstem and larger tributaries are popular recreational retreats for many Ohioans (Plate 2).

As part of Ohio EPA's Five-year Basin Approach for Monitoring and National Pollutant Discharge Elimination System (NPDES) permitting, chemical, physical, and biological sampling was conducted in the Little Miami River and selected tributaries during the summer of 1993. The principal objectives of this study were to:

1) evaluate existing aquatic life use designations and use attainment status;
2) evaluate non-aquatic life uses (*i.e.,* recreational, water supply uses) and status;
3) identify causes and sources associated with **NON** and PARTIAL attainment;
4) provide data in support of NPDES permit reissuance; and,
5) assess changes (trends) in chemical water quality and biological performance since previous surveys and subsequent upgrades by major wastewater treatment facilities.

Similar to the previous surveys of 1982 and 1983, standardized methods were used throughout the study area to collect quantitative and qualitative biological, chemical, and physical data. During the 1993 study, a cumulative total of 178 river miles were evaluated by sampling 36 sites of the Little Miami River mainstem and 51 sites in 18 tributaries (Table 1). Eighteen (18) point source discharges were directly evaluated (*i.e.,* including analyses of pollutant loading trends based on monthly operating reports [MORs], NPDES permit violations, combined sewer overflows, and whole effluent toxicity tests) and other relevant information indicative of potential environmental impacts within the Little Miami River watershed (*e.g.,* spills, overflows, bypasses, unauthorized releases of pollutants, Ohio Department of Natural Resources fish kill reports, and other biological data) was also reviewed and summarized.

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

SUMMARY

Aquatic Life Use Attainment

Little Miami River

Of the 102.1 mainstem miles evaluated in 1993, 41% were in FULL attainment of Exceptional Warmwater Habitat (EWH) criteria, 57% were in PARTIAL attainment, and 2.9% were in **NON** attainment. Within the free-flowing mainstem, macroinvertebrate communities attained the Exceptional Warmwater Habitat (EWH) biocriterion for the Invertebrate Community Index (ICI) at all except one location. The PARTIAL attainment, therefore, was due to the failure of the fish community to meet the EWH criteria for the Index of Biotic Integrity (IBI) and/or modified Index of Well-Being (MIwb) at 14 locations. Both organism groups failed to attain the recommended WWH use designation within the lower three miles of the mainstem which is impounded by the Ohio River.

Within the upper half of the mainstem, a total of 19.5 and 32.6 miles, respectively, were in FULL and PARTIAL attainment of the existing EWH use designation. The PARTIAL attainment in the segment from South Charleston to Clifton was due primarily to excessive organic and nutrient enrichment, fecal contamination, and toxic impacts. The highest fecal bacteria and nitrate-N and the lowest dissolved oxygen (D.O.) levels within the mainstem were recorded in this segment. Sources of pollutants include runoff from a commercial manure storage area in South Charleston, to which a large fish kill in 1992 was attributed, and the South Charleston WWTP. Agricultural activities (*i.e.*, riparian encroachment and unrestricted livestock access) have also adversely impacted the quality of riparian and stream habitat within this segment. The segments from Clifton Gorge to the Narrows and immediately below the Sugar Creek WWTP exhibited FULL attainment of EWH. PARTIAL attainment was observed in the mainstem downstream from Bellbrook and between Spring Valley and Waynesville due to excessive pollutant loadings (*i.e.*, nutrients, oxygen demanding wastes, suspended solids) from the major municipal discharges within and upstream from the segment. Although most of the facilities have improved significantly since 1983 (*i.e.*, reduced loadings of pollutants), the cumulative amounts of pollutants discharged still exceeds the assimilative capacity of the Little Miami River. Higher than expected numbers of fish with external deformities, eroded fins, lesions/ulcers, and tumors (DELT anomalies) were observed and the incidence was correlated with loadings of these pollutants.

Within the lower half of the Little Miami River (downstream from Waynesville) a total of 21.4 miles was in FULL attainment of EWH, 25.6 miles in PARTIAL attainment, and 3.0 miles in **NON** attainment of WWH. The PARTIAL attainment of EWH downstream from Waynesville to Oregonia represents the continued assimilation of point source loadings discharged in the upper half of the mainstem. Recovery to FULL attainment occurred from Fort Ancient to Lake Isabel, but returned to PARTIAL attainment downstream from Sycamore Creek to Beechmont Avenue. In addition to a number of WWTP discharges, this segment also receives excessive amounts of sewage and other pollutants from combined sewer and sanitary sewer overflows (CSOs and SSOs). Downstream from Beechmont Avenue, **NON** attainment of WWH occurred at both sampling locations within the section impounded by the Ohio River. The **NON** attainment was attributed to a combination of chemical impacts from upstream sources and lower habitat quality due to the impoundment effect caused by the Ohio River backwater. The associated causes and sources of the PARTIAL and **NON**

attainment in the mainstem are summarized by waterbody segments (Table 2).

Selected Tributaries
Sampling results in selected tributaries showed 41% of the 44 tributary locations (excluding mixing zones) were in FULL attainment of existing and recommended aquatic life use designation criteria, 36% were in PARTIAL attainment, and 23% were in **NON** attainment (Table 1). The associated causes and sources of the PARTIAL and **NON** attainment in the tributaries are summarized by waterbody segments (Table 2).

Chemical Water Quality
Chemical sampling (daytime grabs) indicated relatively good water quality throughout most of the study area. Approximately 96.3% (13,056) of the total possible parameter tests were within Ohio WQS criteria or guidelines. A total of 499 parameter values (one or more parameters at most locations) however, did not meet criteria or recommended guidelines (Table 5). By category, fecal bacteria counts had the highest rate of exceedence (204 values; 38.9% of the possible tests) followed by conventional parameters (178; 2.3% of the possible tests), and organic compounds (117; 2.3% of the possible tests). Elevated bacteria counts are a good indication of fecal contamination. The *E. coli* criterion was more frequently exceeded (138 values; 67.6%) than for fecal coliform (66 values). Twenty (20) mainstem locations and 14 sites in eight (8) tributaries designated for the Primary Contact Recreation (PCR) use had one or more values which exceeded the maximum criterion. Eleven (11) locations in four (4) tributaries designated for the Secondary Contact Recreation (SCR) use had one or more values which exceeded the maximum criterion.

Phosphorus concentrations above the WQS narrative guideline were the most numerous of the conventional parameter exceedences with 78 values (15.6% of 499 values) greater than 1.0 mg/l. Excluding iron exceedences (which are usually due to natural sources), the most frequent WQS criteria exceedences were for dissolved oxygen (28), temperature (18), and total residual chlorine (16). The lowest D.O. concentrations in the Little Miami River occurred at three daytime grab sample locations upstream from Clifton (RMs 101.3 - 89.98, minimum = 3.5 - 5.6 mg/l). Values below the D.O. criteria were also recorded at 14 locations in seven (7) tributaries. D.O. concentrations below 3.0 mg/l were recorded in Flat Fork (RM 1.7; range = 1.1 - 2.9 mg/l), Turtle Creek (RM 0.70; 2.8 mg/l), and Stonelick Creek (RM 16.74; 2.4 mg/l). D.O. concentrations at most other sites were >6.0 mg/l and considered conducive to healthy and diverse aquatic assemblages. Copper was the most common heavy metal to exceed criteria with eight (8) of the 10 exceedences recorded in Turtle Creek downstream from Cincinnati Milacron. Iron concentrations exceeded the 1.0 mg/l criterion in 130 (33%) of the 392 non-mixing zone samples and exceeded or equaled 5.0 mg/l in 16 of 499 samples (Table 6). Two sites downstream from point source discharges had the highest number of conventional parameter exceedences. These include Turtle Creek downstream from Cincinnati Milacron (RM 0.52; 6 parameters with 15 exceedences) and the Little Miami River downstream from the Lower LMR WWTP (RM 28.0; 4 parameters with 10 exceedences).

Priority pollutant scans of the water column detected one or more organic compounds at 33 of 34 locations (Appendix Table A-5). Dieldrin, an insecticide no longer manufactured in the U.S., was detected at 30 of the 34 locations. Other pesticides detected included aldrin, endrin, endosulfan II, methoxychlor, and heptachlor with several appearing in WWTP mixing zones or immediately downstream. Caesar Creek upstream from the reservoir (RM 16.52) was the only location sampled with no organic compounds detected. Sampling locations with the highest number of organic priority pollutants detected were; Little Beaver Creek downstream from the Montgomery Co. Eastern Regional WWTP (RM 4.53; 15 compounds), the mainstem at Indian Ripple Road (RM 72.30; 13

compounds), Totes, Inc. mixing zone (RM 22.20; 12 compounds) and Sycamore Creek downstream from the Sycamore Creek WWTP (RM 0.05; 12 compounds). Priority pollutant scans from the two locations sampled in the East Fork showed no noticeable change in the number of organic compounds from upstream to downstream from four WWTPs.

Chemical Sediment Quality

Sediment chemistry results from 39 locations revealed non-elevated to slightly elevated (Kelly and Hite 1984) concentrations of eight (8) heavy metals at most sites with higher concentrations at a few scattered locations (Table 7). Arsenic was elevated at three (3) sites with the highest concentration recorded in Turtle Creek downstream from Cincinnati Milacron. Other elevated values occurred at two (2) predominantly rural locations, the mainstem at Dolly Varden Rd. (RM 98.98) and in Flat Fork (RM 1.70). Possible source(s) of the arsenic include past use of pesticides and natural occurrence in groundwater. An elevated lead value was recorded downstream from Simpson Creek (RM 28.0) and three (3) slightly elevated values were found in the urbanized Beaver Creek watershed. Cadmium, nickel, and chromium concentrations were non-elevated or slightly elevated throughout the study area. Elevated zinc concentrations were detected at three (3) locations (Beechmont Ave., Oldtown Creek, and Turtle Creek at RM 6.23). The Beechmont Ave. location was the one site in the study area with multiple parameters in the slightly elevated to elevated ranges (copper, chromium, zinc) and highly to extremely elevated heavy metal concentrations of iron and mercury. This site is immediately downstream from Duck Creek which is extensively impacted by urban runoff, CSOs, spills, and other sources.

