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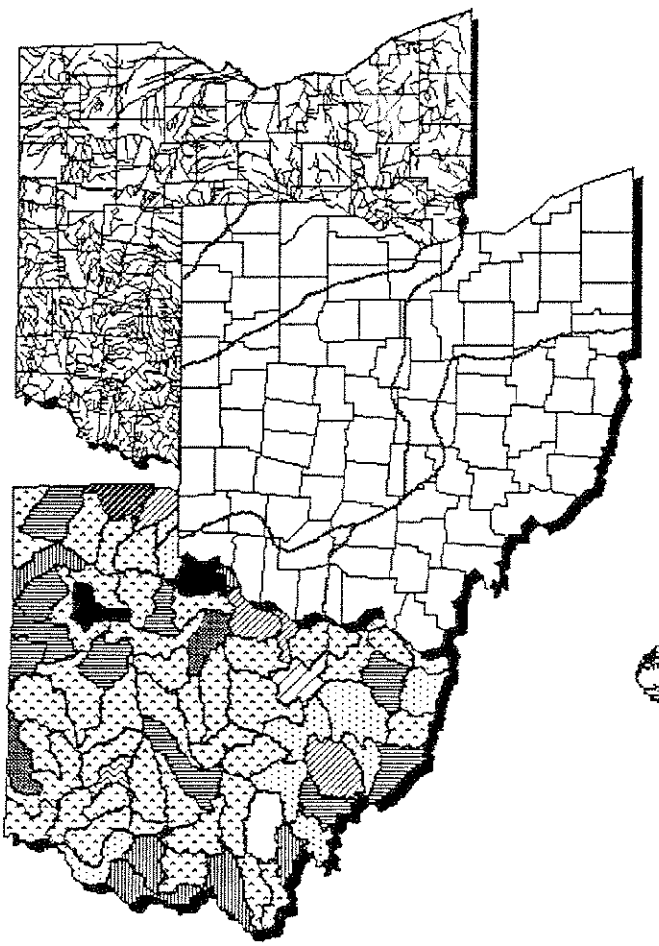
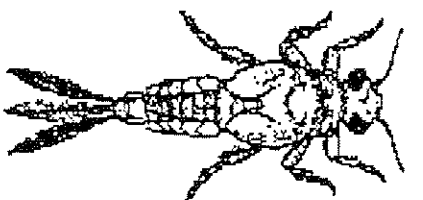
State of Ohio
Environmental Protection Agency

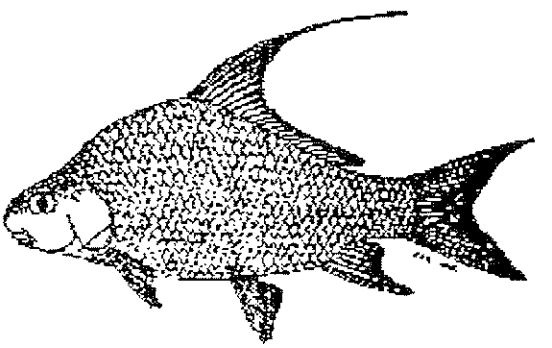
Ecological Assessment Section
Division of Water Quality
Planning & Assessment

Biological and Water Quality Study of the Hocking River Mainstem and Selected Tributaries

Fairfield, Hocking, and Athens Counties, Ohio







October 25, 1991

P.O. Box 1049, 1800 WaterMark Dr., Columbus, Ohio 43266-0149

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Report Number EAS/1991-10-6

October 25, 1991

prepared by

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Introduction

The Hocking River mainstem study area extended from upstream from Lancaster (RM 95.2) to downstream from Coolville (RM 4.6). Also included were chemical effluent and biological mixing zone samples from the Lancaster, Logan, Nelsonville (effluent only), and Athens wastewater treatment plants (WWTPs). Major tributaries were generally sampled near their confluences with the mainstem and included Hunters Run (biological only), Baldwin Run, Rush Creek, Clear Creek, Oldtown Creek, Athens County Landfill Tributary (chemistry only), Monday Creek and its tributary, Little Monday Creek, Sunday Creek, an unnamed tributary to Sunday Creek (fish and chemistry only), Federal Creek and its tributaries, McDougall Branch and Sharps Fork.

Specific objectives of this evaluation were to:

1) Evaluate potential near-field and far-field impacts associated with major municipal WWTPs in Lancaster, Logan and Athens.
2) Evaluate biological and chemical water quality conditions to document current conditions, recommend appropriate aquatic life use designations, pinpoint problem areas and assess trends. Major tributaries were sampled primarily in relationship to their potential effects on the mainstem.
3) Resample and evaluate reference sites for the continued development of ecoregional chemical and biological databases.
4) Compile baseline data for future monitoring comparisons.

The findings of this evaluation may factor into regulatory actions taken by Ohio EPA (*e.g.* NPDES permits) and eventually be incorporated into the State water quality management plans and biennial 305(b) report.

Conclusions

Aquatic Life Use Attainment - Hocking River

The water quality standards attainment status of designated and recommended aquatic life uses in the Hocking River basin study area during 1990 is found in Table 1. The 90.6 miles of the Hocking River mainstem upstream from Lancaster (RM 95.2) to Coolville (RM 4.6) included 31.3 miles fully attaining the current warmwater habitat (WWH) aquatic life use, 43.8 miles partially attaining, and 16.1 miles not attaining. Approximately 50% of the non-attaining river miles were in the upper mainstem and over half of these miles had biological performance in the poor range as indicated by the fish community indices.

Surface water impacts in the upper basin were primarily related to point source discharges from the Lancaster wastewater treatment plant (WWTP), and the 22 combined sewer overflow (CSO) sites on the mainstem and in the Baldwin Run drainage. Urban runoff and past channelization activity in Lancaster also contributed to degraded chemical water quality and reduced biological performance but these influences were considered secondary to the point source discharges. Full attainment of the WWH aquatic life use designation in Hunters Run, an urban and modified tributary which lacks CSO discharges, is an indication of the greater point source influence in the mainstem and Baldwin Run.

Impacts in the lower mainstem were mostly related to sedimentation associated with mine drainage, channel modifications, and moderate to severe bank erosion. Impoundment of the Ohio River by navigational locks and dams also influenced the lower 12 miles of the mainstem. Overall, the highest quality portion of the river was in a 20 mile section between Logan and Nelsonville, downstream from the area impacted by Lancaster and upstream from the acid mine drainage (AMD) impacted Monday and Sunday Creek sub-basins.

Point Source Impacts

Chemical water quality and biological impacts associated with the Lancaster WWTP and CSOs ranged from slight to severe in 1990 and were considered primarily related to organic enrichment. These results however, represented a substantial improvement over the grossly polluted and toxic conditions observed in Lancaster prior to large-scale system upgrades instituted in the mid to late 1980s. Although some continued or residual impacts were observed in 1990, further improvements may occur with additional time following the full implementation of the pretreatment program and recent upgrades in the system.

The Logan WWTP had little demonstrable effect on chemical and biological conditions downstream. Some mild organic enrichment appeared to be associated with the discharge. The percentage of fish with external anomalies from the mixing zone was the second highest observed in the study area. However, biological communities recovered quickly downstream from the discharge and mixing zone area.

No significant biological or chemical impacts were detected 0.5-0.7 miles downstream from the Nelsonville WWTP although mixing zone sampling was not conducted and the condition of the sewer system is poor. The high ammonia levels detected during effluent sampling (mean=23 mg/l) and past observations of large amounts of sludge associated with the discharge indicate potential for more noticeable impacts "near-field" or during more severe low flow conditions.

The Athens WWTP mixing zone had little negative influence on the macroinvertebrate community, but fish community performance was poor. External anomalies in the mixing zone sample were the highest recorded in the study area and considered primarily related to organic enrichment. The low fish community index scores may have been particularly affected by the degraded habitat conditions in the severely channelized area immediately adjacent to the WWTP. Overall biological performance improved downstream and was controlled more by the prevailing habitat and substrate conditions than any extended impacts from the WWTP.

Physical Habitat Quality

Channelization adversely impacted the biota in localized areas in Lancaster and Athens. It was also evident that these areas impacted biological communities downstream from the channelized sections due to increased current velocities during high water periods, accelerated delivery of sediment and silt, and increased bank erosion. In 1990 the combination of high flows, accelerated sediment delivery due to increased runoff from abandoned mine lands, and moderate to severe bank erosion (partially due to encroachment on the riparian zone) resulted in observations of excessive instream sediment bed load and numerous areas of seriously destabilized banks. Although unstable and eroding banks appeared to be a significant problem throughout the mainstem, these impacts were the most severe in the lower, unglaciated section of the mainstem.

Historical Trends

Compared to a 1982 Ohio EPA biological and water quality survey, there are indications of significant chemical and biological improvement in the upper mainstem following system upgrades and the initiation of pretreatment programs in Lancaster. Since 1982, the upper Hocking River has exhibited some of the largest improvement in biological performance of any river system in the state. However, total recovery from the severely degraded conditions observed in 1982 was not complete in 1990. In 1982, 15.7 miles of the 20.5 mile section between Lancaster and Enterprise demonstrated poor and very poor conditions. In 1990, almost two thirds of this section attained or partially attained the WWH use and the extent of poor performance was substantially reduced. The total Area of Degradation Value (ADV) scores in this section were reduced by approximately 85% from 1982-1990 and these results correlate well with the chemical results obtained during the two intensive surveys and from the monthly monitoring site located at RM 87.3, just downstream from Lancaster (see p.15 for a description of the ADV). Water quality conditions have improved substantially as evidenced by reduced concentrations of ammonia-nitrogen, BOD, cyanide, nutrients, several heavy metals, and increased concentrations of dissolved oxygen (D.O.). The most substantial improvements occurred in 1988 and 1989 which corresponds to improvements made at the Lancaster WWTP. However, elevated concentrations of ammonia-N and other parameters were still detected in some samples in 1990 which corresponds to the incomplete recovery noted in the biological community performance of this section of the mainstem.

Levels of D.O. in the river downstream from the Athens WWTP appears to have improved between the late 1970s and late 1980s based on Ohio EPA and USGS continuous monitor data. Upgrades of the Athens sewer system and improved plant operation are likely the major reasons for improvement. In addition, instream D.O. concentrations in the Athens area may also have been influenced by the relocation of the channel in the early 1970s and the

subsequent loss of canopy, widening of the channel and shallow depths. Observations in 1990 indicate some recovery of the channel is taking place between the levies and its restoration should continue if left undisturbed. It is believed that a moderate degree of habitat recovery can occur without compromising the flood protection functions of the original channel diversion.

Recommendations

Aquatic Life Use Designations

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

Hocking River Mainstem

The existing WWH use designation is considered appropriate for the entire length of the mainstem based on the full or partial attainment of biological communities throughout most of the river coupled with a lack of severe background physical impacts. Impacts associated with channelization were not considered sufficient to change the existing WWH use designation due to their localized nature, adequate gradient to promote recovery, and the documented biological performance which, in most areas, met or exceeded the modified warmwater habitat (MWH) criteria. Full WWH attainment in Hunters Run, a modified, urban tributary in Lancaster which lacks point source discharges reinforces the WWH designation for the mainstem. The substantial improvements in biological and chemical quality observed in the Lancaster area are also indications of WWH potential and the ability of the river to recover.

Hunters Run

The current WWH designation is considered appropriate based on the full attainment of biological communities at RM 0.5. Habitat conditions in the channel modified stream were somewhat marginal (QHEI=50) but adequate to support WWH communities. Some oily deposits observed in sediments may have resulted from a diesel fuel spill which occurred in the spring of 1991 at the Lancaster Electroplating Plant.

Baldwin Run

Currently designated WWH, Baldwin Run was similar to Hunters Run in size and habitat quality (QHEI=50.5). NON attainment of the fish and macroinvertebrate communities near the mouth was considered a result of CSO point source discharges upstream. No changes to the existing WWH aquatic life use designation are recommended.

Rush Creek

Rush Creek was originally designated Limited Resource Water (LRW) in 1982 due to the severe impact of acid mine drainage from abandoned mine lands in the upper basin (upstream from Little Rush Creek) and the occasional detection of acidity in the lower mainstem. These impacts were coupled with the presence of excessive sedimentation, precipitated solids and metals, and extensive channel modifications in the lower mainstem. Sampling near the mouth of Rush Creek in 1990 indicated improved biological and chemical conditions (compared to 1982). In addition to higher flows during 1990, improvements may be related to a number of factors including point source upgrades at Bremen, mine closures, abandoned mine land (AML) reclamation in the upper basin, and some limited physical habitat recovery following the channel work performed in the early to mid 1980s. However, despite these limited improvements, the input of acid mine drainage and associated excessive sediment loadings continues and may necessitate future channel maintenance in the lower mainstem. Also, during the late summer of 1991, several slugs of acidic water were observed in lower Rush Creek after light rains which followed extended periods of drought. Apparently, these conditions favored accumulation of surface acid in the AML areas which was then washed into the receiving stream (Ohio EPA Emergency Response IOC, 1991). Macroinvertebrate collections from RM 2.1 during these periods were in the marginally good range (ICI=34) compared to the very good-exceptional conditions in 1990 (ICI=46). Based on all findings, the modified warmwater habitat (MWH-mine drainage) designation is recommended for the 15.7 mile section between Little Rush Creek and the mouth.

Clear Creek

The existing WWH use is considered appropriate. This use was determined from instream biological sampling conducted in 1982. Although macroinvertebrate collections suggest exceptional warmwater habitat (EWH) potential, the fish community failed to exhibit EWH characteristics.

Oldtown Creek

The WWH designation should be retained based on the presence of adequate habitat conditions (QHEI=69.5) and partial attainment of the WWH use based on the 1990 results.

Athens County Landfill Tributary

Based on water quality conditions, drainage area size (< 3 sq. mi.), occasionally low pH (<6.5 S.U.), and the sandstone geotype, the LRW-acid mine drainage designation is considered appropriate for this undesignated stream.