Similar to the water column results, sediment scans for priority organic pollutants detected one or more compounds at 82% of the 39 sampling locations. Phthalates or polycyclic aromatic hydrocarbons (PAHs) were detected at 16 locations, volatile organic compounds at a single location, and organochlorine pesticides at 30 locations (Table 8, Appendix Table A-8a). The seven (7) locations with no organic compounds detected were in the East Fork (RMs 15.60, 13.35, 12.59, and 0.77), Stonelick Creek (RM 1.0), Caesar Creek (RM 16.52), and Newman Run (RM 0.27). The highest number and total quantity of semi-volatile organic compounds in the study area occurred in Sycamore Creek downstream from the Sycamore Creek WWTP (RM 0.05). Thirteen (13) different PAH compounds were detected with a relatively high total concentration of 36.6 mg/kg (ppm). The sediment sample at this location also contained toluene (a solvent), the only volatile organic compound detected. Although potentially due to different particle sizes in the sediment sample, only two (2) PAH compounds, both at markedly lower concentrations, were collected immediately upstream from the WWTP. Sludge deposits were observed downstream from the WWTP during the survey. Sediments in the Little Miami River at Beechmont Ave. contained the second highest number (9) and total quantity of PAH compounds (17.8 mg/kg). Possible sources include the Norwood/Duck Creek landfill (closed) which has an eroding bank along Duck Creek, urban runoff, spills, and numerous CSOs in the Duck Creek subbasin. Turtle Creek at Glosser Road (RM 6.23) contained the next highest number of PAHs (7 compounds; 10.8 mg/kg). The most frequently detected compounds were bis (2-ethylhexyl) phthalate, benzo [B&K] fluoranthene, and fluoranthene. Up to four (4) organochlorine pesticides were detected in the sediment at 77% of the 39 sampling locations (Table 8). Dieldrin was detected at 22 sites, DDT and endosulfan II at eight (8) sites each, aldrin at four (4) sites, and endosulfan sulfate at one (1) site. The highest dieldrin value (highly elevated; Kelly and Hite 1984) occurred in the upper mainstem at Dolly Varden Rd. Three (3) other mainstem and a single tributary value were slightly elevated. Total DDT concentrations were non-elevated with the exception of Beechmont Ave. where it was elevated. Four (4) different organochlorine pesticides were detected at Beechmont Ave. which was the only location with more than two of these compounds.

Fish Tissue Contaminants

Chemical analyses of 34 fish tissue samples suggests relatively little contamination of fish tissue throughout the Little Miami River mainstem. At least two of eight different species were tested for selected heavy metals, pesticides, and PCB compounds at 11 locations between RMs 83.1 and 3.5. All concentrations of compounds from seven (7) sport species (composite fillets) and common carp (whole body composite) were below U.S. FDA action levels (Appendix Table A-8b). Slightly elevated (>50, ≤ 300 µg/kg) concentrations of PCBs, however, were detected in two white bass samples, one freshwater drum sample, and three channel catfish samples. Whole body composite values for eight common carp samples were slightly elevated at six locations, elevated (>300, <1000 µg/kg) at one location, and highly elevated (>1000, <5000 µg/kg) at Beechmont Ave.

A total of seven (7) organochlorine pesticides and derivatives were detected in fish tissues. Similar to the water and sediment scans, dieldrin was the most frequently occurring pesticide with a detection rate of 76.5%. This is higher than the statewide detection rate of 48.1% reported by Estenik and Smith (1992). The second most frequently detected organic compound was 4,4'-DDE (a DDT derivative) with a detection rate of 73.5% (compared to a 60.5% statewide rate of detection). The total PCB detection rate in the mainstem was considerably lower than the reported statewide rate of 97.6%. PCB-1260, the most resilient and only PCB congener detected, was found in 64.7% of the Little Miami River samples. No pesticides or PCBs were detected in composite fillets from smallmouth bass, sauger, or channel catfish at RM 31.9, spotted bass and sauger at RM 18.5, smallmouth bass and freshwater drum at RM 8.0, and smallmouth bass at RM 3.5. The highest number of contaminants detected in the study area again occurred in the whole body composite sample of common carp collected at Beechmont Avenue.

The highest mercury concentration, 0.7 µg/g, occurred in spotted bass fillets collected downstream from the confluence of Sycamore Creek (RM 18.5). This concentration is the highest value recorded to date for mercury in the Ohio EPA fish tissue database and may be related to the re-occurring mercury exceedences in the Sycamore Creek WWTP effluent. Concentrations of cadmium and lead (maximum values of 0.046 and 1.88 µg/g, respectively) were low throughout the mainstem.

Physical Habitat for Aquatic Life

As the result of a complex geological history and predominantly natural stream channels, the Little Miami River watershed contains some of the highest quality riverine habitats in Ohio (Plates 3 through 5). Physical habitats within the mainstem and most tributaries exhibited good to exceptional quality attributes including moderate to high gradients, coarse substrates comprised of mixed glacial till and/or limestone fragments, and wooded riparian corridors. The quality of physical habitats within the mainstem and tributaries has been locally impacted by dams, unrestricted livestock access, channelization, removal of woody riparian vegetation, and excessive soil erosion. Embedded substrates and thick silt deposits were observed in most of the larger pools in the lower mainstem and the East Fork. Flows are also becoming increasingly controlled by reservoir releases and wastewater discharges. The implementation of stream protection measures such as maintaining natural flow regimes, the protection and restoration of wooded riparian zones, bank stabilization, and upland soil erosion control throughout the watershed is critical to the future protection and maintenance of physical habitats conducive to exceptional aquatic faunas.

Biological Community Performance

The overall performance of the biological communities within the Little Miami River study area ranged from exceptional to poor, with good to exceptional quality assemblages present at most locations. The 1993 study yielded a cumulative total of 408 different taxa (321 macroinvertebrate taxa and 87 fish species [109 fish species have historically been recorded]) throughout the study area, with 319 of these taxa (236 macroinvertebrate taxa and 83 fish species) from the Little Miami River mainstem alone. Three Ohio endangered fish species, the tonguetied minnow (*Exoglossum laurae*), mountain madtom (*Noturus eleuthrus*), and blue sucker (*Cycleptus elongatus*; a new record), were collected from the mainstem. A recent survey of Unionidae (freshwater mussels) sponsored by the Ohio DNR, Division of Natural Areas and Preserves (Hoggarth 1992) found two additional state endangered species, the rayed bean mussel and the wartyback mussel, in the mainstem and the little spectaclecase mussel in the East Fork upstream from Harsha Reservoir. Longitudinal trends in the diversity (total cumulative number of taxa collected) of macroinvertebrate, fish, and freshwater mussel species (1993 Ohio EPA collections and Hoggarth 1992) is illustrated in Figure 1. The most diverse faunas were found at South Lebanon (86 taxa of macroinvertebrates at RM 32.9), Loveland (18 mussel species at RM 23.9), and Plainville adjacent to Bass Island (41 fish species at RM 8.0).

Macroinvertebrate community performance was consistent with the applicable Invertebrate Community Index (ICI) criteria at 90.9% of the 33 mainstem sites and 64.3% of the 42 tributary locations. ICI scores or qualitative evaluations were indicative of exceptional to very good quality at most locations in the Little Miami River, Yellow Springs Creek, South Fork of Massies Creek, and the East Fork. Fair or poor quality macroinvertebrate assemblages, however, predominated the lower two miles of the mainstem, South Fork of Massies Creek, Little Beaver Creek downstream from the Montgomery Co. Eastern Regional WWTP, Beaver Creek near the mouth (downstream from the Greene Co. Beavercreek WWTP), Glady Run (and swale) downstream from the Xenia Glady Run WWTP, Newman Run, Flat Fork, Dry Run, and Sycamore Creek.

Fish community performance was consistent with the applicable Modified Index of Well-Being (MIwb) and Index of Biotic Integrity (IBI) criteria at 74.2% and 53.1%, respectively, of the mainstem sites and 80% and 53.5% of the tributary locations. Fish assemblages were indicative of exceptional to very good quality in the mainstem from Clifton Gorge to Lake Isabel, Yellow Springs Creek, Old Town Creek, Massies Creek, Newman Run, Anderson Fork, Caesar Creek upstream from the reservoir, Muddy Creek, Turtle Creek upstream from Cincinnati Milacron, Stonelick Creek near the mouth, and at most sites in the East Fork upstream from Milford. Fair or poor quality assemblages, however, predominated in the lower two miles of the mainstem, Little Beaver Creek both upstream and downstream from the Montgomery Co. Eastern Regional WWTP, Beaver Creek upstream from Little Beaver Creek, Glady Run Swale upstream from the Xenia Glady Run WWTP, Glady Run upstream and immediately downstream from the Xenia Glady Run WWTP, Flat Fork, Dry Run, Stonelick Creek within and upstream from the reservoir, and Sycamore Creek upstream from the Sycamore Creek WWTP.

Although significant improvements have occurred in the mainstem since 1983, biological recovery was not complete in 1993. Evidence of adverse impacts included lower than expected biological index scores, elevated numbers of fish with DELT anomalies, predominance by tolerant species, and fish kills. While the specific types of impacts varied throughout the watershed, most included the inadequate disposal and/or treatment of human and other animal wastes. Associated causes and sources of non-attainment by waterbody segment are listed in Table 2.

Trend Analysis

Little Miami River

During the past decade, significant progress has been made towards restoring the chemical, physical, and biological integrity of the Little Miami River mainstem and tributaries. From 1983 to 1993, the number of miles in FULL attainment of EWH has increased from 1.5 to 40.9 miles while the number of miles in **NON** attainment decreased from 45.4 to 3.0 miles (Table 13). Complete recovery was not evident in 1993, however, because 58.2 miles were in PARTIAL attainment due primarily to a failure of fish assemblages to meet the IBI criteria. The most significant improvements (*i.e.,* restored to FULL attainment) in the mainstem occurred within Greene, southern Warren, and northern Hamilton and Clermont Counties and are due primarily to the improved treatment of sewage by county and municipal WWTPs. Since 1983, the aquatic life use attainment status improved (*i.e.,* changed from **NON** to PARTIAL or PARTIAL to FULL) in all 11 of the similarly sampled segments within the upper half of the mainstem, but improved in only six (6) of the 13 previously PARTIAL or **NON** attaining segments within the lower half (Table 3).

Comparisons of the biological index (ICI, MIwb, and IBI) scores and Area of Degradation (ADV) values (see page 37 for description of ADV) from 1983 to 1993 for similarly sampled segments also confirms that the greatest improvements have occurred within the upper half of the Little Miami River mainstem (Tables 3 and 13). The average increase in ICI scores (>4 ICI units is considered significant) between 1983 and 1993 was higher in the upper half (+13.8 units; range of +2 to +32) than in the lower half (+5.8 units; range of -2 to +18). Area of Degradation Values (ADV) for the ICI declined from 116.9 units/mile to 0.8 units/mile in the upper half and from 21.4 units/mile to 14.9 units/mile in the lower half between 1983 and 1993. The average increase in MIwb scores (>0.5 MIwb units is considered significant) was also higher in the upper half (+1.0 units; range of -0.3 to +2.1) than in the lower half (+0.5 units; range of -0.7 to +1.7). ADV values for the MIwb declined from 45.5 units/mile to 6.1 units/mile in the upper half and from 12.5 units/mile to 5.1 units/mile in the lower half from 1983 to 1993. The average difference between 1983 and 1993 IBI scores (>4 IBI units is considered significant) were only slightly higher in the upper half (+2.8 units; range of -4 to +13) than in the lower half (+1.6 units; range of -8 to +9). ADV values for the IBI declined from 84.7 units/mile to 46.3 units/mile in the upper half and from 39.0 units/mile to 32.6 units/mile in the lower half. ADV/mile values for the IBI showed the least improvement during 1993, an indication that fish assemblages remain functionally impaired in both segments. The cumulative number of fish species collected in the Little Miami River increased from 71 in 1983 to 83 in 1993.

Beaver Creek and Little Beaver Creek

Since 1983, the aquatic life use attainment status in Beaver Creek has shown no significant change downstream from Little Beaver Creek or the Greene Co. Beavercreek WWTP. Miles in PARTIAL attainment of WWH have remained at 0.4. Little Beaver Creek has improved only slightly with a decrease of miles in **NON** attainment (4.2 to 2.1) and an increase of in PARTIAL attainment (0.0 to 0.7 miles) of WWH. NON attainment was observed both upstream and downstream from the Montgomery Co. Eastern Regional WWTP. ADV/mile for the IBI and ICI both showed declines of approximately 50% between 1982 and 1993.

Turtle Creek

Aquatic life use attainment status (WWH) in Turtle Creek improved between 1983 and 1993. Miles in FULL attainment increased from 1.6 to 5.9 while miles in **NON** attainment decreased from 4.0 to 0.0. ADV statistics show a substantial decline to ADV/mile values at or near 0 in 1993. The WWH attainment status immediately downstream from Cincinnati Milacron, however, has recently decreased from FULL attainment during 1989 through 1992 to PARTIAL attainment in 1993.

Sycamore Creek
Since 1983, the aquatic life use attainment status in the lower one-half mile of Sycamore Creek has shown a slight improvement downstream from the Hamilton Co. MSD Sycamore Creek WWTP. The number of miles in PARTIAL attainment of WWH has increased from 0.0 to 0.3 with the miles in the poor to very poor performance range decreasing from 0.6 to 0.1 miles. ADV/mile values declined correspondingly, but still indicated significant impairment in 1993. Impairments exist both upstream and downstream from the Hamilton Co. Sycamore Creek WWTP. The upstream problems are primarily associated with instream sewer line construction and sanitary sewer overflows (Ohio EPA 1992b).

East Fork Little Miami River
The 1993 results show the attainment status within the East Fork has marginally deteriorated since 1982 due primarily to declines in IBI scores. Miles in FULL attainment of EWH decreased from 10.0 in 1982 to 7.1 in 1993, while the miles in PARTIAL attainment increased from 4.8 to 7.8 (Table 13). Compared to 1982, ICI scores increased in four segments, but declined in three (average increase of +1.4 units; range of -6 to +8), MIwb values increased in six segments and decreased in one (average increase of +0.7 units; range of -0.2 to +1.9), and IBI values declined in four segments and increased in three (average decrease of -1.4 units; range of -7 to +7). ADV values, however, indicate the slight magnitude of the declines with the greatest change exhibited by the IBI ADV/mile of 6.9 in 1982 to 15.7 in 1993. Neither value approaches those observed for the mainstem Little Miami River. The ADV/mile for the ICI and MIwb registered little if any changes.

Since 1982, commonly sampled segments upstream and downstream from the Batavia WWTP improved from PARTIAL to FULL (RM 15.5 - 12.7). The reach downstream from the Clermont Co. Middle East Fork WWTP to the confluence of Stonelick Creek has remained FULL. The site at Perintown (RM 6.7), however, decreased from FULL to PARTIAL attainment status. Suspected sources of impact may include the discharge of sewage to Sugar Camp Run, Shayler Run, and other nearby tributaries by SSOs, leaking interceptor sewers, and increased siltation from suburban development. Downstream from the Clermont Co. Lower East Fork WWTP use attainment status improved from PARTIAL to FULL, but evidence of impacts remained (*i.e.*, DELT anomalies). Use attainment in the segment upstream from the Milford WWTP remained PARTIAL and decreased from FULL to PARTIAL downstream from the Milford WWTP.

Point Source Discharge Summaries

The following are general summaries of information about the major point sources evaluated during the 1993 survey, arranged longitudinally from upstream to downstream:

City of Yellow Springs WWTP (Yellow Springs Cr. RM 0.44; Little Miami River (LMR) RM 85.17)
Macroinvertebrate and fish assemblages in Yellow Springs Creek showed no discernable evidence of adverse impacts from the Yellow Springs WWTP. Sites immediately upstream and downstream were in FULL attainment of EWH biocriteria, thus a use designation change from WWH to EWH is recommended. Mixing zone (the effluent splits into several channels in the floodplain and enters the headwater tributary at the upstream and downstream ends of a large bend) results indicated no obvious evidence of acute toxicity. Sludge deposits, however, were observed within the effluent channels and in Yellow Springs Creek immediately downstream. The incidence of DELT anomalies increased slightly in the Little Miami River mainstem downstream from Yellow Springs Creek (0.3 to 0.8%). Ammonia-N violations and phosphorus exceedences were also recorded downstream from the WWTP. The facility reported 25 NPDES permit violations (primarily for ammonia-N and suspended solids) during 1992. The potential impact of the effluent is apparently mitigated by the cascading falls and divided effluent channels that allow the discharge to enter Yellow Springs Creek at two or more widely spaced locations.

City of Xenia-Ford Road WWTP (Little Miami River RM 77.05)
Biological sampling in the mainstem revealed FULL attainment of the EWH biocriteria upstream and downstream from the Xenia Ford Rd. WWTP. The incidence of DELT anomalies increased within the mixing zone and downstream from the WWTP indicating some degree of impact, possibly a mild toxicity. The mean percentage of fish with DELT anomalies increased from 0.6% upstream to 4.1% in mixing zone to 1.6% downstream from the WWTP indicating some degree of impact. The mean number of fish with DELT anomalies increased from 7.8 to 51.8 to 16.6, respectively. Figures 76a - 77c show a positive relationship to the incidence of anomalies and total volume of effluent discharged to the upper half of the Little Miami River mainstem. The source(s) of stress within the effluent causing the higher than normal numbers of anomalies is not known, but may be due to a mild toxicity. A direct relationship with anomalies is also suggested in the mainstem with mean total phosphorus and total suspended solids concentrations, two common constituents of municipal WWTP effluent. These results do not, however, indicate widespread avoidance or acute toxicity. The facility reported 5 NPDES permit violations (primarily fecal coliform) during 1992. Grab water samples from the mainstem revealed one phthalate exceedence downstream from the WWTP and upstream from Shawnee Creek. Compared to 1983, the 1993 results reveal increased ICI, MIwb, and IBI scores (+6, +1.6, and +3 units, respectively). The use attainment status of the Little Miami River downstream from the WWTP improved to FULL from PARTIAL.

Montgomery Co. Eastern Regional WWTP (Little Beaver Cr. RM 4.57; Beaver Cr. RM 1.12)
Macroinvertebrate community performance declined from good upstream from the WWTP to poor downstream and further indicated an acutely toxic impact. Fish assemblages, however, were of poor quality both upstream and downstream from the WWTP suggesting an upstream source of impact as well. The tolerant fish assemblage showed no indication of avoiding the mixing zone. Habitat quality markedly declined downstream from the WWTP mixing zone, possibly the after-effect of old channelization. The channel was wide, shallow, and uniform with little instream cover. The macroinvertebrate and fish assemblages improved to good and fair quality, respectively, near the mouth. A large fish kill occurred downstream from the WWTP during 1992 due to a sewage spill. The facility reported 20 NPDES permit violations (primarily metals) during 1992. Ambient water chemistry showed elevated phosphorus levels throughout the four mile reach downstream from the WWTP. The mean number of fish species collected from Little Beaver Creek near the mouth increased from one (1) in 1982 to 15 in 1993.