Little Monday Creek

Currently designated a Limited Warmwater Habitat (LWH) - acid mine drainage stream (based on the 1978 Ohio WQS), biological communities were very near partial attainment of the WWH use and chemical violations of WWH criteria were limited to a single iron exceedence. Elevated sulfates and manganese indicate surface mining impacts, but no serious acid mine problems were noted. The WWH designation is considered appropriate.

Monday Creek

The existing LRW-acid mine drainage designation is considered appropriate based on severe biological and chemical degradation due to acid mine drainage from extensive abandoned mine

lands throughout the watershed.

Sunday Creek
Currently designated LWH-acid mine drainage (based on the 1978 Ohio WQS), the biological and chemical conditions near the mouth were similar to those observed in Monday Creek. Portions of the subbasin have some limestone geotype, but this appeared to have no significant positive influence on the lower mainstem. The LRW-acid mine drainage designation is considered appropriate given the existence of extensive abandoned mine lands in the watershed.

Unnamed Tributary to Sunday Creek
This small headwater tributary to Sunday Creek is currently undesignated in the Ohio WQS. Based on the habitat evaluation (QHEI=67.5) and the lack of any acute acid mine drainage impacts the appropriate use is WWH. The WWH biocriteria for the IBI were not achieved due primarily to the limiting effects of sedimentation.

Federal Creek
The existing EWH designation for Federal Creek upstream from Sharps Fork is considered appropriate based on full attainment of the use. Although the EWH designation dates back to the 1978 Ohio WQS, the biological results confirm that the use is appropriate. This segment also possesses adequate habitat quality and exhibits a lack of significant chemical water quality problems. Partial attainment of the EWH designation was observed during both 1984 and 1990 in the lower section of Federal Creek which currently is designated as an LWH-acid mine drainage stream. Partial attainment of the EWH involving *both* organism groups indicates that the EWH use is appropriate for this segment as well. Chemical data were not indicative of significant mine drainage problems in this section and the physical habitat is adequate to support the recommended EWH designation.

McDougall Branch / Sharps Fork
A change in the use from the current EWH designation to the WWH designation is recommended. The EWH designation originally dates back to the 1978 Ohio WQS. NON attainment of the EWH biological criteria in Sharps Fork, a lack of FULL attainment in past (1983, 1984) and present samples from McDougall Branch, coupled with the habitat evaluation results for each stream (mean QHEI=58), resulted in the WWH recommendation.

Aquatic Habitat and Nonpoint Source Impacts

Biological results and habitat observations in 1990, particularly from the lower mainstem, demonstrated the adverse impacts associated with channel modifications and encroachment on the riparian zone including tree removal, both of which result in a loss of bank stability. These conditions were exacerbated by the already extensive inputs of sediments from upland nonpoint sources. Based on these results, consideration should be given by the appropriate authority (County Engineers or local conservancy districts) to modifying and where possible, reducing or eliminating channel maintenance programs which adversely affect habitat quality in the basin. A full review of any existing maintenance of new channel modification programs on streams and rivers designated WWH or EWH is recommended to ensure drainage benefits are commensurate with the resultant environmental damage.

The lack of any significant woody riparian buffer along the mainstem contributes markedly to the moderate to severe bank erosion. In some sections the entire bank is devoid of any woody vegetation which leaves the banks open to severe erosion especially during elevated flows. Any further clearing or disturbance of riparian borders in the lower section of the basin should be discouraged and efforts should be made to restore woody buffer strips in already denuded sections. In some areas this requireS immediate intervention using vegetative bank stabilization techniques (*e.g.*, dormant willow plantings, waddlings), while in other areas natural succession should be permitted to occur. Single rows of trees, as was evident in several sections, did little to deter bank erosion. The goal for the mainstem should be to achieve *woody* vegetative buffer strips of widths at least equal to *two* widths of the river on either bank. This should have the net effect of stabilizing the river channel within its normal meander and also initiate a reduction in the amount of sediment as bed load. It may also be necessary to stabilize some of the active bed load segments that are presently migrating downstream and destabilizing adjacent stream banks. These bed loads were most often observed immediately downstream from the extensively channelized segments.

Localized elevations of fecal coliform bacteria counts in portions of the mainstem suggest the presence of failing on-site disposal systems. The status of these systems should be determined and improved.

Future Monitoring Concerns

- Conduct additional sediment sampling for heavy metals and organics in the Lancaster urban area to determine background levels and possible residual contamination from heavy industrial and CSO discharges prior to further assessment and upgrading of the Lancaster sewer system.

- Collect continuous monitor data for D.O. in the Lancaster area to determine diurnal trends.

- Continue to monitor the upper Hocking mainstem near Lancaster to determine if improvement trends observed in 1990 continue. Also, expand the study area upstream to evaluate increasing housing and commercial development in the headwaters north of Lancaster.

- Conduct additional sampling in the middle section of Rush Creek to document potential changes in chemical, physical, and biological conditions following upgrading of the Bremen WWTP, recovery from past channelization, and AML reclamation conducted in the headwaters. Also, investigate specific causes and sources of mine drainage slugs observed in Rush Creek during the summer of 1991.

- Verify upstream extent of acid mine drainage in Sunday Creek and Monday Creek and biologically evaluate other streams in the basin which are currently designated as Limited Warmwater Habitat due to mine drainage.

Table 1. Summary of aquatic life use attainment status for stations in the Hocking River basin based on data collected during July to October, 1990. Attainment status is based on ecoregional criteria for the Erie-Ontario Lake Plain and Western Allegheny Plateau ecoregions.

Stream Name River Mile Fish / Invertebrate	IBI	MIwb	ICI[a]	QHEI[b]	Warmwater Habitat (WWH) Attainment Status[c]	Comments
Hocking River Mainstem						
95.2 / 95.1	35[ns]	8.2	50	66.5	FULL	Ambient
92.2 / 91.9	27*	6.5*	52	44.0	NON	Channelized
90.8 / 90.7	28*	6.9*	46	37.0	PARTIAL	Dst. CSO's; urban
89.4 / 89.4	24*	5.9*	38	42.0	NON	Dst. Wheeling Lift Sta.
89.1 / 89.1	25*	4.7*	26*	49.5	**	Lanc. WWTP mix zone
89.0 / 88.9	30*	6.5*	32[ns]	38.0	PARTIAL	Dst. WWTP mix zone
87.1 / 87.2	25*	4.9*	MG[a]	59.0	NON	Dst. Lancaster
82.0 / 82.9	33*	6.5*	46	62.0	PARTIAL	Dst. Lancaster
81.2 / 81.3	39[ns]	8.1[ns]	44	57.5	FULL	Dst. Rush Creek
77.2 / 77.1	34*	7.5*	G[a]	63.5	PARTIAL	@ Rockbridge
73.2 / 73.4	43	8.1[ns]	G[a]	63.5	FULL	@ Enterprise
69.5 / 69.4	40	8.6	46	78.0	FULL	@ West Logan
67.5 / 67.6	39[ns]	8.3[ns]	32[ns]	NA	**	Logan WWTP mix zone
67.3 / 67.4	45	8.1ns	40	68.5	FULL	Dst. mix zone
66.2 / 66.3	45	8.7	38	68.5	FULL	Dst. Logan
60.6 / 60.8	41	8.9	G[a]	77.5	FULL	Ambient
55.7 / 55.3	39[ns]	8.4[ns]	44	63.5	FULL	Dst. Landfill
51.6 / 51.4	41	8.6	52	66.0	FULL	Dst. Nelson. WWTP
47.9 / 48.5	39[ns]	7.1*	48	62.0	PARTIAL	Dst. Monday Creek
41.8 / 42.2	41	7.8*	40	72.0	PARTIAL	Dst. Sunday Creek
36.7 / 36.9	37[ns]	7.4*	56	53.5	PARTIAL	Ust. Athens
36.2 / 36.1	38[ns]	9.4	42	50.0	FULL	Relocated channel
33.1 / 32.6	35*	8.9	40	55.5	PARTIAL	Channelized; urban
32.5 / 32.5	19*	6.0*	38	41.0	**	Athens WWTP mix zone
32.3 / 32.0	34*	8.1[ns]	46	37.0	PARTIAL	Dst. WWTP; channelized
31.5 / 29.5	33*	8.6	44	74.0	PARTIAL	Dst. Athens;
25.0 / 24.9	37[ns]	8.5[ns]	50	74.5	FULL	Dst. Athens
20.4 / 19.7	33*	8.6	44	74.5	PARTIAL	Ambient
16.3 / 16.1	30*	8.9	52	76.0	PARTIAL	Ust. Federal Creek
12.9 / 14.0	33*	8.0*	48	63.5	PARTIAL	Begin Ohio R. influence
9.8 / ---	31*	7.1*	—	47.0	(NON)	Ohio River influenced
4.9 / 4.6	31*	7.2*	36	43.5	PARTIAL	Impounded by Ohio River

Table 1. (continued)

Stream Name River Mile Fish / Invertebrate	IBI	MIwb	ICI[a]	QHEI[b]	Warmwater Habitat (WWH) Attainment Status[c]		Comments
Hunters Run							
0.5 / 0.5	39[ns]	NA	38	50.0	FULL		Channelized; urban
Baldwin Run							
0.3 / 0.2	31*	NA	16*	50.5	NON		CSO's; urban
Clear Creek							
2.0 / 2.0	42[ns]	7.7[ns]	50	78.0	FULL		Reference site
Oldtown Creek							
0.6 / 0.6	44	NA	22*	69.5	PARTIAL		Dst. G.E., silty
					Use Attainment Status Existing / Recommended		
Rush Creek					LRW[d]	MWH[e]-Mine Affected	
2.0 / 2.1	28 / 28	6.3 / 6.3	46 / 46	41.5	FULL	FULL	Modified; sedimentation
Little Monday Creek					LWH[f]	WWH	
1.0 / 0.1	26* / 26*	5.7* / 5.7*	38 / 38	50.0	NON	NON	Sedimentation
Sunday Creek					LWH	LRW	
0.2 / 0.2	12* / 12*	2.4* / 2.4*	VP[a] / VP[a]	50.0	NON	NON	Acid Mine Drainage
U.T. to Sunday Creek					None	WWH	
0.2/ -	22*/22*	N/A	—	67.5	-	(NON)	Sedimentation, mining
Monday Creek					LRW	LRW	
1.8 / 1.7	12*	0.0*	VP[a]	40.0	NON	NON	Acid Mine Drainage
McDougall Branch					EWH[g]	WWH	
2.6 / 2.9	42* / 42[ns]	9.1[ns] / 9.1	G[a] / G[a]	52.0	PART.	FULL	Reference Site
Sharps Fork							
0.3 / 0.2	44* / 44	8.1* / 8.1[ns]	G[a] / G[a]	59.0	NON	FULL	Sedimentation, mining
Federal Creek					EWH	EWH	
11.4 / 11.7	48[ns]	9.0[ns]	46	81.5	FULL	FULL	Ust. Amesville
Federal Creek					LWH	EWH	
1.3 / 0.9	46 / 46[ns]	8.7 / 8.7*	54 / 54	75.5	FULL	PARTIAL	Reference Site

Table 1. (continued)

Ecoregion Biocriteria:

Erie/Ontario Lake Plain (EOLP; RM 95.2-87.1)

INDEX - Site Type	WWH	EWH	MWH[h]	LRW[i]
IBI - Headwaters	40	50	24	18
IBI - Wading (RM 95.2-87.1 and tributaries)	38	50	24	18
Mod. Iwb - Wading	7.9	9.4	6.2	4.5
ICI (RM 95.1-87.2 and tributaries)	34	46	22	14

Western Allegheny Plateau (WAP; RM 82.9-4.6)

INDEX - Site Type	WWH	EWH	MWH[h]	LRW[i]	Mine MWH-Affected)
IBI - Wading (RM 82.0 and tributaries)	44	50	24	18	24
IBI - Boat (RM 81.2-4.9; Rush Cr. RM 2.0)	40	48	24	16	24
Mod. Iwb - Wading (RM 82.0 and tributaries)	7.9	9.4	6.2	4.5	5.5
Mod. Iwb - Boat (RM 81.2-4.9; Rush Cr. RM 2.0)	8.6	9.6	5.8	5.0	5.4
ICI (RM 82.9-4.6 and tributaries)	36	46	22	14	30

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* - Significant departure from ecoregion biocriteria; poor and very poor results are underlined.

** Attainment status not applied to mixing zones.

ns - Nonsignificant departure from biocriterion (4 IBI or ICI units; 0.5 Iwb units).

a - Narrative evaluation is used in lieu of ICI for sites with qualitative samples only (MG= Marginally good, G=Good, P=Poor, VP= Very Poor).

b - Qualitative Habitat Evaluation Index (QHEI) values based on the most recent version (Rankin 1989).

c Use attainment status based on one organism group is parenthetically expressed.

d LRW- Limited Resource Water / Acid Mine Drainage

e MWH-- Modified Warmwater Habitat for channelized and/or non-acidic mine affected streams.

f LWH- Limited Warmwater Habitat-Streams; these streams are exempted from specific chemical standards but all other WWH criteria apply.

g EWH- Exceptional Warmwater Habitat

h MWH biocriteria for channel modified segments.

i Interim criteria for Limited Resource Water / Acid Mine Drainage streams.

Study Area Description

The Hocking River basin covers 1,197 square miles in southeast Ohio and spans parts of seven counties: Athens, Fairfield, Hocking, Meigs, Morgan, Perry and Washington (ODNR) 1960; 1985; Figure 1. The basin headwaters are in the glacial deposits of Fairfield County about 35 miles southeast of Columbus, Ohio. The river flows in a southeasterly direction through unglaciated, rugged topography to drain into the Ohio River at Hockingport. Major tributaries include Clear, Federal, Monday, Rush and Sunday creeks. The largest urban areas and municipal point source discharges are located along the mainstem on the Hocking River flood plain and include Lancaster, Logan, Nelsonville and Athens. Table 2 presents the general characteristics of streams in the study area.