Greene Co. Beavercreek WWTP (Beaver Creek RM 0.4; LMR RM 72.74)
Biological results from the mixing zone suggested no significant acute toxicity. Macroinvertebrates, however, declined from exceptional quality upstream from the WWTP to only fair quality downstream from the mixing zone. The fish community also changed with a decline in the MIwb and a reduction in the number of redhorse. Ambient water chemistry showed elevated phosphorus levels both upstream and downstream from the WWTP. The facility reported 4 NPDES permit violations (primarily mercury) during 1992. ICI, MIwb, and IBI scores in the mainstem of the Little Miami River downstream from Beaver Creek have significantly improved since 1983 (+24, +1.1, and +7 units, respectively) resulting in a use attainment status change from PARTIAL to FULL at the Narrows. All three biological index scores also increased (+10, +2.1, and +10 units, respectively) further downstream, however, the use attainment status changed from **NON** to only PARTIAL suggesting an impact due to the assimilation of an excessive total nutrient/organic loading from upstream discharges. Since 1983, the incidence of DELT anomalies in mainstem has decreased immediately downstream from Beaver Creek, but increased near Bellbrook within the impaired segment. Elevated phosphorus concentrations both upstream and downstream from this WWTP is also an indication of the high nutrient/organic loadings within the watershed.

Greene Co. Sugarcreek WWTP (Little Miami River RM 64.43)
Biological sampling in the mixing zone showed no evidence of significant acute toxicity to fish or macroinvertebrates. The fish community performance improved (*e.g.*,, higher MIwb and IBI values, high diversity, and slightly lower, but still elevated incidence of DELT anomalies) downstream from the WWTP, but returned to an impaired state at Spring

Valley. Ambient water chemistry results downstream from the WWTP showed the highest mean and maximum concentrations of ammonia-N and $CBOD_5$ within the upper half of the mainstem. A highly elevated concentration of bis (2-ethylhexyl) phthalate was also detected. The facility reported no NPDES permit violations during 1992.

City of Xenia-Glady Run WWTP (Glady Run RM 4.78; LMR RM 63.72)
Biological sampling in the mixing zone showed no evidence of significant acute toxicity, although macroinvertebrate community performance declined downstream from the WWTP. Ambient water chemistry showed elevated phosphorus levels along with residual chlorine and pesticide exceedences downstream from the WWTP. The facility reported only 3 NPDES permit violations (D.O. and mercury) during 1992. Downstream from the confluence of Glady Run, the Little Miami River had the highest mean concentration of phosphorus within the upper half of the mainstem. The incidence of DELT anomalies in the mainstem has increased since 1983 (from 5.0%/10.5/km in 1983 to 7.3%/34.2/km in 1993). Since 1983, however, biological index values have significantly increased (+ 10 ICI units, +1.6 MIwb units, and +13 IBI units) and the attainment the attainment status has improved from **NON** to PARTIAL.

City of Waynesville WWTP (Little Miami River RM 53.7)
The 1993 biological index scores from the Little Miami River mainstem downstream from the Waynesville WWTP indicate an impact from this facility and upstream WWTPs, but may also reflect physical habitat change from a predominance of high-gradient shallower habitats to large, deep low-gradient pools. The facility reported 7 fecal coliform NPDES permit violations during 1992 and 8 (primarily ammonia-N and D.O.) violations during 1993. Biological index scores since 1983, have remained similar for the ICI and IBI (+2 and -1 units, respectively) and increased moderately for the MIwb (+0.7 units). The aquatic life use attainment status of the mainstem has improved from **NON** to PARTIAL in the vicinity of the WWTP. The highest percentage (mean) of DELT anomalies (9.3%) in 1993 occurred in the mainstem downstream from this facility.

Cincinnati Milacron (Turtle Creek RM 0.5; LMR RM 33.2)
Turtle Creek, downstream from Cincinnati Milacron, the highest number of conventional parameter exceedences in the study area (6 parameters, 15 values) was observed. The facility reported only 4 NPDES permit violations (nickel and residual chlorine) during 1992; nine violations (silver and copper) were reported in 1993. Fish sampling in the mixing zone showed no evidence of significant acute toxicity. The presence of pollution sensitive fish species and IBI and ICI scores consistent with WWH biocriteria suggests the below standard MIwb value (which resulted in PARTIAL attainment) was due to the loss of deeper habitats as opposed to chemical impacts from Cincinnati Milacron. Water levels and flows in Turtle Creek (upstream and downstream from this discharger) were noticeably lower in 1993 than during previous years. De-watering appears to be the cause of the shallower than normal pool and run-riffle habitats, but the source(s) are in dispute. Biological sampling results prior to the de-watering impacts indicated FULL attainment of WWH under similar loadings from Cincinnati Milacron. Ambient water chemistry results, however, revealed copper, conductivity, total dissolved solids, ammonia-N, and phosphorus exceedences downstream from the facility. An elevated cadmium value was also recorded in the Little Miami River mainstem downstream from the confluence of Turtle Creek. Despite these exceedences, aquatic life use attainment has been FULL and is partially explained by the dynamics of the discharge. A diffuser was installed in 1993 in an attempt to alleviate effluent and mixing zone toxicity. The high number of exceedences are likely due to less dilution caused by the lower than normal flow. The industry reported a significant number of failed bioassays during 1992 and 1993.

City of Lebanon WWTP (Little Miami River RM 32.12)
Biological sampling within the mixing zone also showed no significant acute toxicity. Ambient water chemistry showed elevated concentrations of ammonia-N and phosphorus in the mixing zone. Fish in the mixing zone had an elevated incidence of DELT anomalies (6.1%, 40.3/km). The Lebanon WWTP reported no NPDES permit violations during 1992. Compared to 1983, the 1993 results showed significant biological improvements (+8 ICI units, +1.7 MIwb units, and +7 IBI units). Use aquatic life use attainment status downstream from the WWTP improved from PARTIAL to FULL attainment.

City of Mason WWTP (Muddy Creek RM 3.24; LMR RM 31.9)
Macroinvertebrate and fish community samples from Muddy Creek fully attained WWH biocriteria during the 1993 survey. An abundance of common carp and high percentage of other diptera/non-insects, however, were indicative of nutrient/organic enrichment from the WWTP. Sludge deposits were also evident along the stream margins at RM 2.5. Ambient water chemistry results downstream from the WWTP detected exceedences for residual chlorine, copper, phosphorus, and fecal bacteria. The facility reported 70 NPDES permit violations (primarily BOD_5 and suspended solids) during 1990 and 42 violations during 1992. The fish community at RM 1.6 has improved dramatically since 1981 when the IBI scored a 15 (and only 3 fish species were collected) compared to an IBI of 46 in 1993 (and 21 fish species were collected). Macroinvertebrates were not sampled in 1981 and have shown a slight improvement at RM 2.5 since 1989 (ICI scored a 28 in 1989 and a 34 in 1993). Fish sampling at RM 2.4/2.5 yielded an IBI of 23 in 1981, a 37 in 1989, and a 30 in 1991.

Warren Co. Lower LMR WWTP (Simpson Creek RM 0.1; LMR RM 28.1)
Ambient water chemistry samples from the Little Miami River downstream from Simpson Creek had the highest number of conventional parameter exceedences (4 parameters, 10 values) of all the mainstem sampling locations. Six (6) values exceeded the water quality standard for total residual chlorine, two (2) values for temperature, one (1) value for mercury, and one (1) value for phosphorus. The facility reported only 7 NPDES permit violations (primarily ammonia-N) during 1992. Biological sampling immediately downstream from Simpson Creek showed no evidence of significant acute toxicity. Since 1983, mean biological index scores have increased (+2 ICI units, +1.7 MIwb units, and +9 IBI units). The use attainment status has improved to FULL throughout an eight mile reach downstream from the WWTP.

Totes Inc. (Little Miami River RM 22.2)
Ambient water chemistry samples detected an elevated phosphorus value and highly elevated zinc concentration downstream from this industrial discharge. NPDES permit violations were reported for BOD_5 (7 in 1992) and suspended solids during 1992-3. The industry discharges to a large pool which has been adversely impacted by sedimentation. The PARTIAL use attainment status downstream from the discharge was due to a low MIwb value which was most likely due to a combination of excessive sedimentation and the lack of riffle-run habitat in the sampling zone. The incidence of DELT anomalies downstream from the discharge was one of the lowest in the mainstem (1.0%, 2.7/km).

Hamilton Co. MSD Polk Run WWTP (Unnamed Tributary RM 0.1; LMR RM 21.5)
Ambient water chemistry showed fecal bacteria and temperature exceedences in the mainstem downstream from the WWTP. The facility reported only one NPDES permit violation during 1992. Sanitary sewer overflows (SSO) begin to enter the mainstem here. Compared to the 1983 biological results, the 1993 samples show marked improvement has occurred to macroinvertebrate and fish assemblages downstream from the WWTP (+18 ICI units, +0.7 MIwb units, and +6 IBI units). Since 1983, the aquatic life use attainment status downstream from the facility has improved from NON to FULL.

Hamilton Co. MSD Sycamore Creek WWTP (Sycamore Creek RM 0.26; LMR RM 19.2)
Biological sampling in Sycamore Creek during 1993 detected no acute toxicity within the WWTP mixing zone and non attaining (fair) macroinvertebrate assemblages both upstream and downstream from the discharge. Fish assemblages improved from fair quality upstream from the WWTP to marginal good quality (attained WWH) downstream from the mixing zone. Sludge deposits, however, were observed only in the large pool downstream from the WWTP in 1993. Ambient water chemistry downstream from the WWTP in 1993 detected elevated phosphorus and fecal bacteria levels Elevated fecal bacteria levels were also detected in Sycamore Creek upstream from the WWTP. The highest number and total quantity of semi-volatile organic compounds in the study area occurred in Sycamore Creek downstream from the Sycamore Creek WWTP (RM 0.05). Thirteen (13) different PAH compounds were detected with a relatively high total concentration of 36.6 mg/kg (ppm). The sediment sample at this location also contained toluene (a solvent), the only

detected volatile organic compound. Only two (2) PAH compounds, both at markedly lower concentrations, were collected immediately upstream from the WWTP. The WWTP reported 20 NPDES permit violations for mercury in 1992 and a extremely high ambient mercury value (2.4 ug/l) was recorded in January 1994. In the Little Miami River downstream from the confluence of Sycamore Creek, mercury contamination was detected in spotted bass fillets (RM 18.5) and the use attainment status has remained PARTIAL since 1983, unlike many segments which have demonstrated improvement.

City of Batavia WWTP (East Fork LMR RM 13.5; LMR RM 11.5)
No ambient water quality exceedences were detected in 1993 downstream from the WWTP. Biological sampling in 1993 showed no evidence of significant acute toxicity. However, there was a marked decline in the percentage of top carnivores in the East Fork downstream from Batavia. The total relative numbers (density) of rock bass, smallmouth bass, and spotted bass combined (the three most abundant game species) declined from 167/km at RM 15.5 to 26/km at RM 12.7. Densities fluctuated further downstream, but remained low (6-61/km) to the mouth. The mean relative number of these three common game species in the lower 13 miles of the East Fork declined from 59/km in 1982 to 16/km in 1993. Compared to the 1982 results, the 1993 samples showed a decline of 2 ICI units, but higher MIwb +1.4 units) and IBI values (+7 units, the largest IBI increase from 1982 to 1993 of the eight East Fork sampling locations). A higher ICI value of 54 was recorded further downstream from the WWTP and immediately upstream from the Middle East Fork WWTP. The RM 2.7 macroinvertebrate sample also had the highest numbers of EPT taxa collected in the study area. Since 1982, however, the use attainment status improved from PARTIAL (1982) to FULL (1993) downstream from the WWTP. The 1993 incidence of DELT anomalies downstream from this discharge (0.9% at RM 12.7) was only slightly higher than upstream (0.7% at RM 15.5). Compared to the 1982 DELT percentages, the incidence of DELT anomalies in 1993 were lower at RM 15.5 (2.1% in 1982), but slightly higher at RM 12.7 (0.3% in 1982).

Clermont Co. Middle East Fork Regional WWTP (East Fork LMR RM 12.6; LMR RM 11.5)
Ambient water chemistry showed elevated phosphorus levels downstream from the WWTP. Biological sampling downstream from the WWTP showed no evidence of acute toxicity. Compared to the 1982 biological index scores, the 1993 results from RM 12.4 to 12.2 showed higher MIwb and IBI values (+1.9 and +2 units, respectively). The use attainment status was FULL in 1982 and 1993. The use attainment further downstream (RM 10.1/9.1) was also FULL despite a 5 unit decline in the IBI from 1982 to 1993 (the ICI and the MIwb increased +2 and +0.6 units, respectively). At Perintown (RM 6.7/6.6), the IBI also declined 5 units causing the use attainment status to change from FULL 1982) to PARTIAL (1993). The ICI also decreased 6 units while the MIwb remained unchanged since 1982. In addition to the assimilation of pollutants discharged by the two upstream WWTPs, sanitary sewer overflows (SSO) in Sugar Camp Run and other tributaries from within the Lower East Fork WWTP infrastructure may also contribute to the impacts observed at Perintown. Other possible sources include land development and spills. Since the previous survey, the incidence of DELT anomalies downstream from this discharge (RM 12.5 - 6.6) has increased (ranged from 0.9 - 1.5% in 1982 and 2.7 - 4.6% in 1993).

Clermont Co. Lower East Fork Reg.WWTP (East Fork LMR RM 4.9; LMR RM 11.5)
Ambient water chemistry showed elevated levels of phosphorus and fecal bacteria downstream from the WWTP. Biological results were indicative of no acute toxicity downstream from the effluent tributary, however, patches of waterwillow (a pollution sensitive aquatic plant) noticeably declined within the East Fork's channel downstream from the discharge. Although two (2) of the three (3) 1993 biological index scores from RMs 4.7 and 4.1 were slightly lower than in 1982 (- 4 ICI units, and - 0.2 MIwb units), the aquatic life use attainment status changed from PARTIAL to FULL due to a one (1) unit IBI increase. Further downstream (RM 2.4/1.7), the 1993 results showed higher values for the ICI (+4 units) and the MIwb (+0.5 units), but a lower IBI score (- 4 units). Longitudinally, the IBI also declined in 1993 from a 44 at RM 4.7 to a 36 at RM 1.7 (upstream from the Milford WWTP). The PARTIAL use attainment status has not changed in this segment since 1982.

City of Milford WWTP (East Fork LMR RM 1.3; LMR RM 11.5)
Ambient water chemistry downstream from the WWTP showed a below standard D.O. value and elevated levels of fecal bacteria. The WWTP reported 11 NPDES permit violations (mostly TSS) during 1992. Compared to the 1982 results, the 1993 samples showed increased values for the ICI and MIwb (+8 and +0.5 units), but lower IBI (-7 units) that caused the use attainment status to changed from FULL (1982) to PARTIAL (1993). The lower IBI score in 1993 may be partially attributed to sampling a different location which was comprised mostly of large deep pools. The Qualitative Habitat Evaluation Index (QHEI) scored a 65, the lowest value of the 8 East Fork sites.

CONCLUSIONS

- With more than 83 fish species, 36 mussel species, and 234 additional taxa of aquatic macroinvertebrates, the mainstem of the Little Miami River is one of the most biologically diverse rivers in Ohio. The mainstem fauna includes five (5) Ohio endangered species; blue sucker, mountain madtom, tonguetied minnow, rayed bean mussel, and wartyback mussel (Plates 7 - 8).

- Significant improvements have occurred since the 1983 survey, but recovery was not yet complete in 1993 due to a variety of impacts. The principal cause of the observed PARTIAL and **NON** attainment of aquatic life use designations are organic and nutrient enrichment from point sources. More than 99% of the effluent discharged by point sources is from municipal and county WWTPs as opposed to industrial sources. Although most of the WWTPs have significantly reduced total annual loadings of pollutants since 1983, the cumulative total amount of pollutants still exceeds the assimilative capacity of the Little Miami River between Bellbrook and Oregonia and in Hamilton and Clermont counties as evidenced by a failure to attain the EWH use designation.

- Higher than expected numbers of fish with external deformities, eroded fins, lesions/ulcers, and tumors (DELT anomalies) were collected in the mainstem downstream from many of the WWTPs, even in sections currently meeting EWH criteria (Plate 10). Expansion of flows at most of WWTPs poses a threat to the recovery of the mainstem to FULL EWH attainment and the specter of higher than normal DELT anomalies. The incidence of DELT anomalies was correlated with phosphorus levels in the mainstem.

- Nonpoint source pollutants, such as silt, manure runoff, and habitat alterations also impact streams throughout the watershed and pose a threat to the EWH goals. Stream protection measures, such as erosion controls, and improved riparian management and restoration are needed to bring other sections of the mainstem and tributaries into FULL attainment and protect and preserve the existing high quality segments.

- Future strategies to accomplish meeting WQS goals need to include reduced nutrient loadings, controlling the total volume of effluent discharged, watershed programs to reduce soil erosion, the virtual elimination of raw sewage releases (*i.e.*, CSO and SSO discharges), and the reduction and elimination of spills and other unauthorized releases throughout the basin.

- Pollutant discharges from spills, overflows, permit violations, and unauthorized releases are a significant source of acute and chronic stresses for aquatic communities in the Little Miami River watershed (Plate 10). Of the approximately 1500 incidents recorded by the Ohio EPA from 1983 to 1993, the most significant spills resulted in the cumulative discharge of more than 78,393,659 gallons and 48,326 pounds of pollutants (Appendix Table A-1). Sewage overwhelmingly

predominated these releases comprising 98.1% by volume and 53% of the spill events. Other pollutants included petroleum products (22%, 52 events), chemicals (13%, 32 events), and agricultural related activities (9%, 21 events). Spills and other pollutant releases have killed approximately 58,590 fish and other wild animals within the Little Miami River watershed since 1983 (Ohio DNR pollution investigations listed 49 incidents). Agricultural related activities (primarily manure runoff and fertilizer spills) were the leading cause (accounted for 37.3% of the total kill) followed by chemical/industrial sources (26.7%; primarily petroleum products and chemicals), public services (21.7%; primarily municipal sewage), and unknown causes (14.3%). The highest number of incidents in tributaries occurred within Greene (13), Clinton (12), and Clermont (11) counties. The highest number of incidents by subbasin occurred in the Todds Fork subbasin (12), East Fork subbasin (8); Shawnee Creek (6); Caesar Creek subbasin (6), and the Little Beaver Creek subbasin (3). Eighteen (18) of the kills have occurred during the last four years (1990-1993).