The basin is situated in three ecoregions with small portions of the upper basin in the Erie/Ontario Lake Plain (EOLP) and Eastern Corn Belt Plains (ECBP) and the majority situated in the Western Allegheny Plateau (WAP). The WAP ecoregion constitutes the foothills to the Appalachian Mountains and is distinctly different from the headwater ecoregions. Generally, the relief is hilly with steep slopes, the majority of which are heavily wooded. Less than one-fifth of the WAP is used for cropland and pasture which tend to be located along narrow stream valleys. Residual soils have formed on sedimentary shales, siltstones and sandstones with alluvial soils in the stream valleys. The northwestern end of the Hocking River basin includes a small portion of glacial till soils from the southernmost extension of the last glacier (Omernik and Gallant, 1988).

The ECBP region, principally found in the headwaters of Clear Creek, is characterized by relatively flat terrain and usually with less than fifty foot changes in elevation. Soils are derived from glacial till materials and poor soil drainage has prompted extensive stream channelization to assist artificial field drainage systems. In Clear Creek, the unsewered village of Amanda and a county landfill are located in the upper basin.

The EOLP ecoregion is a glacial plain characterized by outwash terraces, till plains, glacial till ridges, drumlins and elevated remnant beach ridges. These glacial features have a significant local relief with erratic changes from 100 to 300 feet over a short distance. To control flooding in marshy floodplain areas, many streams have been channelized. This ecoregion generally is a transition zone between the flatter, glaciated lands (ECBP ecoregion) to the west and the very hilly, unglaciated terrain (WAP ecoregion) to the southeast. The EOLP accounts for much of the mainstem drainage from the Lancaster area to Rush Creek.

In the upland unglaciated portion of the basin (WAP ecoregion) the most common nonpoint source problem related to land uses are resource extraction and silviculture. Active and abandoned underground and surface coal mines are common with heaviest concentrations in the Rush Creek, Monday Creek and Sunday Creek drainages. These basins were recognized as significant sources of acidic mine drainage and sediment associated with abandoned mine lands in a 1985 USDA report on assessment and treatment of AML impacted basins. The severity of impact is often dependent on the local geology with acidic conditions most common

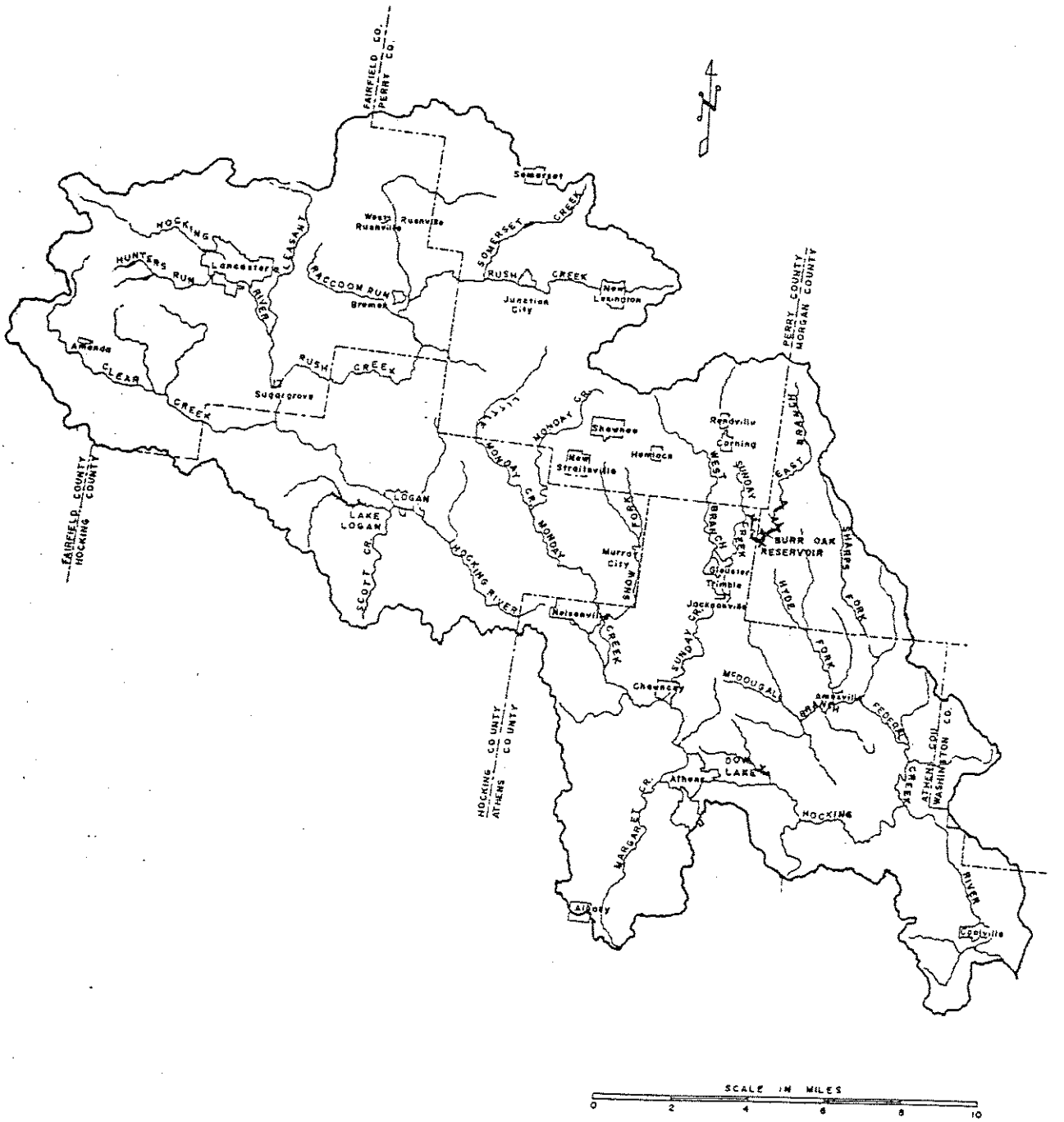

Figure 1. The Hocking River basin study area showing principal streams, tributaries and population centers.

in predominantly sandstone basins while areas with a limestone bedrock component may be adequately buffered. Sedimentation from upland sources contributes to the sediment load in the mainstem and exacerbates the already significant problems associated with loss of bank integrity and channel modifications.

Agriculture is the dominant land use along floodplains and in the glaciated areas. Channel and bank modification associated with urban and agricultural land uses appears to be the most widespread nonpoint influence in the lowland flood plains.

Oil and gas development exists within the basin but not extensively. Related problems include oil and brine contamination of ground and surface waters from brine holding pits, cutting pits, improperly plugged wells and careless handling of product. In urban areas, excessive runoff can cause overflows of combined sewers or can drain directly into streams from storm sewers carrying nonpoint source pollutants such as heavy metals, sediment and animal waste (Ohio EPA, 1990).

Table 2. Stream Characteristics and Significant Identified Pollution Sources in the Hocking River Study Area.

Stream Name	Length (Miles)	Average Fall (Feet/Mile)	Drainage Area (Square Miles)	Identified Nonpoint Source Pollution Categories	Point Sources Evaluated
Hocking River	94.9	4.6	1197.0	Stream bank Modification	Lancaster WWTP Logan WWTP Nelsonville WWTP Athens WWTP
Rush Creek	37.2	8.4	235.6	Resource extraction, channelization	
Clear Creek	23.0	15.1	91.3	Agriculture, urban runoff, silviculture, channelization, land disposal	
Monday Creek	27.0	10.4	116.1	Resource extraction, land disposal	
Sunday Creek	27.2	11.5	138.5	Resource extraction, urban runoff, land disposal	
Federal Creek	23.8	19.1	144.9	In-place pollutants, agriculture, resource extraction	

Methods

All chemical, physical, and biological field, laboratory, data processing, and data analysis methods and procedures adhere to those specified in the *Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices* (Ohio Environmental Protection Agency 1989a) and *Biological Criteria for the Protection of Aquatic Life, Volumes II-III* (Ohio Environmental Protection Agency 1987, 1989b, 1989c), and *The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application* (Rankin 1989) for aquatic habitat assessment.

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

Performance expectations for the basic aquatic life uses [Warmwater Habitat (WWH), Exceptional Warmwater Habitat (EWH) and a proposed Modified Warmwater Habitat (MWH)] were developed using the regional reference site approach (Hughes *et al.* 1986; Omernik 1988). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981). Attainment of an aquatic life use is FULL if all three indices (or those available) meet the applicable criteria, PARTIAL if at least one of the indexes does not attain and performance does not fall below the fair category, and NON if all indices either fail to attain *or* any index indicates poor or very poor performance.

Physical habitat is evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989). Various attributes of the available habitat are scored based on their overall importance to the establishment of viable, diverse aquatic faunas. Evaluations of type and quality of substrate, amount of instream cover, channel morphology, extent of riparian canopy, pool and riffle development and quality, and stream gradient are among the metrics used to determine the QHEI score which generally ranges from 20 to 100. The QHEI is used to evaluate the characteristics of a stream segment, not just the characteristics of a single sampling site. As such, individual sites may have much poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values higher than 60 are generally conducive to the establishment of warmwater faunas while those scores in excess of 75-80 often typify habitat conditions which have the ability to support exceptional faunas.

During this survey, macroinvertebrates were sampled using modified Hester/Dendy multiple-plate artificial substrate samplers supplemented with a qualitative assessment of the available natural substrates. Exceptions included Sunday and Monday Creeks and those locations where the artificial substrate samplers were lost (qualitative sampling only).

Fish were sampled 2-3 times using pulsed DC electrofishing gear using either the wading method (150 meter zones) or boat method (500 meter zones). With the exception of Rush Creek, tributary locations were electrofished using the wading method. All chemical/physical and biological sampling locations are listed in Table 3.

An Area Of Degradation Value (ADV; Rankin and Yoder 1991) was calculated for the study area based on the longitudinal performance of the biological communities. The ADV portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, and ICI) departs from the stream criterion or the upstream level of performance (Figure 2). The magnitude of impact refers to the vertical departure of each index below the criterion. The total ADV is the area beneath the ecoregional criterion when the results for each index are plotted against river mile. This is also expressed as ADV/mile to normalize comparisons between segments and other areas.

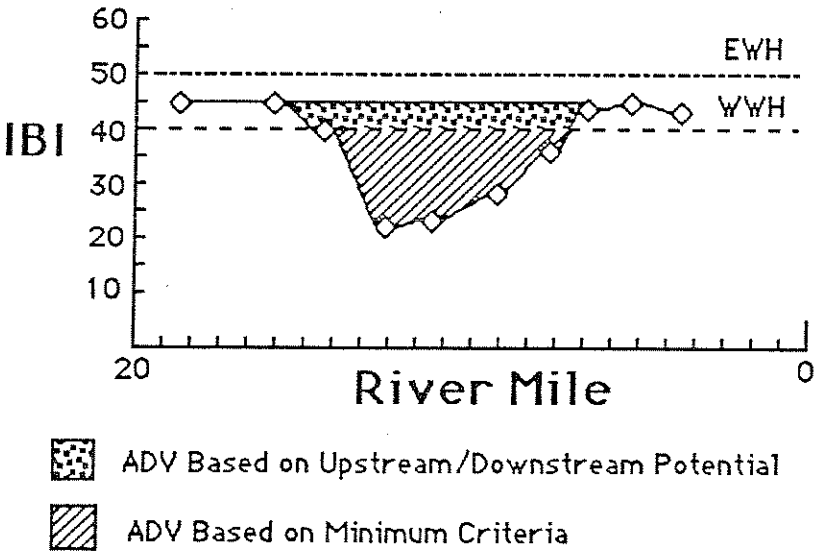

Figure 2. Graphic illustration of the calculation of Area of Degradation Values (ADV) based on upstream potential and the ecoregion warmwater habitat use or minimum criteria (WWH). Criteria for exceptional warmwater habitat use (EWH) is provided for reference.

Table 3. Sampling locations (effluent sample - E, water chemistry - C, sediment chemistry - S, benthos - B, fish - F, fish tissue - FT) in the Hocking River basin study area, 1990.