- The cumulative pattern of non-compliance with NPDES permit limits within the study area shows there is a high probability that one or more of the point sources will record a violation in any given month. During 1992, the 21 major point source dischargers reported a cumulative total of 225 NPDES permit violations (Table A-3). The highest number of exceedences were reported by the Mason WWTP (42), Cedarville WWTP (28), Yellow Springs WWTP (25), Hamilton County MSD Sycamore Creek WWTP (22), and the Montgomery County Eastern Regional WWTP (20). The combination of permit violations and pollutant discharges from spills, CSOs, SSOs, and stormwater outfalls subject the mainstem and tributaries to frequent episodes of ambient chemistry which approach or exceed water quality criteria. These episodes undoubtedly contribute to the observed PARTIAL and **NON** attainment of designated aquatic life uses and other symptoms of impacted aquatic communities (*i.e.,* increased incidence of external DELT anomalies, below standard biological index values).

- Sediments in the Little Miami River at Beechmont Avenue had the greatest number and the highest concentrations of contaminants in the study area. Contaminants included four (4) pesticides and nine (9) PAH compounds. Beechmont Avenue was the only site with highly to extremely elevated concentrations of heavy metals in the sediment. While future abatement efforts are needed throughout the basin, they are particularly important in Hamilton and Clermont counties to protect and enhance the only known reproducing Ohio population of blue suckers, one of the State's rarest endangered species.

- The frequency and distribution of fecal coliform and *E. coli* bacterial exceedences in the study area are also indicative of negative water quality impacts throughout the basin. Fecal bacteria counts exceeded the maximum criteria for the designated contact recreation use in 38.9% of the possible tests during the 1993 survey. Thirty-four (34) locations in nine (9) streams designated for Primary Contact Recreation (PCR) had one or more values which exceeded the maximum criterion. Eleven (11) locations in four (4) tributaries designated for Secondary Contact Recreation (SCR) had one or more values which exceeded the maximum criterion. Water with high fecal bacteria counts has been contaminated by human and/or animal wastes and may contain other harmful bacteria and/or viruses, thus posing an increased risk to humans for water borne disease and/or illness. Major sources of fecal contamination include WWTPs (spills, malfunctioning systems, and bypassing), CSOs, SSOs, failing on-site (septic) systems, livestock, wild animals, and urban runoff.

- Ambient fecal bacteria counts were usually highest immediately following a rainfall/runoff event. The highest counts within the study area occurred in the Little Miami River downstream from

South Charleston (fecal coliform; RM 101.3) and downstream from Sycamore Creek (*E. coli;* RM 18.14). Sites with the most exceedences were Sycamore Creek downstream from the Hamilton Co. Sycamore Creek WWTP (12 values; RM 0.05) and the Little Miami River downstream from the Lebanon WWTP (nine values; RM 31.96).

- Excessive levels of suspended sediment from soil erosion continue to enter the Little Miami River and tributaries following rainfall/runoff events. Fluvial sediment data from the Little Miami River at Milford between 1977 and 1986 showed a mean annual suspended sediment discharge of 474,000 tons. The Little Miami River had the third highest watershed rate (394 tons/year/square mile) of the 10 monitoring stations throughout Ohio with daily data reported between 1977 and 1986 (Hindall 1989). The Little Miami R. also had the highest rate for the four largest tributary rivers to the Ohio River mainstem. Major sources of sediment include agricultural runoff (row crops), construction activities, and severely eroding banks (Plate 12).

- Land use within the Little Miami River watershed is becoming increasingly developed (Plate 14). NPDES permit requests for new WWTPs and the expansion of existing WWTPs is an indication of increased suburbanization. The principal threats to rivers and streams from the increasing development include an increased demand for raw water supplies, increasing volumes of wastewater (resulting in increasingly effluent dominated stream flows), increased rates of runoff, riparian encroachment, and decreased groundwater recharge which helps maintain surface water base flows. To mitigate the negative effects of increased land development, resource management strategies such as stream protection measures, adequate and efficient WWTPs, pollution prevention, the implementation of new abatement programs (*e.g.*, stormwater runoff and CSO controls), and the protection and restoration of wooded areas (*e.g.*, Greene Co. Parks, City of Indian Hill Green Areas, and Little Miami Incorporated programs) are essential to restore and maintain this high quality water resource.

RECOMMENDATIONS

Based upon the findings of this report, the following general recommendations are made.

Point Sources

- Past upgrades at most WWTPs within the watershed have improved the aquatic life use attainment status in the mainstem and many streams throughout the watershed. Results from this study, however, indicate that the total cumulative pollutant loading discharged to the Little Miami River (directly or via tributaries) still exceeds the assimilative capacity of the mainstem. Evidence of point source impacts include elevated levels of DELT anomalies on fish, below standard biological index scores, and chemical criteria and fecal bacteria exceedences. The amount of flow from WWTPs in the Little Miami River watershed has increased since 1983 and the overall quality of macroinvertebrate and fish assemblages have generally improved. However, the highest performing EWH streams in Ohio receive markedly lower volumes of WWTP effluent (*e.g.*, Big Darby Creek). At approximately 50 MGD discharged during the third quarter of 1993, the Little Miami River mainstem receives the greatest volume of any EWH stream in the state. Conditions for granting increased volumes of effluent should be conservative and may need to include heretofore unconventional measures (*e.g.*, nutrient removal) in order to insure the restoration and maintenance of the EWH use designation.

- The source(s) of mercury and PAHs in Sycamore Creek downstream from the Hamilton County

MSD Sycamore Creek WWTP should be determined and controlled. Sludge samples from within the WWTP should be analyzed for these parameters as soon as possible to determine if the facility is responsible.

- The relatively frequent incidence of pesticides detected in excess of water quality criteria merits further investigation. While these compounds were found in upstream segments, the frequency of detection and exceedence was highest immediately downstream from selected WWTPs. The source of these compounds should be ascertained.

- Major sources of fecal bacteria contamination should be identified and corrected to improve the attainment of the Primary Contact Recreation (PCR) use designation within the Little Miami River mainstem and tributaries. Fecal bacteria counts exceeded the maximum criteria for the designated recreational use in 38.9% of the possible tests during the 1993 survey. Thirty-four (34) locations in nine (9) streams designated for Primary Contact Recreation (PCR) had one or more values which exceeded the maximum criterion. Eleven (11) locations in four (4) tributaries designated for Secondary Contact Recreation (SCR) had one or more values which exceeded the maximum criterion.

- The lime sludge discharge to the Little Miami River by the City of Milford Water Treatment Plant should be eliminated.

Nonpoint Sources

- A variety of stream protection techniques should be widely implemented throughout the watershed to significantly reduce soil erosion including (but not limited to) bank stabilization, restoring woody riparian vegetation, and best management practices for stormwater and soil erosion at construction sites.

- The number and quantity of spills and other unauthorized releases should be reduced and eliminated whenever possible. Actions should be taken against on-going sources of spills, overflows, and other unauthorized releases. SSO and CSO discharges should be eliminated, or controlled by treatment, particularly those that discharge during dry weather and under minimal precipitation events.

Status of Aquatic Life Uses

- Aquatic life uses for some streams evaluated during this study were originally designated in the 1978 Ohio WQS without the presently employed standardized approaches to the collection of instream biological data and numerical biocriteria. Revisions are recommended for certain stream segments because this study represents the first use of biological data and numerical biocriteria to evaluate and establish aquatic life use designations. While some of the 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.), these 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 made in 1978 (other than WWH) prior to basing any permitting actions on these existing, unverified use designations. Thus, some of the following aquatic life use recommendations constitute a fulfillment of that obligation. Based on the 1993 survey results, the following aquatic life use designation changes are recommended for streams within the Little Miami River basin study area.

Little Miami River: EWH Use Designation Existing;*WWH Recommended for Ohio R. backwaters (RM 3.0 - 0.0).*

Yellow Springs Creek: WWH Use Designation Existing; *EWH Recommended (entire length).*
Glady Run Swale: No Use Designation Existing; *WWH Recommended.*

No changes are recommended for the remaining 15 rivers and streams which were sampled.

Status of Non-Aquatic Life Uses

- Results of the present study support the existing non-aquatic life uses (Agricultural Water Supply, Industrial Water Supply, Primary Contact Recreation, and Secondary Contact Recreation) currently designated for the Little Miami River and selected tributaries. During the summer of 1993, fecal coliform and *E. coli* bacteria counts exceeded the Primary and Secondary Contact Recreation criteria in many of the streams sampled.

Future Monitoring

- Biological and water quality sampling should continue in the Little Miami River basin to track the progress in attaining improved water quality. The next complete survey for the watershed is scheduled for 1998 according to the Five-Year Basin Approach to Monitoring and NPDES Permit Reissuance. In addition to re-sampling the mainstem, biological and chemical monitoring should also be conducted in tributaries with reoccurring spills, fish kills, and other unauthorized releases. The highest number of incidents (12) occurred in the Todd Fork subbasin, with two tributaries (Lytle and Cowan Creeks) having received high ammonia-N concentrations from deicing chemicals and jet fuel from Airborne Express. Other areas with these types of incidents include the East Fork sub-basin (8), Shawnee Creek (6), Caesar Creek subbasin (6), and Little Beaver Creek subbasin (3).

- To determine the source(s) of the high number of water column organic exceedences in Little Beaver Creek and other streams with WWTPs, chemical water samples from locations upstream of the point source discharges should also be collected and analyzed for organics.

Table 1. Aquatic life use attainment status for the streams sampled in the Little Miami River basin, June-October 1993. Italics denote effluent mixing zone sampling locations.

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Use Attainment Status[c]	Comment
Little Miami River						
Eastern Corn Belt Plains - EWH Use Designation (Existing)						
102.1/101.5	33*	NA	E	62.0	PARTIAL	Dst. South Charleston
98.3/98.8	35*	7.8*	50	75.0	PARTIAL	Dolly Varden Road
92.2/89.2	35*	7.9*	E	68.5	PARTIAL	Pitchin Road /SR 72
85.4/85.3	47ns	9.0ns	46	87.0	PARTIAL	Grinnel Road
83.1/83.1	45ns	10.1	48	76.5	FULL	Jacoby Road
77.3/80.6	48	10.3	46	78.0	FULL	Ust. Xenia-Ford WWTP
77.0/77.0	*42*	*10.1*	*G*	*63.5*	*NA*	*Xenia-Ford Rd.WWTP mixing zone*
76.8/76.7	49	10.1	44ns	76.0	FULL	Dst. Xenia-Ford Road WWTP
74.5/74.6	48	10.5	E	77.5	FULL	Ust. Beaver Cr. (Beavercreek WWTP)
71.8/72.3	52	9.9	52	77.5	FULL	Dst. Beaver Cr. (Beavercreek WWTP)
64.7/65.6	41*	9.0*	44ns	73.0	PARTIAL	Ust Sugar Creek WWTP
64.4/64.4	*33*	*9.2*	*38*	*62.5*	*NA*	*Sugar Cr. WWTP mixing zone*
64.2/64.2	46ns	9.6	46	74.0	FULL	Dst. Sugar Cr. WWTP
63.4/63.0	39*	8.5*	46	71.0	PARTIAL	Spring Valley
53.5/53.2	33*	9.3ns	40*	65.0	PARTIAL	Dst. Waynesville WWTP
Interior Plateau - EWH Use Designation (Existing)						
47.5/47.5	39*	9.3ns	VGns	76.5	PARTIAL	Oregonia, OH
44.2/43.7	49	9.8	48	83.5	FULL	Ust. SR 350 near Ft. Ancient
38.6/38.6	47ns	10.0	50	83.5	FULL	SR 123, Morrow
35.50/35.9	49	10.2	VGns	76.5	FULL	Stubbs Mill Rd. near Morrow
32.9/32.9	47ns	9.3ns	56	74.0	FULL	Ust. Lebanon WWTP
32.1/32.1	*37*	*9.6*	*34*	*77.0*	*NA*	*Lebanon WWTP mixing zone*
31.9/32.0	48	11.0	56	86.5	FULL	Dst. Lebanon WWTP
- /30.7	-	-	52	-	[FULL]	Grandin Road
28.3/29.2	34*	9.0*	52	57.5	PARTIAL	Ust. Simpson Creek
27.9/28.0	50	10.7	E	80.0	FULL	Dst. Lower LMR WWTP
23.9/23.9	47ns	10.2	50	82.5	FULL	Loveland, OH
22.1/22.2	46ns	8.7*	VGns	63.5	PARTIAL	Dst. Tote's
21.5/21.4	49	10.4	56	84.0	FULL	Dst. Polk Run WWTP
20.9/20.6	45ns	9.6	58	80.0	FULL	I-275
18.5/18.9	40*	9.3ns	VGns	72.5	PARTIAL	Ust. Camargo Road
13.3/13.1	35*	8.8*	VGns	86.5	PARTIAL	Milford, OH
8.3/8.8	33*	8.9*	52	73.0	PARTIAL	Newtown Road
8.0/8.8	43*	10.1	52	82.0	PARTIAL	Bass Island
3.5/3.4	40*	9.9	42ns	77.5	PARTIAL	Beechmont Avenue
Interior Plateau - EWH Use Designation (WWH Recommended)						
1.6/1.6	33*	7.4*	F*	51.0	**NON**	Kellogg Avenue
0.2/0.4	29*	7.3*	F*	50.0	**NON**	Ust. mouth

Table 1. (continued).

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Use Attain-ment Status[c]	Comment
Yellow Springs Creek						
	Eastern Corn Belt Plains - EWH Use Designation (Recommended)					
0.5/0.5	48[ns]	NA	46	80.0	FULL	Ust. Yellow Springs WWTP
0.43/0.43	*51*	*NA*	*36*	*73.5*	*NA*	*Y.S.WWTP mixing zone*
0.3/0.3	50	NA	46	79.0	FULL	Dst. Yellow Springs WWTP
Oldtown Creek						
	Eastern Corn Belt Plains - WWH Use Designation (Existing)					
0.1/0.4	56	NA	38	82.5	FULL	Ust. mouth
South Fork Massies Creek						
	Eastern Corn Belt Plains - WWH Use Designation (Existing)					
- /2.1	-	-	E	-	[FULL]	Dst. Weimer Road, ust. quarry
1.1/1.1	30*	NA	VG	66.5	PARTIAL	Adj. Quarry
Massies Creek						
	Eastern Corn Belt Plains - WWH Use Designation (Existing)					
0.3/0.3	46	9.0	G	67.5	FULL	US 68
Beaver Creek						
	Eastern Corn Belt Plains - WWH Use Designation (Existing)					
1.6/1.6	28*	6.8*	48	54.5	PARTIAL	Dayton-Xenia Road
0.5/0.5	32*	8.7	48	74.0	PARTIAL	Ust. Beaver Cr. WWTP
0.39/0.39	*37*	*8.0*	*36*	*64.0*	*NA*	*Beaver Cr. WWTP mix zone*
0.3/0.2	32*	7.9[ns]	F*	70.5	PARTIAL	Dst. Beaver Creek WWTP
Little Beaver Creek						
	Eastern Corn Belt Plains - WWH Use Designation (Existing)					
4.7/4.7	26*	NA	40	67.5	**NON**	Ust. Montg. Co. E. WWTP
4.57/4.57	*23*	*NA*	*4*	*72.0*	*NA*	*Montg. WWTP mixing zone*
4.4/4.4	24*	NA	P*	48.5	**NON**	Dst. Montg. Co. E. WWTP
2.1/2.0	31*	NA	20*	76.0	**NON**	N. Fairfield Road
0.1/0.1	33*	7.0*	38	70.5	PARTIAL	Factory Road
Glady Run						
	Eastern Corn Belt Plains - WWH Use Designation (Existing)					
4.9/4.9	34*	NA	36	54.0	PARTIAL	Ust. Xenia WWTP swale
4.7/4.7	33*	NA	28*	66.0	**NON**	Dst. Xenia WWTP swale
0.3/0.3	40	NA	24*	69.0	PARTIAL	SR 725

Table 1. (continued).

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Use Attainment Status[c]	Comment
Glady Run Swale						
		Eastern Corn Belt Plains - WWH Use Designation (Recommended)				
0.3/0.3	24*	NA	F*	53.0	**NON**	Ust. Xenia WWTP
0.20/-	*28*	*NA*	-	*49.0*	*NA*	*Xenia WWTP mix zone*
0.1/-	40	NA	-	48.5	[FULL]	Dst. Xenia WWTP
Newman Run						
		Eastern Corn Belt Plains - WWH Use Designation (Existing)				
0.3/0.3	54	NA	F*	76.0	PARTIAL	US 42 near Waynesville
Anderson Fork						
		Eastern Corn Belt Plains - EWH Use Designation (Existing)				
5.0/5.0	54	10.0	G*	75.0	PARTIAL	Old Winchester Trail
Flat Fork						
		Eastern Corn Belt Plains - WWH Use Designation (Existing)				
1.7/1.7	24*	NA	F*	50.0	**NON**	Nonpoint at Oregonia Road
Caesar Creek						
		Eastern Corn Belt Plains - EWH Use Designation (Existing)				
16.5/16.5	46[ns]	9.5	VG[ns]	76.0	FULL	Springvalley-Paintersville Road
		Eastern Corn Belt Plains - WWH Use Designation (Existing)				
0.1/0.1	50	8.7	F*	81.5	PARTIAL	Dst. Reservoir at Corwin Road
Dry Run						
		Interior Plateau - WWH Use Designation (Existing)				
1.8/1.8	34*	NA	F*	54.5	**NON**	Snook Road
Turtle Creek						
		Interior Plateau - WWH Use Designation (Existing)				
6.3/6.3	43	NA	26[ns]	69.5	FULL	Glosser Road
4.7/4.3	39[ns]	8.5	36	69.5	FULL	McClure Road
0.6/0.6	50	10.1	MG[ns]	75.5	FULL	Mason Road
0.5/-	*41*	*8.3*	-	*68.0*	*NA*	*Dst. C. Mil. diffuser*
0.4/0.4	41	6.7*	26[ns]	68.0	PARTIAL	Dst. Cincinnati Milacron
0.1/0.1	46	8.9	16*	68.5	PARTIAL	Near mouth
Muddy Creek						
		Interior Plateau - WWH Use Designation (Existing)				
1.6/2.5	46	NA	34	78.0	FULL	Mason-Morrow Road

Table 1. (continued).