Stream River Mile	Type of [a] Sampling	USGS 7.5 min. Latitude/Longitude	Landmark	County	Quad. Map
Hocking River					
95.2	F	39°44'47" 82°40'12"	Hooker Cemetery	Fairfield	Amanda
95.1	B	39°44'50" 82°40'10"	Hooker Cemetery	Fairfield	Amanda
94.9	C	39°44'51" 82°39'54"	Campground Rd	Fairfield	Amanda
92.2	F	39°43'14" 82°37'36"	Pierce Ave.	Fairfield	Lancaster.
91.9	C,B	39°43'41" 82°37'05"	Pierce Ave.	Fairfield	Lancaster.
90.8	F	39°42'45" 82°37'06"	U.S. Rt. 22	Fairfield	Lancaster
90.7	C,F	39°42'16" 82°36'34"	U.S. Rt. 22	Fairfield	Lancaster
89.4	C,F,B	39°42'22" 82°35'37"	Maple St	Fairfield	Lancaster
89.1	E	39°42'24" 82°35'12"	Lancaster WWTP	Fairfield	Lancaster
89.1	F,B	39°42'23" 82°35'11"	Lanc. WWTP mix zone	Fairfield	Lancaster
89.0	F	39°42'17" 82°35'04"	Dst. WWTP mix zone	Fairfield	Lancaster
88.9	B	39°42'20" 82°35'06"	Dst. WWTP mix zone	Fairfield	Lancaster
88.5	C	39°41'57" 82°35'00"	Deeds Rd	Fairfield	Lancaster
87.3	C	39°41'09" 82°34'24"	1st U.S. Rt. 33 bridge	Fairfield	Lancaster
87.2	B	39°41"06" 82°34'25"	1st U.S. Rt. 33 bridge	Fairfield	Lancaster
87.1	F	39°41'02" 82°34'27"	1st U.S. Rt. 33 bridge	Fairfield	Lancaster
82.9	C,B	39°38'11" 82°33'14"	3rd U.S. Rt. 33 bridge	Fairfield	Lancaster
82.0	F	39°37'27" 82°33'09"	Ust. Rush Creek	Fairfield	Lancaster
81.3	C,B	39°37'08" 82°32'43"	Adj. Buckeye Rd.	Fairfield	Rockbridge
81.2	F	39°36'53" 82°32'36"	Adj. Buckeye Rd	Fairfield	Rockbridge
77.3	C	39°34'55" 82°31'00"	@ Rockbridge	Hocking	Rockbridge
77.2	F	39°34'55" 82°31'59"	@ Rockbridge	Hocking	Rockbridge
77.1	B	39°34'55" 82°30'58"	@ Rockbridge	Hocking	Rockbridge
73.4	C,B	39°34'54" 82°28'30"	@ Enterprise	Hocking	Logan
73.2	F	39°33'38" 82°28'30"	@ Enterprise	Hocking	Logan
69.5	F	39°32'25" 82°25'17"	@ West Logan	Hocking	Logan
69.4	B	39°32'30" 82°25'21"	@ West Logan	Hocking	Logan
68.3	C	39°32'27" 82°24'28"	S.R. 93	Hocking	Logan
67.6	E	39°31'20" 82°23'45"	Logan WWTP	Hocking	Logan
67.6	B	39°31'19" 82°23'44"	Logan WWTP mix zone	Hocking	Logan
67.5	F	39°31'44" 82°23'29"	Logan WWTP mix zone	Hocking	Logan
67.4	B	39°31'44" 82°23'26"	Dst. WWTP mix zone	Hocking	Logan
67.3	F	39°31'42" 82°23'22	Dst. WWTP mix zone	Hocking	Logan
66.3	C,B	39°31'45" 82°22'40"	S.R. 328	Hocking	Logan
66.2	F	39°31'05" 82°22'30"	S.R. 328	Hocking	Logan / Gore
60.8	B	39°28'30 82°19'49"	Wandling Rd.	Hocking	Union Furnace
60.6	F	39°28'18" 82°19'29"	Wandling Rd.	Hocking	Union Furnace
59.1	C	39°27'34" 82°18'57"	Laurel Run Rd	Hocking	Union Furnace
55.7	F	39°27'30" 82°16'04"	Dst. Landfill Trib.	Athens	Union Furnace
55.3	B	39°27'50" 82°15'42"	Dst. Landfill Trib.	Athens	Union Furnace
53.8	C	39°27'32" 82°14'25"	S.R. 278	Athens	Nelsonville
52.1	E	39°26'47" 82°13'05"	Nelsonville WWTP	Athens	Nelsonville
51.6	F	39°26'35"82°12'57"	S.R. 691	Athens	Nelsonville
51.4	C,B	39°26'24" 82°12'40"	S.R. 691	Athens	Nelsonville
48.5	B	39°24'38" 82°11'30"	Ust. Glen Elbon Rd.	Athens	Nelsonville

Table 3. (continued)

Stream River Mile	Type of [a] Sampling	USGS 7.5 min. Latitude/Longitude	Landmark	County	Quad. Map
Hocking River (continued)					
48.0	C	39°24'15" 82°11'22"	Glen Elbon Rd.	Athens	Nelsonville
47.9	F	39°24'12" 82°11'09"	Glen Elbon Rd.	Athens	Nelsonville
44.0	C	39°23'19" 82°08'27"	S.R. 682, ust. Sunday Cr.	Athens	Nelsonville
42.2	B	39°23'02" 82°06'57"	Adj. T-251	Athens	Jacksonville
41.8	F	39°22'58" 82°06'39"	Adj. T-251	Athens	Jacksonville
40.3	C	39°21'50" 82°06'42"	U.S. 33, dst. Sunday Cr.	Athens	Athens
36.9	B	39°20'15" 82°07'15"	Adj. T-404	Athens	Athens
36.7	F	39°20'02" 82°07'33"	Adj. T-404	Athens	Athens
36.3	C	39°19'51" 82°07'37"	S.R. 56	Athens	The Plains
36.2	F	39°19'43" 82°07'17"	White Mill	Athens	The Plains \ Athens
36.1	B	39°19'47" 82°07'20"	White Mill	Athens	Athens
33.1	C,F	39°19'51" 82°05'15"	Stimson Ave.	Athens	Athens
32.6	B	39°19'59" 82°04'49"	U.S. 33	Athens	Athens
32.5	E	39°19'59" 82°04'47"	Athens WWTP	Athens	Athens
32.5	F,B	39°19'59" 82°04'46"	Athens WWTP mix zone	Athens	Athens
32.3	F	39°19'59" 82°04'30"	Dst. Athens WWTP	Athens	Athens
32.0	B	39°19'59" 82°04'12"	Dst. Athens WWTP	Athens	Athens
31.5	F	39°19'57" 82°01'27"	Adj. Harmony Lane	Athens	Athens
29.5	B	39°19'55" 82°01'42"	Adj. Harmony Lane	Athens	Athens
27.8	C	39°19'39" 82°00'18"	Harmony Lane bridge	Athens	Athens
25.0	F	39°18'14" 81°58'39"	Adj. T-129	Athens	Stewart
24.9	B	39°18'13" 81°58'45"	Adj. T-129	Athens	Stewart
20.6	C	39°17'10" 81°55'36"	U.S. Rt. 50 bridge	Athens	Stewart
20.4	F	39°17'18" 81°55'30"	U.S. Rt. 50 bridge	Athens	Stewart
19.7	B	39°17'24" 81°55'00"	@ Guysville	Athens	Stewart
16.3	F	39°18'39" 81°53'28"	@ Stewart	Athens	Stewart
16.1	B	39 °18'47" 81°53'28"	@ Stewart	Athens	Stewart
14.0	B	39°18'32" 81°51'58"	Adj. SR 144 @ Beebee	Athens	Cutler
13.6	C	39°18'42" 81°51'27"	T-189 @ Beebee	Athens	Cutler
12.9	F	39°18'36" 81°50'55"	Adj. SR 144 @ Beebee	Athens	Cutler
9.9	C	39°16'32" 81°49'54"	CR 58 near Frost	Athens	Cutler
9.8	F	39°16'26" 81°49'43"	CR 58 near Frost	Athens	Cutler
5.4	C	39°13'29" 81°47'29"	SR 144 @ Coolville	Athens	Coolville
4.9	B	39°13'16" 81°47'04"	@ Coolville	Athens	Coolville
4.6	F	39°13'00" 81°46'55"	@ Coolville	Athens	Coolville
Hunters Run					
0.5	F,B	39°42'48" 82°37'06"	SR 22	Fairfield	Lancaster
Baldwin Run					
0.3	F	39°42'33" 82°35'00"	Lawrence Rd	Fairfield	Lancaster
0.2	C,B	39°42'31" 82°35'03"	Lawrence Rd	Fairfield	Lancaster
Rush Creek					
2.1	C,B	39°38'41" 82°31'46"	Hansley Rd.	Fairfield	Lancaster
2.0	F	39°38'40" 82°31'47"	Hansley Rd.	Fairfield	Lancaster
Clear Creek					
2.0	C,F,B	39°35'18" 82°34'42"	@ USGS Gage	Hocking	Rockbridge

Table 3. (continued)

Stream River Mile	Type of [a] Sampling	USGS 7.5 min. Latitude/Longitude	Landmark	County	Quad. Map
Oldtown Creek					
0.6	C,F,B	39°32'10" 82°23'30"	Old US 33 bridge	Hocking	Logan
Athens Co. Landfill Trib					
0.5	C	39°27'23" 82°16'51"	Dst. Landfill	Hocking	Union Furnace
Little Monday Creek					
1.0	F	39°32'52" 82°16'54"	Near Greendale	Hocking	Gore
0.2	C	39°32'26" 82°16'34"	SR 595 @ Greendale	Hocking	Gore
0.1	B	39°32'22" 82°16'32"	SR 595 @ Greendale	Hocking	Gore
Monday Creek					
1.8	F	39°26'11" 82°11'33"	@ Doanville	Hocking	Nelsonville
1.7	B	39°26'16 82°11'30"	@ Doanville	Hocking	Nelsonville
0.6	C	39°25'20" 82°11'15"	Old US 33	Hocking	Nelsonville
Sunday Creek					
0.2	C,F,B	39°23'42" 82°07'20"	SR 13 @ Chauncey	Athens	Jacksonville
U.T. to Sunday Creek					
0.3	C	39°25'20" 82°06'38"	Near Millifield	Athens	Jacksonville
0.2	F	39°25'12" 82°06'43"	Near Millifield	Athens	Jacksonville
McDougall Branch					
3.0	C	39°22'57" 81°59'30"	SR 690 @ Amesville	Athens	Amesville
2.9	B	39°22'57"81°59'28"	SR 690 @ Amesville	Athens	Amesville
2.6	F	39°23'39" 81°58'22"	Near Amesville	Athens	Amesville
Sharps Fork					
0.3	F	39°24'20" 81°55'44"	Ust. SR 329	Athens	Amesville
0.2	B	39°24'15" 81°55'45'	Ust. SR 329	Athens	Amesville
0.1	C	39°24'09" 81°55'47'	@ SR 329	Athens	Amesville
Federal Creek					
11.7	B	39°24'13" 81°57'37"	Adj. SR 329 @ Amesville	Athens	Amesville
11.4	C,F	39°24'00" 81°57'28"	SR 550 @ Amesville	Athens	Amesville
1.4	C	39°19'58" 81°52'37"	Ust.T-231 nr. Stewart	Athens	Stewart
1.3	F	39°19'58" 81°53'31"	Ust.T-231 nr. Stewart	Athens	Stewart
0.9	B	39°19'47" 81°53'15"	@.T-231 nr. Stewart	Athens	Stewart

Results and Discussion: Chemical/Physical Water Quality

Hocking River Mainstem - General

The results of the chemical/physical sampling for the Hocking River mainstem from Hooker (RM 92.0) to Coolville (RM 5.4) indicated substantial compliance with Ohio's Water Quality Standards (WQS.) for the Warmwater Habitat use designation (30 day average concentrations). WQS exceedences of the WWH chronic criteria in the Hocking River mainstem included:

- Total Iron (40 of 124 samples)
- Fecal coliform (13 of 29 samples)
- Dissolved oxygen-D.O. (2 of 124 samples)
- Copper (1 of 124 samples)
- Zinc (1 of 124 samples)

A list of WQS exceedence concentrations for all stations in the Hocking River basin study area can be found in Table 4. A summary of results for selected chemical/physical parameters from the mainstem, the lower reaches of major tributaries and significant point source outfalls can be found in Table 5.

The large number of iron exceedences observed in the Hocking River basin are fairly typical of Ohio streams due to the high iron content of the local geology. These background concentrations rarely result in observable impairment of the instream biota. However, extremely high iron concentrations are also common to acid mine runoff which primarily impacts selected tributaries to the mainstem. Elevated fecal coliform levels were also common in the Hocking basin and throughout Ohio streams in the summer of 1990 following the numerous runoff events and high flow periods which existed during the sampling period. Municipal waste treatment systems, urban runoff, agricultural runoff from livestock and on-site disposal systems are common sources of high coliform levels. The two mainstem D.O. exceedences were measured in and downstream from the city of Lancaster while the copper and zinc exceedences were found downstream from the cities of Athens and Nelsonville, respectively.

Record rainfall amounts throughout most of Ohio in 1990 resulted in elevated flows in the Hocking River (Figure 3). Mean flows recorded at USGS gages in Enterprise and Athens for the 1990 water year were approximately 35-40% above average. During the summer months, mean flows in June and July exceeded 10-20% duration at both locations. Flows stabilized somewhat in August and September but remained well above 50% duration for the remainder of the survey sampling period.

Table 4 . Exceedences of Ohio EPA Warmwater/Modified/Exceptional Warmwater/Cold Water Habitat water quality criteria (OAC 3745-1) for chemical/physical parameters measured in the Hocking River Basin study area, 1990. (Units are ug/l for metals; S.U. for pH; #/100ml for Fecal Coliform and mg/l for other parameters)

Stream Name (Current Use Designation)	River Mile	Exceedence: Parameter
Hocking River (WWH)	92.0	Fe (1180, 1250, 1630, 1060)*, Fecal Coliform (3200)[a]
	90.7	Fe (1140)* D.O.(4.9)*, Fecal Coliform(4600)[a]
	89.4	Fecal Coliform (3500, 3200)[a]
	88.5	Fecal Coliform (2900)[a]
	87.3	D.O. (4.7)*, Fecal Coliform (2600)[a], (60000)[b]
	82.9	Fecal Coliform (3300)[a]
	81.3	Fe (1570)*
	77.3	Fe (1160, 2200, 1490)*
	73.4	Fe (2770, 1610, 1190)*, Fecal Coliform(19000)[b]
	68.3	Fe (1040, 1770, 1160)*, Fecal Coliform(11000)[b]
	66.3	Fe (1100, 1830)*
	59.1	Fe (1470, 2170)*
	53.8	Fe (1720, 2520)*, Fecal Coliform (17000)[b]
	51.4	Fe (2480, 5620)*, Zn (385)*
	48.0	Fe (3630, 1090)*, Fecal Coliform (3800)[a]
	44.0	Fe (3230)*
	40.3	Fe (1910, 3840, 1320, 1570, 2030)*
	36.3	Fe (1060, 2460, 1070)*
	33.1	Fe (3510)*
	27.8	Cu (75)**, Fecal Coliform (>60000)[b]
	20.6	Fe (5950)*
	9.9	Fe (5980)*
	5.4	Fe (2940, 1240)*
Baldwin Run (WWH)	0.2	Fecal Coliform. (17000)[b]
Rush Creek (LRW)[c]	2.1	Fecal Coliform (2600)[a], Fe (6300)*
Clear Creek (WWH)	2.0	Fe (2800, 1260, 2900)*, Fecal Coliform (3250)[a]
Oldtown Creek (WWH)	0.6	Fe (1520)*,Fecal Coliform (4900)[a]
Athens County Landfill Tributary (Undesignated)	0.5	Fe (1810, 1160, 1040, 1450, 2330)*; **pH (6.10)****; Fecal Coliform (16000)[b]

Table 4. (Continued)

Stream Name	River Mile	Exceedence: Parameter
Monday Creek (LRW)[c]	0.6	Fe (3770, 3920, 2390, 3200, 2890)*; **pH (3.9. 3.75, 3.4, 3.5, 5.0)****
Little Monday Creek (LWH)[d]	0.2	Fe (1790)*
Sunday Creek (LWH)[d]	0.2	**Fe (31600, 31900, 32000, 47500, 33400)**[e] **pH (6.05, 3.0, 3.2, 4.1)****
Federal Creek (EWH)	11.4	Fecal Coliform (6000)[b]
Federal Creek (LWH)[d]	1.4	Fe (1780)*

* Indicates an exceedence of numerical criteria for prevention of chronic toxicity (CCC).

** Indicates an exceedence of numerical criteria for prevention of acute toxicity (CMC).

a Indicates an exceedence of the Primary Contact Recreation standard

b Indicates an exceedence of the Secondary Contact Recreation standard

c LRW-Acid Mine Drainage streams are exempted from standards for TDS/Conductivity, pH, iron and zinc

d LWH-Acid Mine Drainage; all WWH criteria apply with the exception of TDS/Conductivity, pH, iron and zinc in Sunday Creek and TDS/Conductivity in lower Federal Creek.

e Indicates an exceedence of the Agricultural Water Supply standard

Table 5. A summary of chemical/physical sampling results (mean, minimum/maximum)[a] for selected parameters in the Hocking River basin during the summer of 1990. All concentrations are in mg/l with the exception of aluminum, iron and zinc (ug/l).

Stream Name RM	D.O	NH_3-N	SO_4	Mn	Al	Cl	Fe	Zn
			Mean (Minimum/Maximum)					
Hocking River								
94.9	8.4	0.05	44	36	200	13	290	10
	(6.1/9.8)	(<0.05/<0.05)	(39/51)	(25/55)	(<200/<200)	(12/14)	(210/360)	(<10/<10)
91.9	7.9	0.054	59	93	682	22	1136	14
	(5.8/9.7)	(<0.05/0.06)	(54/67)	(65/125)	(340/1070)	(19/265)	(560/1630)	(<10/25)
90.7	6.9	0.060	57	65	354	25	674	28
	(4.9/9.1)	(<0.05/0.09)	(54/58)	(55/70)	(230/570)	(20/37)	(380/1140)	(<10/100)
89.4	7.2	0.062	55	110	330	25	704	20
	(5.3/9.5)	(<0.05/0.08)	(49/59)	(75/155)	(<200/440)	(18/41)	(320/940)	(<10/50)
Lancaster WWTP 001 Effluent								
(89.1)	7.4	0.05	195	11	200	418	98	41
	(5.4/8.9)	(<0.05/<0.05)	(169/234)	(10/15)	(<200/<200)	(339/506)	(70/120)	(20/75)
Baldwin Run								
0.2/89.0	8.3	0.13	59	67	200	21	240	43
	(5.9/12.0)	(<0.05/0.29)	(53/63)	(40/105)	(<200/<200)	(11/42)	(200/340)	(<10/135)
Hocking River								
88.5	7.2	0.068	96	94	212	132	474	36
	(5.3/9.7)	(<0.50/0.10)	(76/114)	(80/125)	(<200/250)	(88/170)	(260/640)	(10/80)
87.3	7.3	0.11	89	102	248	114	835	22
	(4.7/9.8)	(<0.05/0.44)	(78/104)	(70/150)	(<200/320)	(28/162)	(420/1990)	(<10/40)
82.9	7.1	0.072	82	109	250	119	554	23
	(5.2/9.6)	(<0.05/0.11)	(72/100)	(85/165)	(<200/380)	(76/154)	(370/880)	(15/35)
Rush Creek								
2.1/81.6	7.6	0.07	148	1025	1606	27	2560	31
	(5.6/9.1))	(<0.05/0.11)	(35/245)	(115/1740)	(270/4360)	(14/39)	(560/6300)	(20/40)
Hocking River								
81.3	7.4	0.068	129	799	458	41	806	21
	(5.5/9.5)	(<0.05/0.10)	(69/227)	(440/1400)	(210/920)	(25/52)	(520/1570)	(<10/45)
Clear Creek								
2.0/79.5	8.9	0.05	48	291	3816	15	6354	42
	(7.0/10.1)	(<0.05/0.05)	(34/84)	(45/840)	(220/16300)	(10/33)	(360/29000)	(<10/115)
Hocking River								
77.3	7.5	0.054	118	523	646	42	1166	13
	(6.2/8.5)	(<0.05/0.07)	(72/157)	(245/800)	(260/1360)	(26/52)	(480/2200)	(<10/20)
73.4	7.4	0.054	99	364	784	44	1340	20
	(5.8/8.3)	(<0.05/0.07)	(69/114)	(195/550)	(300/1850)	(25/64)	(550/2770)	(<10/45)

Table 5 (continued)

Stream Name. RM	D.O	NH_3-N	SO_4	Mn	Al	Cl	Fe	Zn
			Mean (Minimum/Maximum)					
Hocking River								
68.3	8.2	0.05	108	333	578	47	1044	24
	(6.7/9.1)	(<0.05/<0.05)	(67/133)	(170/590)	(340/990)	(24/62)	(570/1770)	(<10/35)
Logan WWTP 001 Effluent								
(67.6)	6.4	0.82	97	67	264	177	600	49
	(5.4/7.2)	(0.34/1.31)	(89/119)	(55/90)	(220/300)	(159/196)	(360/760)	(35/60)
Oldtown Creek								
0.6/67.29	7.9	0.06	60	154	420	128	914	15
	(6.9/8.4)	(<0.05/0.11)	(51/66)	(135/175)	(<200/900)	(91/236)	(540/1520)	(<10/25)
Hocking River								
66.3	8.0	0.05	108	312	584	52	1042	16
	(6.8/9.0)	(<0.05/<0.05)	(68/126)	(165/570)	(390/1040)	(29/64)	(650/1830)	(<10/20)
59.1	7.3	0.052	104	252	720	53	1140	14
	(5.8/8.7)	(<0.05/0.06)	(71/123)	(175/330)	(460/1240)	(24/68)	(610/2170)	(<10/25)
53.8	7.6	0.058	105	217	896	55	1282	15
	(6.5/8.3)	(<0.05/0.09)	(71/130)	(165/310)	(530/1550)	(25/73)	(610/2520)	(<10/25)
Nelsonville WWTP 001 Effluent								
(52.1)	6.6	23	198	185	482	88	384	24
	(6.1/7.0)	(21/26)	(176/241)	(150/250)	(<200/1115)	(72/107)	(200/660)	(15/35)
Hocking River								
51.4	7.8	0.058	106	218	850	53	2064	86
	(6.9/9.3)	(<0.05/0.08)	(68/138)	(135/290)	(490/1640)	(25/75)	(590/5620)	(<10/385)
Monday Creek								
0.6/48.9	7.6	0.13	387	3054	10772	37	2712	185
	(7.0/8.1)	(<0.05/0.18)	(54/550)	(330/4450)	(6780/16400)	(32/43)	(280/3920)	(50/275)
Hocking River								
48.0	8.0	0.05	153	532	1714	51	1496	29
	(7.1/9.20)	(<0.05/<0.05)	(98/193)	(400/635)	(1100/2770)	(26/71)	(840/3630)	(15/45)
44.0	7.9	0.05	149	436	1090	49	1123	15
	(7.0/9.4)	(<0.05/0.05)	(105/202)	(350/515)	(590/2240)	(25/71)	(340/3230)	(<10/30)
Sunday Creek								
0.2/42.9	6.7	0.47	529	2104	796	27	35300	77
	(5.6/9.4)	(<0.05/0.74)	(194/751)	(460/3280)	(<200/2200)	(19/33)	(31600/47500)	(40/120)
Hocking River								
40.3	7.7	0.052	184	537	642	46	2134	11
	(6.8/9.2)	(<0.05/0.06)	(114/242)	(400/625)	(280/1710)	(25/67)	(1320/3840)	(<10/15)
37.3	7.9	0.05	180	447	468	45	1246	12
	(6.6/9.2)	(<0.05/<0.05)	(114/234)	(545/3200)	(200/1230)	(23/65)	(810/2460)	(<10/15)

Table 5. (continued)

Stream Name. RM	D.O	NH_3-N	SO_4	Mn	Al	Cl	Fe	Zn
			Mean (Minimum/Maximum)					
Hocking River (continued)								
33.1	8.2 (6.7/9.9)	0.05 (<0.05/<0.05)	175 (109/209)	244 (185/310)	592 (230/1900)	50 (23/71)	1384 (680/3510)	42 (<10/170)
Athens WWTP 001 Effluent								
(32.5)	6.8 (5.3/7.8)	0.16 (<0.05/0.47)	164 (154/185)	20 (10/30)	200 <200/<200)	106 (92/120)	102 (70/130)	28 (35/25)
Hocking River								
27.8	8.4 (7.4/9.3)	0.62 (<0.05/0.11)	171 (101/226)	176 (135/240)	424 (200/3430)	50 (23/72)	1646 (570/4950)	35 (<10/85)
20.6	8.2 (7.6/8.9)	0.05 (<0.05/<0.05)	167 (96/209)	152 (100/275)	1044 (310/3620)	47 (20/64)	1820 (760/5950)	18 (<10/35)
Federal Creek								
1.4/15.3	8.2 (6.8/9.2)	0.05 (<0.05/<0.05)	113 (92/139)	187 (125/230)	678 (420/1270)	21 (12/29)	936 (510/1780)	13 (10/15)
Hocking River								
13.6	8.0 (7.4/8.7)	0.05 (<0.05/<0.05)	180 (142/201)	122 (110/130)	493 (350/580)	53 (47/60)	833 (760/900)	10 (<10/<10)
9.9	8.4 (7.7/9.0)	0.05 (<0.05/<0.05)	128 (87/168)	170 (105/235)	2165 (510/3820)	34 (19/49)	3445 (910/5980)	25 (<10/40)
5.4	8.3 (7.6/9.8)	0.05 (<0.05/<0.05)	139 (81/178)	119 (95/140)	870 (390/2050)	42 (19/53)	1294 (530/2940)	15 (<10/20)

a Arithmetic means calculated using detection limits as the minimum value when reported minimum was less than detection limit.

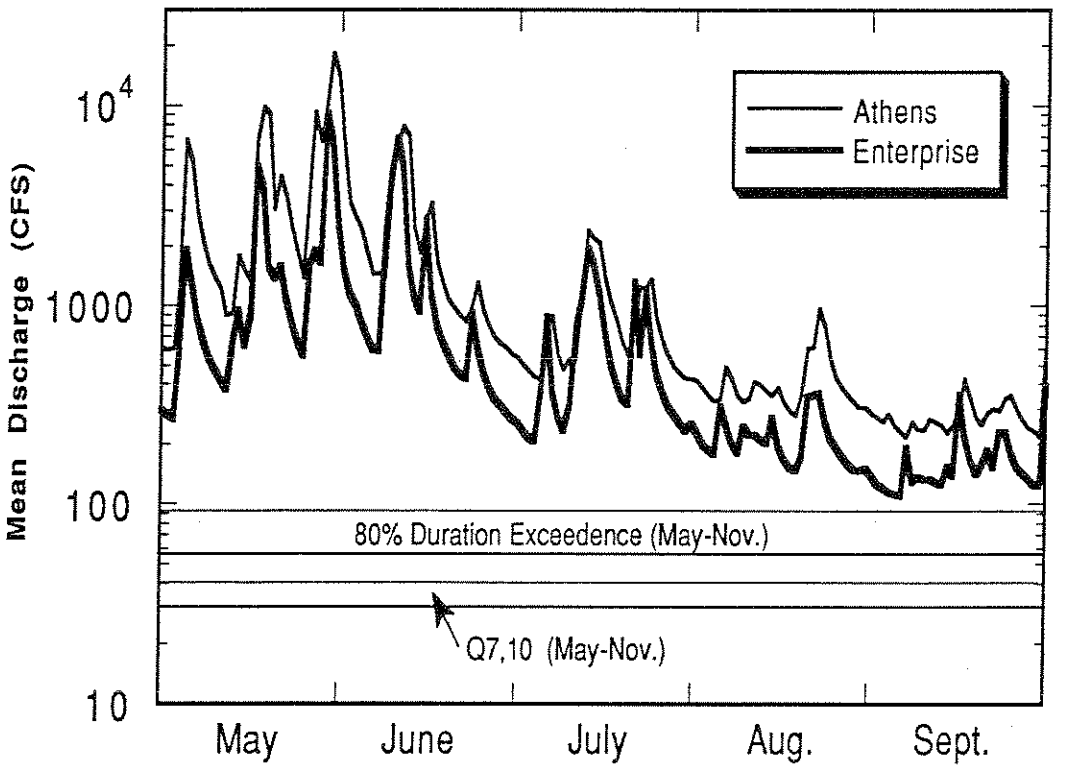

Figure 3. Flow hydrograph for the Hocking River near Enterprise and Athens, Ohio (RMs 73.4 and 35.1, respectively); May through September,1990. Summer through fall low flow conditions ($Q_{7,10}$ in cfs for May through November for the period of record 1915 to 1976) and the 80% duration flow are also indicated on the figure.