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Use Attain-ment Status[c]	Comment
Sycamore Creek						
		Interior Plateau - WWH Use Designation (Existing)				
0.4/0.5	34*	6.6*	F*	76.0	**NON**	Ust. Sycamore Cr. WWTP
0.26/0.26	*29*	*6.6*	*32*	*70.5*	*NA*	*Sycamore WWTP mixing zone*
0.2/0.1	38ns	7.7ns	20*	75.0	PARTIAL	Dst. Sycamore Cr. WWTP
Stonelick Creek						
		Interior Plateau - WWH Use Designation (Existing)				
20.0/17.7	30*	NA	24*	69.0	**NON**	Dst. Woodville Road
16.7/ -	30*	7.5*	-	48.0	**[NON]**	Stonelick Lake at SR 133
3.1/2.9	45	8.8	32	73.5	FULL	Dst. Lick Fork
1.2/1.0	49	10.4	36	78.0	FULL	US 50
East Fork Little Miami River						
		Interior Plateau - EWH Use Designation (Existing)				
15.5/15.5	45ns	9.4ns	54	86.0	FULL	Ust. Batavia at SR 222
-/13.3	-	-	46	-	[FULL]	Dst. Batavia WWTP
12.7/12.7	47ns	10.5	54	83.5	FULL	Dst. Batavia WWTP
12.4/-	47ns	11.1	-	87.0	[FULL]	Dst. Middle EFK WWTP
9.2/9.2	44ns	10.4	54	86.0	FULL	Olive Branch Stonelick Rd.
6.6/6.7	42*	9.4ns	46	87.0	PARTIAL	Roundbottom Road
4.7/4.7	44ns	10.1	44ns	68.5	FULL	Dst. Lower EFK WWTP
1.7/1.9	36*	10.2	48	70.5	PARTIAL	I-275, ust. Milford WWTP
1.4/0.8	39*	10.0	50	65.0	PARTIAL	Dst. Milford WWTP

Ecoregional Biological Criteria:

	E. Corn Belt Plains (ECBP)			*Interior Plateau (IP)*		
INDEX - Site Type	WWH	EWH	MWHd	WWH	EWH	MWHd
IBI - Headwaters	40	50	24	40	50	24
IBI - Wading	40	50	24	40	50	24
IBI - Boat	42	48	24	38	48	24
Mod. Iwb - Wading	8.3	9.4	6.2	8.1	9.4	6.2
Mod. Iwb - Boat	8.5	9.6	5.8	8.7	9.6	5.8
ICI	36	46	22	30	46	22

* significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns nonsignificant departure from ecoregional biocriteria for WWH or EWH (≤4 IBI, ≤4 ICI, ≤0.5 MIwb units).
NA Not applicable.
a Narrative evaluation used in lieu of ICI (E=Exceptional; VG= Very Good; G=Good; MG=Marginally good; F=Fair; P=Poor; VP=Very Poor).
b Qualitative Habitat Evaluation Index (QHEI) values based on Rankin (1989).
c Attainment status based on one organism group is parenthetically expressed.
d MWH (Modified Warmwater Habitat) for channel modified areas.

Table 2. Waterbody segment (305b) summaries for streams sampled in the Little Miami River basin during 1993.

Waterbody (RM) Upper/Lower	Segment Length	Attainment Miles FULL	PARTIAL	NON	Unknown	Causes, Sources, and Comments
Little Miami River (Exceptional Warmwater Habitat)						
105.5/91.6	13.8	0.0	10.5	0.0	3.3	*Causes:* ammonia, nutrients, organic enrichment/D.O., residual chlorine, habitat alteration, silt, pesticides *Sources:* manure runoff (Pay Gro), S. Charleston WWTP, agriculture, livestock *Comments:* low D.O., fecal bacteria and pesticide exceedences, large fish kill in 1992
91.6/79.5	12.1	5.9	6.2	0.0	0.0	*Causes:* metals (Cu), D.O., habitat alteration, silt, ammonia, nutrients, pesticides *Sources:* manure runoff (Pay Gro), S. Charleston WWTP, agriculture, livestock *Comments:* ambient D.O., fecal bacteria, Cu, and pesticide exceedences; elevated incident of DELT anomalies
79.5/72.7	6.8	6.8	0.0	0.0	0.0	*Comments:* ambient residual chlorine, fecal bacteria, phosphorus, phthalate, and pesticide exceedences; sewage and chemical spills in Shawnee Cr., elevated incident of DELT anomalies
72.7/63.7	9.0	6.5	2.5	0.0	0.0	*Causes:* ammonia, CBOD, TSS, cumulative nutrient load, large D.O. swing *Sources:* Montgomery Co. East Reg. WWTP, Greene Co. Beaver Creek and Sugar Creek WWTPs, Xenia Glady Run WWTP, Xenia-Ford WWTP *Comments:* improving quality, but elevated incidence of DELT anomalies; ambient fecal bacteria, phthalate, and pesticide exceedences
63.7/50.9	12.8	0.3	12.5	0.0	0.0	*Causes:* nutrients, CBOD, TSS *Sources:* Xenia Glady Run WWTP, Waynesville WWTP, cumulative nutrient load from other upstream WWTPs *Comments:* improving quality, but elevated incidence of DELT anomalies; ambient fecal bacteria and phosphorus exceedences
50.9/38.5	12.4	5.7	6.7	0.0	0.0	*Causes:* nutrients, TSS, sedimentation *Sources:* cumulative nutrient load from upstream WWTPs, land development, agriculture *Comments:* ambient fecal bacteria and pesticide exceedences
38.5/33.2	5.3	5.3	0.0	0.0	0.0	*Comments:* ambient pesticide exceedences, frequent spills in Todd Fork basin

Table 2. Continued.

Waterbody (RM) Upper/Lower	Segment Length	Attainment Miles FULL	PARTIAL	NON	Unknown	Causes, Sources, and Comments
Little Miami River, continued						
33.2/24.0	9.2	8.2	1.0	0.0	0.0	*Causes:* sedimentation, nutrients, ammonia, metals (Cd, Hg) *Sources:* Cincinnati Milacron, Lebanon WWTP, Mason WWTP, Warren Co. Lower LMR WWTP, cumulative nutrient load, land development, agriculture *Comments:* ambient fecal bacteria, cadmium, phosphorus, pesticide, temperature, residual chlorine, and mercury exceedences
24.0/11.5	12.5	2.2	10.3	0.0	0.0	*Causes:* metals (Hg), nutrients, sedimentation, CBOD, ammonia, TSS *Sources:* Hamilton Co. MSD Polk Run and Sycamore Cr. WWTPs, Batavia WWTP, Clermont Co. Middle and Lower East Fork WWTP's, Milford WWTP; CSOs, SSOs, cumulative nutrient load, land development, agriculture *Comments:* ambient phosphorus, zinc, temperature, fecal bacteria, and pesticide exceedences
11.5/0.0	11.5	0.0	8.5	3.0	0.0	*Causes:* CSOs, sedimentation, nutrient enrichment, hydromodification *Sources:* Hamilton Co. MSD, Clermont Co. MSD, Ohio River backwater, landfills, cumulative nutrient load, land development, agriculture *Comments:* segment contains Ohio endangered species; temperature, ambient phosphorus, fecal bacteria, and pesticide exceedences; WWH recommended for lower three miles
Yellow Springs Creek (Exceptional Warmwater Habitat)						
2.5/0.0	2.5	0.5	0.0	0.0	2.0	*Comments:* fecal bacteria, phosphorus, ammonia, and pesticide exceedences; sludge deposits from Yellow Springs WWTP, EWH use recommended
Oldtown Creek (Warmwater Habitat)						
6.0/0.0	6.0	0.4	0.0	0.0	5.6	*Comments:* ambient fecal bacteria and pesticide exceedences; lower section predominantly channelized.
Massies Creek (Warmwater Habitat)						
9.9/0.0	9.9	0.3	0.0	0.0	9.6	*Comments:* ambient fecal bacteria exceedences; numerous permit violations by Cedarville WWTP
South Fork Massies Creek (Warmwater Habitat)						
9.6/0.0	9.6	0.5	1.0	0.0	8.1	*Causes:* habitat modifications, channelization, unknown *Sources:* agriculture, quarry *Comments:* historical hydromodification adjacent to quarry

Table 2. Continued.

Waterbody (RM) Upper/Lower	Segment Length	Attainment Miles FULL	PARTIAL	NON	Unknown	Causes, Sources, and Comments
Beaver Creek (Warmwater Habitat)						
8.4/0.0	8.4	0.0	1.6	0.0	6.8	*Causes:* habitat, nutrients, unknown *Sources:* Greene Co. Beaver Creek WWTP, Montgomery Co. East Reg. WWTP, unknown *Comments:* ambient phosphorus, fecal bacteria, and pesticide exceedences; ICI and MIwb decline downstream from the Beaver Creek WWTP
Little Beaver Creek (Warmwater Habitat)						
9.0/0.0	9.0	0.0	0.1	4.6	4.3	*Causes:* metals (Ag, Zn, Cu, Cn, Ni), ammonia, unknown , habitat *Sources:* Montgomery Co. Eastern WWTP, unknown upstream source (possibly spills) *Comments:* ambient temperature phosphorus, fecal bacteria, and pesticide exceedences; fish kill, toxicity to macroinvertebrates in the mixing zone of the Mont. Co. WWTP
Glady Run Swale (Warmwater Habitat)						
0.6/0.0	0.6	0.1	0.1	0.0	0.4	*Causes:* channelization, nutrients *Sources:* Xenia Glady Run WWTP *Comments:* ambient phosphorus exceedences, recovering channel downstream from railroad grade
Glady Run (Warmwater Habitat)						
6.3/0.0	6.3	0.0	0.5	4.4	1.9	*Causes:* flow alteration, bacteria, chlorine, phosphorus, pesticides *Sources:* natural, Xenia Glady Run WWTP *Comments:* ambient residual chlorine, phosphorus, and pesticide exceedences, washout has rerouted Glady Run's flow into the WWTP Swale, macroinvertebrates declined in Glady Run downstream from the swale (WWTP)
Newman Run (Warmwater Habitat)						
4.0/0.0	4.0	0.0	0.3	0.0	3.7	*Causes:* flow alteration *Sources:* natural drought conditions *Comments:* exceptional fish assemblage during early summer, but only fair macroinvertebrate assemblage on 31 August
Anderson Fork (Exceptional Warmwater Habitat)						
18.3/11.0	7.3	0.0	0.5	0.0	6.8	*Causes:* unknown *Sources:* unknown, natural (possibly drought affected) *Comments:* exceptional fish assemblage, but only a good macroinvertebrate assemblage; ambient D.O. and pesticide exceedences
Flat Fork (Warmwater Habitat)						
3.7/0.0	3.7	0.0	0.0	1.7	2.0	*Causes:* organic enrichment/low dissolved oxygen, low flow *Sources:* agriculture (possibly animal husbandry), natural drought *Comments:* ambient bacteria, DO, and pesticide exceedences, poor fish and fair macroinvertebrate assemblages