Hocking River - Hooker to Rush Creek (RM 94.9 - 81.6)

Water quality conditions were considered good upstream from Lancaster at RM 94.9. No water quality exceedences or significantly elevated chemical parameters were observed. Beginning in the channelized section of the river at RM 92.0, water quality gradually declined as the river flowed through Lancaster. An increasing trend in phosphorus, total suspended solids (TSS) and 5-day Biochemical Oxygen Demand (BOD_5) levels began at RM 92.0 and was followed by sporadic increases in heavy metals and declines in D.O. at additional sites downstream. Fecal coliform exceedences were detected at three urban sites from RM 92.0-89.4. Results suggest nonpoint or CSO problems beginning in upper Lancaster and increasing in severity downstream from the major CSO and urban runoff locations.

The Lancaster WWTP effluent (RM 89.1) was in compliance with NPDES permit limitations during the 1990 survey. Highly elevated chlorides, dissolved solids and conductivity levels were related to the cities water softening discharge which is tied in to the WWTP. The relatively low concentrations of heavy metals were an indication of the effectiveness of the local pretreatment program.

Remaining stations between Lancaster and the confluence with Rush Creek reflected a modest impact and recovery pattern. WQS exceedences were limited to fecal coliform at RM 87.3 and 82.9 and one D.O. at RM 87.3 (high fecal coliform at RM 82.9 may have resulted from a nearby trailer park discharge). Chlorides remained elevated downstream to Rush Creek and elevated heavy metals were detected periodically, a trend which began in Lancaster, upstream from the WWTP. Recovery appeared nearly complete upstream from the confluence with Rush Creek.

Hocking River- Rush Creek to Monday Creek (RM 81.6 - 48.9)

Water chemistry in the approximately 33 mile section between Rush Creek and Monday Creek primarily reflected the influence of nonpoint mine drainage from the Rush Creek basin. Increased WQS exceedences for iron and significant increases in manganese, aluminum and sulfates were observed downstream from the confluence. Although smaller in size, Clear Creek also contributed high iron and aluminum concentrations, particularly following rainfall events.

High fecal coliform counts at Enterprise (RM 73.4) and upstream from Nelsonville (RM 53.8) appeared to result from localized nonpoint sources while an exceedence in Logan at RM 68.3 may have been a consequence of pumping from a sanitary sewer to a storm sewer by the city of Logan. An apparent raw sewage discharge from a storm sewer was observed by the fish sampling crew during the survey.

Plant upgrades at the Logan WWTP (RM 67.6) were completed in 1989 and good effluent quality was maintained throughout the 1990 survey. Grab sampling downstream at RM 66.3 indicated little influence from the WWTP with all parameters except iron well within acceptable concentrations. Continuous monitor data from the Logan area indicated no major D.O. problems associated with the WWTP or the town of Logan (Table 5). Mean and 25th

percentile values were well above WWH limits.

Table 5. Summary of diurnal D.O.(mg/l) data recorded with Datasonde continuous monitors at four locations in the Hocking River and Oldtown Creek during August 8-9, 1990.

Stream RM	N[a]	Mean	Max.	Min.	25th %ile
Hocking River					
68.3	24	9.0	10.3	8.2	8.3
Logan WWTP/Oldtown Cr. Confluence					
67.0	25	9.0	10.5	8.1	8.1
66.4	22	8.8	10.5	7.7	7.8
Oldtown Creek					
0.5	25	8.2	9.5	7.4	7.6

[a] number of hourly readings

With few exceptions, good water quality conditions were maintained between Logan and Monday Creek (RM 66.3 - 51.4). Despite the rather poor operating history of the Nelsonville sewerage system (*i.e.*, lack of solids removal, maintenance, operation and possible bypassing problems) and high ammonia levels in the effluent (mean=23 mg/l), no significant changes in water quality were detected downstream from the outfall (located at RM 52.1). One exceedence for zinc detected at RM 51.4 could not be directly attributed to the WWTP but at this time a specific source has not been identified.

Hocking River Monday Creek to Coolville (RM 48.9 - 5.4)

Water quality in the upper reaches of this segment was strongly influenced by acid mine drainage in the Monday Creek and Sunday Creek basins. Monday Creek contributed significant amounts of sulfates, manganese and aluminum while additional exceedences for iron were observed downstream from Sunday Creek. Large amounts of aluminum hydroxide ("snowflake floc") and ferrous hydroxide ("yellow-boy") were also observed downstream from the Monday and Sunday Creek confluences, respectively. Buffering capacity in the mainstem was adequate to avoid acidic conditions but mine drainage parameters remained elevated downstream to Athens.

In the city of Athens, no noticeable water quality impacts were detected downstream from CSO and storm sewer locations. The next sampling location at RM 27.8 was approximately five miles downstream from the Athens WWTP. A single copper exceedence and some elevation of ammonia, compared to upstream levels, was observed. The copper and ammonia elevations did not correlate closely with the Athens WWTP effluent sampling results but may indicate a

sporadic occurrence.

Water quality conditions remained fairly similar at additional stations between Athens and Coolville. Some modest recovery from the AMD and point source inputs upstream was observed but elevated mine drainage parameters persisted downstream to the Ohio River. Additional inputs from Federal Creek and local drainages may have also contributed to the mainstem levels.

Hocking River Tributaries

WQS exceedences at tributary stations were generally low in number and limited to iron or fecal coliform. Exceptions were the numerous pH exceedences in the mine drainage impacted Sunday Creek (5 of 5 samples). Sunday Creek is currently designated a Limited Warmwater Habitat; this designation is being phased out by the Ohio EPA and the applicable criteria default to WWH levels until an appropriate use is determined. Extremely low pH values were also found in Monday Creek and some elevated iron was found in lower Rush Creek but these streams are exempted from the mine drainage criteria under the existing LWH use designations.

Baldwin Run

WQS. exceedences at RM 0.2 were limited to a fecal coliform sample but some elevation of ammonia levels (0.29 max.) and the sporadic occurrence of zinc (135 ug/l max.) suggested input from CSOs located upstream.

Rush Creek

Rush Creek is currently designated a Limited Resource Water due to acidic mine drainage sources in the upper basin. Sampling near the mouth at RM 2.1, however, revealed no exceedences of WWH criteria with the exception of iron and fecal coliform. Mine drainage parameters such as sulfate, manganese and aluminum were elevated but no acidic conditions were detected during the 1990 survey.

Clear Creek

While WQS exceedences near the mouth at RM 2.1 were limited to iron, water quality in Clear Creek appears adversely affected by nonpoint sources and land use practices in the headwaters (Erie Ontario Lake Plain ecoregion). Significant slugs of iron, suspended solids, aluminum and, to some degree, nutrients and zinc were observed during runoff events.

Oldtown Creek

Exceedences for iron and fecal coliform and some detectable quantities of ammonia (0.11 mg/l max.) were noted at RM 0.6 suggesting some introduction of sewage from upstream. The most significant elevations were for chlorides which was probably related to oil and gas wells upstream.

In past years, the General Electric plant at RM 2.0 was a known discharger of lead (Ohio EPA,

1990b). However, changes in the manufacturing process have since reduced the amounts to minor levels; no significant elevations were detected during the 1990 survey (Ohio EPA, SEDO, pers. comm.).

Athens County Landfill Tributary

The tributary was sampled to determine present water quality conditions and its possible affect on the Hocking River and the town of Nelsonville's water intake, located 1.5 miles downstream from the confluence. Currently undesignated, five exceedences of the WWH criterion for iron and one for pH were detected. Elevations of sulfates, manganese and aluminum were also characteristic of mine drainage while modest elevations of ammonia (NH_3), BOD and the previously mentioned coliform exceedence may indicate some leachate from the upstream landfill. No detectable influence on the mainstem downstream was observed.

Little Monday Creek

Although currently designated a Limited Warmwater Habitat-Acid Mine Drainage stream, WQS exceedences of WWH criteria were limited to a single iron concentration. Elevated sulfates and manganese may indicate some past mining activity but no serious acid mine problems were noted.

Monday Creek

Monday Creek (RM 0.6) was severely impacted by acid mine drainage with an average pH of 3.64. Mine drainage parameters were consistently elevated, including aluminum which averaged 10,772 ug/l and clearly influenced the Hocking River downstream.

Sunday Creek

Sunday Creek at RM 0.2 was also severely impacted by mine drainage with an average pH of 4.92, severe exceedences of both the WWH and Agricultural Water Supply standard for iron (mean=35,300 ug/l) and elevated levels of manganese, aluminum and sulfate. Acid mine drainage impacts were obvious in the lower section but more sampling is needed to determine the extent of mine influences in the upper basin and tributaries.

Federal Creek Basin

WQS exceedences were limited to iron and fecal coliform in Federal Creek (one each) with no exceedences detected in the McDougall Branch or Sharps Fork tributaries. Some elevation of ammonia and TSS at Federal Creek RM 11.5 may indicate a slight impact immediately downstream from the unsewered village of Amesville and sulfate concentrations in Sharps Fork were an indication of mining activity. There appeared to be no significant changes in water quality in the lower section of Federal Creek which is currently designated a Limited Warmwater Habitat.

Sediment Chemistry

Sediment metals samples were collected from five mainstem locations and the tributaries Monday Creek, Sunday Creek and the Athens County Landfill Tributary (Table 6). Mainstem locations were generally located downstream from significant point and nonpoint pollution sources and included samples from RM 87.3 (dst. Lancaster), RM 73.4 (dst. Rush Creek and Clear Creek), RM 53.8 (dst. Logan / ust. Nelsonville), RM 36.3 (dst. Monday and Sunday Creek) and at Coolville (RM 5.4) in the Ohio River impounded section.

With few exceptions sediment metals concentrations in the mainstem were described as non-elevated or slightly elevated using classification criteria described by Kelly and Hite (1984). All classified concentrations at Enterprise and Coolville were in these lower ranges. Criteria for aluminum and nickel are not available but showed a general increasing trend from upstream to downstream as the river flowed through the WAP ecoregion and mine drainage inputs increased.

Lead concentrations in the "elevated" and "highly elevated" range were found below Lancaster (RM 87.3) and well downstream from Logan (RM 53.8), respectively. In Lancaster, a possible reason for the elevation was continued pretreatment compliance problems with a local industrial laundry service which discharges lead (Ohio EPA Central District Office IOC, 1991). In Logan, the G.E. plant on Oldtown Creek was a known source of lead but has significantly reduced their discharges following a processing change.

"Highly elevated" arsenic, zinc and iron concentrations were found at RM 36.3, immediately upstream from Athens. Mine drainage from the Monday and Sunday Creek basins was considered the probable source of these heavy metals.

Mine drainage influences in the Sunday and Monday Creeks were evident in the sediment results with "elevated" or "extremely elevated" levels of zinc (both streams), iron (Monday Creek) and arsenic (Sunday Creek) detected. The highest sediment concentrations of aluminum in the survey were also found in these drainages.

Despite the presence of mining activity and a landfill in the Athens County Landfill Tributary drainage, all classified concentrations were in the "non-elevated" range.

Table 6. Concentrations of heavy metals in sediments of the Hocking River basin study area, 1990.[1]

Stream Name Upstream Description/Landmark River Mile	Sediment Concentration (mg/kg. dry weight) Ar	Al	Cd	Cr	Cu	Fe	Pb	Ni	Zn
Hocking River									
Lancaster									
87.3	2.64[a]	2,910	0.87[b]	7.24[a]	11.8[a]	7,100[a]	41.1[c]	10.1	59.9[a]
Rush Creek/Clear Creek confluences									
73.4	2.55[a]	3,670	0.42[a]	5.27[a]	7.5[a]	8,040[a]	17.0[a]	11.8	50.0[a]
Logan									
53.8	6.32[a]	10,900	0.41[a]	13.8[a]	14.5[a]	19,300[b]	**60.4[d]**	26.5	89.2[b]
Monday Creek/Sunday Creek confluences									
36.3	**15.60[d]**	NA	NA	20.2[b]	26.2[a]	**34,700[d]**	26.6[a]	47.8	**174[d]**
Ohio River impoundment influence									
5.4	5.52[a]	15,700	0.33[a]	13.5[a]	15.3[a]	22,900[b]	15.7[a]	27.1	84.4[b]
Monday Creek									
AMD									
0.6	5.52[a]	18,300	0.10[a]	20.0[b]	23.0[a]	**86,900[e]**	21.7[a]	20.2	103[c]
Sunday Creek									
AMD									
0.2	**30.70[e]**	32,700	0.18[a]	23.5[c]	23.5[a]	19,200[b]	22.2[a]	27.3	137[c]
Athens Co. Landfill Trib.									
Sanitary landfill and Mine Drainage									
0.5	4.25[a]	6,630	0.26[a]	10.7[a]	32.5[a]	16,000[a]	27.8[a]	32.1	77.8[a]

1 All parameter concentrations, excluding aluminum and nickel, were ranked based on a stream sediment classification system described by Kelly and Hite (1984).

a Non-elevated

b Slightly elevated

c Elevated

d **Highly elevated**

e **Extremely elevated**

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

Assessment of Macrohabitat Quality

Macrohabitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) at the 31 mainstem and the 13 tributary fish sampling locations. The QHEI considers six major features of instream habitat (substrate, cover, channel morphology, riparian zone, pool/run/riffle quality, and local gradient) and has a practical scoring range of 20 to 100. A matrix of specific QHEI attributes is used along with the composite QHEI score to evaluate macrohabitat quality. Although habitat information is collected at each sampling location the QHEI is interpreted on a reach or segment basis with regard to determining the suitability of habitat for aquatic life (Rankin 1989).

Hocking River Mainstem

The Hocking River is comprised almost entirely of free-flowing, riverine habitat with two exceptions: the Whites Mill dam immediately upstream from Athens (impounds approximately 2 miles of mainstem) and the Ohio River backwater which extends nearly 12 miles above the mouth. Habitat modifications to the mainstem have occurred primarily in Lancaster and Athens, each involving channelization, extensive diking, and channel relocation. Localized channelization has also taken place in the vicinity of Logan. QHEI scores ranged from 37 at RM 32.3 in Athens to 78 at RM 69.5 above Logan. The mainstem was divided into 6 relatively homogenous segments (Table 7) based on macrohabitat characteristics. The highest segment average QHEI of 72.5 was found between the channelized segment in Athens and the Ohio River backwater area (RM 31.5 - 12.9). The two segments between Lancaster and the channelized area in Athens averaged 66.1 (RM 87.1 - 51.6) and 62.5 (RM 47.9 - 36.7), respectively. Generally, segment scores of 60 and higher have habitat consistent with the WWH use designation. The effects of past channel modification were evident in the segment average QHEI scores of 40.3 in Lancaster (RM 92.2 - 89.0) and 47.5 in Athens (RM 36.2 - 32.3).

Examination of the QHEI matrix (Table 8) shows the effect of the channel modified areas in Lancaster and Athens. The ratio of modified to warmwater attributes is greater than 2 at all except one of the channel modified sites and the sites within the influence of the Ohio River backwater. High influence modified attributes (*i.e.* those having the most direct, negative influence on the biota) were observed most frequently in these three modified areas. Conversely, the remaining sites had modified to warmwater attribute ratios less than 1 which indicates a predominance of higher quality habitat attributes.

The combined impact of land use in the Hocking River watershed and riparian zone condition along the mainstem also was apparent in the QHEI matrix. Most of the sampling locations had heavy or moderate siltation and high or moderate substrate embeddedness. Most of the sites downstream from Rush Creek (RM 81.2) had sand as one of the predominant substrates. Extensive or moderate riffle/run embeddedness was observed between RM 95.2 above Lancaster downstream to the lower part of the channel modified area in Athens. Coal fines and chunks were observed to be intermingled with the natural sand, gravel, and cobble substrates. This extended throughout the mainstem downstream from Monday Creek. The predominance and/or presence of these substrate attributes reveals that background land use (agricultural, urban, and surface mining)

Table 7. Average QHEI scores for six relatively homogenous segments of the Hocking River mainstem based on sampling conducted during July - October, 1990.

Upstream River Mile	Downstream River Mile	Sample Loc. River Mile	Sample Location QHEI	Segment Average QHEI
Upstream from Hooker		95.2	66.5	
Segment 1: Pierce Rd. to Baldwin Run				
92.2	89.0	92.2	44.0	**40.3**
		90.8	37.0	
		89.4	42.0	
		89.0	38.0	
Segment 2: U.S. Rt. 33 to Nelsonville				
87.1	51.6	87.1	59.0	**66.1**
		82.0	62.0	
		81.2	57.5	
		77.2	63.5	
		73.2	63.5	
		69.5	78.0	
		67.3	68.5	
		66.2	68.5	
		60.6	77.5	
		55.7	63.5	
		51.6	66.0	
Segment 3: Glen Ebon Rd. to upstream Whites Mill Dam				
47.9	36.7	47.9	62.0	**62.5**
		41.8	72.0	
		36.7	53.5	
Segment 4: Union Street to U.S. 50				
36.2	32.3	36.2	50.0	**47.5**
		33.1	55.5	
		32.3	37.0	
Segment 5: U.S. 50 to Beebe				
31.5	12.9	31.5	74.0	**72.5**
		25.0	74.5	
		20.4	74.5	
		16.3	76.0	
		12.9	63.5	
Segment 6: Frost to Coolville				
9.8	4.6	9.8	47.0	**45.3**
		4.6	43.5	

Table 8. Matrix of attributes characteristic of good habitat quality (WWH attributes) and modified habitats (MWH attributes) for the Hocking River mainstem and selected tributaries based on Qualitative Habitat Evaluation Index (QHEI) evaluations conducted during July - October, 1990 at electrofishing locations.

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes: No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Mod/High Sinuosity	Extensive/Moderate Cover	Fast Current/ Eddies	Low/Normal Embeddedness	Max Depth >40 cm	Low/No Riffle Embeddedness	Total WWH Attributes	MWH Attributes (High Influence): Channelized or No Recovery	Silt/Muck Substrates	Low Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD,HW)	Total (High Influence) MWH Attributes	MWH Attributes (Moderate Influence): Recovering Channel	Heavy/Mod. Silt Cover	Sand Substrates (BT)	Hardpan Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Mod. Embeddedness	Ext./Mod. Riffle Embeddedness	No Riffle	Total (Moderate Influence) MWH Attributes	MWH (High)/WWH Attributes	MWH (Mod.)/WWH Attributes
HOCKING RIVER																																	
Year: 90																																	
95.2	66.5	13.16	■	■		■	■	■	■		■		7						0	▲							▲	▲	▲			4	.13	.63
92.2	44.0	4.73		■					■		■		2	●			●		2	▲		▲	▲				▲	▲			5	1.00	2.67
90.8	37.0	4.73		■					■		■		3	●			●		2	▲		▲	▲				▲	▲			5	.75	2.00
89.4	42.0	4.73		■					■		■		3	●			●		2	▲		▲	▲				▲	▲			5	.75	2.00
89.1	49.5	4.73	■	■				■			■		4						0	▲		▲	▲				▲	▲		▲	6	.20	1.40
89.0	38.0	4.63		■					■		■		3	●			●		2	▲		▲	▲				▲	▲			5	.75	2.00
87.1	59.0	4.63	■		■	■	■	■			■		6						0	▲							▲	▲			3	.14	.57
82.0	62.0	6.67	■	■		■	■	■			■		7						0	▲							▲	▲			3	.13	.50
81.2	57.5	4.67	■					■	■		■		4						0	▲	▲	▲	▲	▲	▲		▲	▲			8	.20	1.80
77.2	63.5	3.13	■		■	■	■	■			■		6						0	▲	▲	▲					▲	▲			5	.14	.86
73.2	63.5	3.13	■		■	■	■	■			■		6						0	▲	▲				▲		▲	▲			5	.14	.86
69.5	78.0	3.72	■	■		■	■	■	■		■		7						0								▲	▲			2	.13	.38
67.3	68.5	3.41		■				■	■		■		4						0	▲	▲		▲	▲			▲	▲			6	.20	1.40
66.2	68.5	3.41	■	■		■	■	■	■		■		7						0	▲	▲		▲				▲	▲			5	.13	.75
60.6	77.5	2.36	■	■		■	■	■	■		■		7						0	▲	▲						▲	▲	▲		5	.13	.75
55.7	63.5	6.45	■	■			■	■	■		■		6						0	▲		▲		▲			▲	▲			5	.14	.86
51.6	66.0	1.92	■	■			■	■	■	■	■		7						0	▲	▲		▲		▲			▲			5	.13	.75
47.9	62.0	1.92	■			■	■	■			■		5				●		1	▲	▲		▲				▲	▲		▲	6	.33	1.33
41.8	72.0	1.96	■	■		■	■	■			■		6						0	▲	▲						▲	▲	▲		5	.14	.86
36.7	53.5	1.96	■	■				■	■		■		5	●			●		2	▲		▲	▲	▲			▲	▲		▲	7	.50	1.67
36.2	50.0	1.96	■					■			■		3						0	▲	▲	▲		▲	▲			▲	▲	▲		8	.25	2.25
33.1	55.5	1.63	■					■			■		3						0	▲	▲	▲		▲	▲			▲	▲	▲		8	.25	2.25
32.5	41.0	1.63	■								■		2	●			●		2	▲	▲		▲	▲	▲			▲	▲	▲		8	1.00	3.67
32.3	37.0	1.63									■		1	●			●		2	▲	▲		▲	▲	▲			▲	▲	▲	▲	9	1.50	6.00
31.5	74.0	1.63	■	■		■	■	■			■		7						0	▲	▲							▲	▲	▲		5	.13	.75
25.0	74.5	1.63	■	■		■	■	■			■	■	7						0	▲	▲							▲	▲			4	.13	.63
20.4	74.5	2.24	■	■		■	■	■	■		■	■	8				●		1	▲	▲							▲				3	.22	.56
16.3	76.0	2.24	■	■		■	■	■	■		■	■	8						0	▲	▲							▲				3	.11	.44
12.9	63.5	.10	■	■		■	■	■			■		6						0	▲	▲		▲					▲	▲		▲	6	.14	1.00
9.8	47.0	.10	■					■			■		3	●			●		2	▲	▲		▲	▲				▲	▲		▲	7	.75	2.50
4.6	43.5	.10	■					■			■		3	●			●		2	▲			▲	▲				▲	▲		▲	6	.75	2.25
OLDTOWN CREEK																																	
Year: 90																																	
0.6	69.5	6.57	■	■		■	■	■	■		■		7			●	●		2				▲								1	.38	.50

Table 8. (continued).

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes: No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Mod/High Sinuosity	Extensive/Moderate Cover	Fast Current/ Eddies	Low/Normal Embeddedness	Max Depth >40 cm	Low/No Riffle Embeddedness	Total WWH Attributes	MWH Attributes: High Influence: Channelized or No Recovery	Silt/Muck Substrates	Low Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD,HW)	Total (High Influence) MWH Attributes	Moderate Influence: Recovering Channel	Heavy/Mod. Silt Cover	Sand Substrates (BT)	Hardpan Origin	Fair/Poor Development	Low/No Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Mod. Embeddedness	Ext./Mod. Riffle Embeddedness	No Riffle	Total (Moderate Influence) MWH Attributes	MWH (High)/WWH Attributes	MWH (Mod.)/WWH Attributes
BALDWIN RUN																																	
Year: 90																																	
0.3	50.5	13.89	■			■		■	■		■		4	●		●			2			▲						▲	▲	▲	4	.60	1.40
HUNTER RUN																																	
Year: 90																																	
0.5	50.0	6.54	■			■		■	■		■		4	●		●			2		▲		▲	▲				▲	▲		5	.60	1.60
FEDERAL CREEK																																	
Year: 90																																	
11.4	81.5	8.30	■	■		■	■	■	■	■	■	■	9						0												0	.10	.10
1.3	75.5	2.31	■	■		■		■	■	■	■	■	8						0				▲								1	.11	.22
MCDOUGALL BRANCH																																	
Year: 90																																	
2.6	52.0	7.69	■		■				■	■	■		5	●		●			2	▲		▲	▲				▲				4	.50	1.17
SHARPS FORK																																	
Year: 90																																	
0.3	59.0	4.39	■	■			■		■	■	■		6			●			1			▲	▲				▲				3	.29	.71
SUNDAY CREEK																																	
Year: 90																																	
0.2	50.0	1.80	■	■			■				■		4			●			1	▲		▲					▲	▲		▲	5	.40	1.40
TRIB. TO SUNDAY CREEK																																	
Year: 90																																	
0.2	67.5	12.82	■	■		■	■	■	■	■	■	■	9						0	▲	▲							▲			3	.10	.40
MONDAY CREEK																																	
Year: 90																																	
1.8	40.0	2.21									■		1	●		●			2	▲		▲	▲	▲				▲	▲	▲		7	1.50	5.00
LITTLE MONDAY CREEK																																	
Year: 90																																	
1.0	50.0	5.80	■			■		■			■		4			●			1	▲		▲	▲						▲	▲	▲	6	.40	1.60
CLEAR CREEK																																	
Year: 90																																	
2.0	78.0	4.12	■	■		■	■	■	■	■	■	■	9						0	▲												1	.10	.20
RUSH CREEK																																	
Year: 90																																	
2.0	41.5	2.91					■				■		2	●		●			2	▲	▲		▲						▲	▲	▲	6	1.00	3.00

has had a profound influence on the habitat of the mainstem.

The encroachment of land use activities on the riparian zone was apparent along much of the mainstem. Most of these activities included the removal of mature woody vegetation which in turn permits extensive erosion of the banks, particularly during elevated flows. Eroded materials (mostly clayey silts and sand) are then deposited as bed load in the river channel. In many areas large trees were either absent or present only in single rows. This also permits more rapid than normal erosion of the banks which leads to an unstable river channel. Extensive areas of high, eroded outside bends lacking any vegetative cover were evident especially downstream from the channelized sections below Lancaster, Athens, and Logan. This appeared to be due to increased delivery of bed load sediments and increased flow velocities from the channelized segments. One solution would be to reduce the high flow velocities and bed load export by permitting natural recovery processes to take place unhindered within each segment. Such initial habitat recovery was evident in the Athens area in the formation of sand/gravel bars and riffles. Furthering this process should result in a narrowing of the river channel, stabilization of sediment, and less export of both sediment and high flow velocities into downstream segments. Without this type of "intervention" the erosional forces will continue to result in continued bank erosion and de-stabilization.

Of the many habitat impacts observed in the mainstem, channelization in the Lancaster and Athens areas are the most profound. Only slight recovery was noted in the Lancaster segment between RM 92.2 and 89.0. However, a gradient of nearly 5 feet/mile should permit sufficient recovery of WWH attributes provided no further channel maintenance activities take place. The Athens segment is somewhat different in that the channel modification is due to channel relocation and the re-channelized section is much wider. Although the river between RM 36.2 and 32.3 retains many modified habitat attributes, the results of initial natural recovery processes were evident in the partial reformation of pools, runs, and riffles. This segment should also recover sufficient WWH attributes provided no further channel maintenance activities take place and sufficient riparian vegetation is allowed to return.

Hocking River Tributaries

Macrohabitat near the mouth of thirteen tributaries was also assessed. QHEI scores ranged from a high of 78 in Clear Creek to a low of 40 in Monday Creek (Table 8). Only two tributaries (Monday Creek and Rush Creek) had modified to warmwater attribute ratios greater than 2, the result of extensive impacts from surface mine runoff and channel modification (Table 8). Five tributaries had ratios greater than 1 and included two impacted by urban land use (Baldwin Run and Hunter Run) and three by surface mine runoff (McDougall Branch, Sunday Creek, and Little Monday Creek). The currently undesignated unnamed tributary to Sunday Creek had a QHEI of 67.5 indicating good quality habitat for this headwater stream. The highest quality habitat was observed in Federal Creek and Clear Creek.

Macroinvertebrates

Hocking River Mainstem

Quantitative data were collected from 27 Hocking River mainstem stations between RM 95.1 and 4.9 (Table 9). Narrative evaluations ranged from exceptional at RM 36.9 (ICI=56) to fair (ICI=28) at RM 89.1 in the Lancaster WWTP mixing zone. With the exception of the mixing zone site, all mainstem ICI scores met or exceeded the applicable WWH ICI biocriterion (Figure 4). Outside of the immediate influence of significant point and nonpoint sources, these ICI scores generally ranged between the very good to exceptional range.

Benthic communities were in the exceptional range upstream from Lancaster and in the channelized urban area upstream from the Lancaster combined sewer overflows (ICIs = 50 and 52 at RM 95.1 and 91.9, respectively). The ICI began to decline at RM 90.7 (ICI=46) and reached a low of 38 upstream from the Lancaster WWTP (RM 89.4) and downstream from Hunters Run and several major CSOs. In contrast to earlier sampling, CSO impacts in 1990 appeared much less severe. The recent data gave little indication of the grossly polluted conditions upstream from the Wheeling Street lift station at RM 91.2 (ICI=8), or the severely toxic conditions downstream at RM 89.4 (ICI=2) that were observed in 1982.

Communities in the Lancaster WWTP mixing zone reflected fair conditions (ICI=26) and were primarily indicative of organic enrichment. Densities increased sharply with nutrient tolerant oligochaetes accounting for 71% of the artificial substrate community. The continued presence of more pollution sensitive mayflies, caddisflies and tanytarsini midges coupled with the lack of severe impact (*i.e.*, poor or very poor conditions) suggested toxicity was not a major problem in the mixing zone.

Station RM 88.9 was located immediately downstream from the Lancaster WWTP and the confluence with Baldwin Run. The ICI score of 32 indicated marginal conditions but met the minimum criterion for WWH attainment of the macroinvertebrates.

Macroinvertebrates improved considerably with increased distance downstream from Lancaster. The ICI reached an exceptional level at RM 82.9 (ICI=46) and remained in the good to exceptional range from Rush Creek to Logan (Station RMs 81.3-69.4). Artificial substrate communities were characterized by steady declines in the abundance of tolerant taxa (ICI metric #9) and other dipterans / non-insects (metric #8) with corresponding increases in densities of filter-feeding midges of the *Reotanytarsus exiguus* group (metric #7). These midges are considered relatively sensitive to toxic substances but often proliferate in areas of strong current and high suspended solids. Overall, conditions in this stretch were considered good but moderately enriched downstream from Lancaster.

The Logan WWTP mixing zone ICI of 32 was in the area of nonsignificant departure from the WWH criterion and reflected marginally good water quality conditions. The primary influence on the benthos appeared to be organic enrichment.

Table 9. Summary of macroinvertebrate data collected from artificial substrates (quantitative data) and natural substrates (qualitative data) in the Hocking River study area, July 25 to September 7, 1990.

Stream River Mile	Narrative Evaluation[a]	Quantitative Evaluation ICI	No. Quant. Taxa	Relative Density	No. Qual. Taxa	Qual. EPT[b]
Hocking River						
95.1	Exceptional	50	39	1199	49	14
91.9	Exceptional	52	47	855	55	16
90.7	Exceptional	46	47	696	59	13
89.4	Good	38	49	943	43	7
89.1	Fair	26*	41	2788	23	3
88.9	Marg. Good	32[ns]	42	1105	49	9
87.2	Marg. Good	Samplers lost - see Qual. Evaluation			43	9
82.9	Exceptional	46	46	1292	53	13
81.3	Good-Excep.	44	32	2348	44	15
77.1	Good	Samplers lost - see Qual. Evaluation			35	11
73.4	Good	Samplers lost - see Qual. Evaluation			43	13
69.4	Exceptional	46	28	4057	47	12
67.6	Marg. Good	32[ns]	31	2488	32	8
67.4	Good	40	28	3898	45	9
66.3	Good	38	41	1486	38	9
60.8	Good	Samplers lost - see Qual. Evaluation			41	13
55.3	Good	44	37	1148	41	11
51.4	Exceptional	52	46	2017	45	15
48.5	Exceptional	48	38	596	39	11
42.2	Good	40	36	250	42	10
36.9	Exceptional	56	38	1109	43	14
36.1	Good	42	30	2234	47	10
32.6	Good	40	31	3152	44	12
32.5	Good	38	40	2894	37	8
32.0	Exceptional	46	37	1761	39	10
29.5	Exceptional	50	32	2152	57	17
24.9	Exceptional	46	28	2588	48	15
19.7	Good-Excep.	44	29	2355	49	15
16.1	Exceptional	52	37	838	56	15
14.0	Exceptional	48	38	1718	34	8
4.9	Good	36	38	566	22	3
Hunters Run						
0.5	Good	38	44	655	41	7
Baldwin Run						
0.2	Fair	16*	39	243	28	3
Rush Creek						
2.1	Exceptional	46	38	1852	39	11
Clear Creek						
2.0	Exceptional	50	48	705	70	15
Oldtown Creek						
0.6	Fair	22*	26	259	38	8
Little Monday Creek						
0.1	Good	38	40	304	30	7
Federal Creek						
11.7	Exceptional	46	46	230	44	10
0.9	Exceptional	54	37	788	42	14

Table 9.(continued)

Stream River Mile	Narrative Evaluation	Qualitative Evaluation: No. Qual. Taxa	Qual. EPTb	Relative Density	Predominant Organisms
Hocking River					
87.2	Fair-Good	43	9	High	Midges, blackflies
77.1	Good	35	11	Low-mod.	Mayflies, blackflies
73.4	Good	43	13	Low	Blackflies, mayflies
60.8	Good	41	13	Mod.	Mayflies, midges
Monday Creek					
1.7	Poor	8	0	Low	Red midges
Sunday Creek					
0.2	Poor	10	0	Low-none	None
McDougal Branch					
2.9	Good	45	9	Low	Hydropsychid caddisflies
Sharps Fork					
0.2	Good	44	13	Low	Elmid beetles, blackflies, crane flies

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

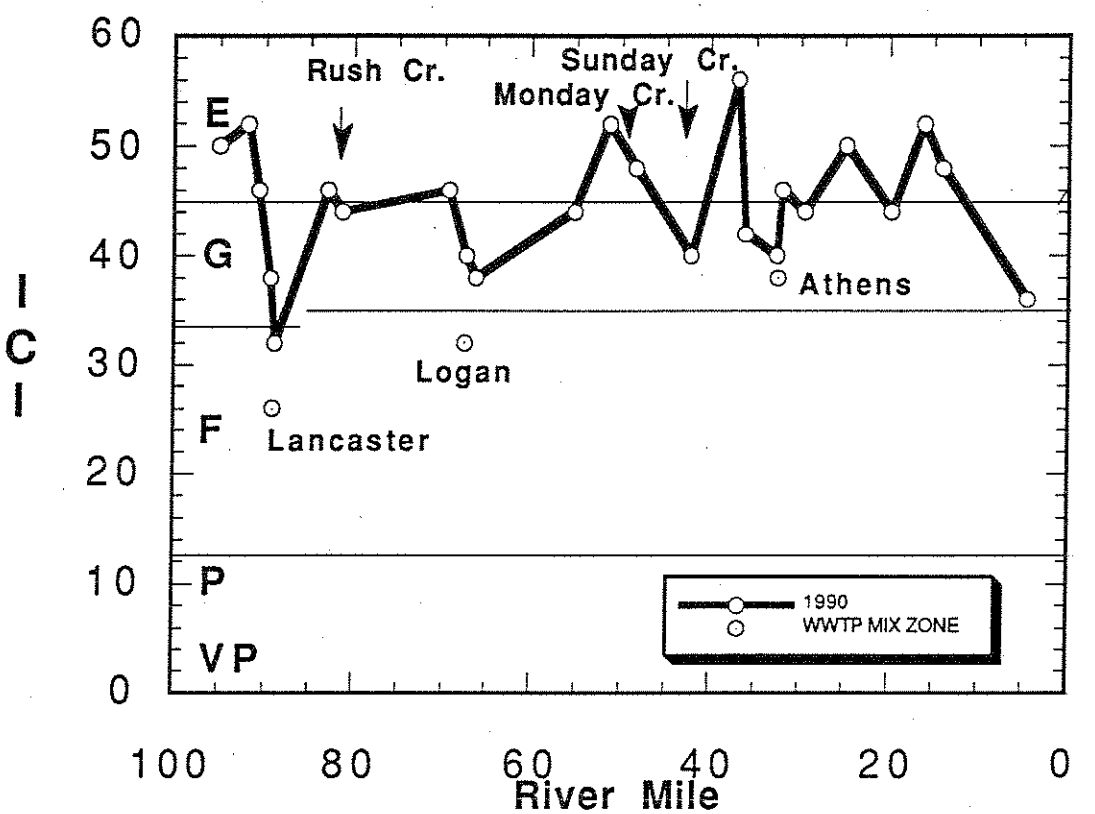

Figure 4. Longitudinal trend of the Invertebrate Community Index (ICI) in the Hocking River mainstem, 1990. E denotes exceptional invertebrate communities (meets EWH criteria), G denotes good invertebrate communities (meets WWH criteria), and F, P, and VP denote fair, poor, and very poor invertebrate communities (non-attainment of aquatic life use).

At four stations between the Logan WWTP mixing zone and Monday Creek (RM 67.4 - 51.4) ICI scores ranged from 38 to 52 and reflected good to exceptional water quality conditions. A gradual improving trend with increased distance downstream from Logan was observed with the highest ICI value noted at RM 51.4, downstream from the Nelsonville WWTP .

Slight to moderate impacts were observed downstream from Monday Creek (ICI=48 at RM 48.5) and Sunday Creek (ICI= 40 at RM 42.2). Samplers downstream from Sunday Creek may have also been affected by slower current velocities and excessive deposition of "yellow-boy". Communities were characterized by declines in density, qualitative EPT taxa and a sharp decrease in tanytarsini midge predominance coupled with proportional increases in the numbers of the genus *Baetis sp*, a pollution intermediate mayfly. Community composition improved upstream from Athens (RM 36.9) where the ICI of 56 was in the exceptional range.

ICI values declined in the channelized section in Athens upstream from the WWTP but remained above the WWH criterion (ICIs = 42 and 40 at RMs 36.1 and 32.6, respectively). The change in the ICI between the channelized section (RM 36.1) and the more natural section immediately upstream (RM 36.9) resulted from numerous, relatively slight shifts in community composition and did not appear to reflect a significant decline in water quality. In contrast to previous sampling efforts, the influence of urban runoff or combined sewers in Athens appeared minimal with no significant changes in composition at RM 32.6, immediately upstream from the WWTP.

The Athens WWTP mixing zone ICI exceeded the WWH criterion and community composition was fairly similar to collections immediately upstream. Data indicated no significant "near field" impacts associated with the discharge.

ICIs at remaining free-flowing sites from RM 32.0 - 14.0 were in the very good to exceptional range and indicated no significant impacts downstream from Athens. Nonpoint runoff or sedimentation effects appeared minimal although the artificial substrates have a tendency to control for variations of the natural substrates which, in the case of the lower Hocking River, were mostly loosely compacted sand and gravel. These finer substrates tended to harbor more depauperate faunas than coarser deposits of gravel, rubble, leaf pack and woody debris.

Station RM 4.9 was impounded by navigation locks and dams in the Ohio River. Despite sluggish flow conditions, the ICI of 36 exceeded the WWH criterion. This was one of the few impounded invertebrate sites in the OEPA database which has met WWH levels.

Hocking River Tributaries

Hunters Run

The ICI from RM 0.5 was in the good range (38) and slightly exceeded the WWH biocriterion. The community was predominated by dipteran and non-insect taxa while more pollution sensitive mayflies and caddisflies were present in proportionately lower numbers. Natural

substrates had fairly heavy silt and solids deposition and some areas were permeated with oil (a diesel fuel spill was reported from the Lancaster Electroplating plant in March 1990). Hunters run is subject to nonpoint urban and industrial runoff but lacks CSO discharges.

Baldwin Run

Samples from RM 0.2 scored in the low fair range (ICI=16) and reflected significant water quality impacts downstream from several of the Lancaster CSOs. Nutrient tolerant oligochaetes and pulmonate snails accounted for about 50% of the total organisms on the artificial substrates. Water quality degradation appeared primarily related to conventional sewage introduction although the severity of impact suggests these pollutants may have reached moderately toxic levels.

Clear Creek

Quantitative data from RM 2.0 was in the exceptional range (ICI=50) with extremely diverse populations collected from both the artificial and natural substrate samples (86 total taxa). The RM 2.0 site has been sampled four times since 1982 with ICIs reflecting very good to exceptional conditions (range: 42-52).

Rush Creek

The ICI of 46 at RM 2.1 was in the low exceptional range, and the sample was predominated by dense populations of midges of the *Reotanytarsus exiguus* group, suggesting high background levels of suspended solids. During qualitative sampling, organisms were virtually absent from the mostly sand substrates but were found in large numbers on non-embedded pieces of woody debris, detritus and scattered coarse substrates. This suggests that the availability of adequate substrates, as opposed to water quality, was the major limiting factor for the establishment of widespread populations of macroinvertebrates. An additional sample was collected at RM 2.1 in the late summer of 1991 following observations of acid mine waters which reached as far downstream as the mouth. The ICI of 34 was in the marginally good range and indicated a decline in water quality conditions compared to the 1990 data.

Oldtown Creek

The ICI of 22 at RM 0.6 was in the fair range and well below the WWH criterion of 36. Although substrates were predominantly coarse rubble and gravel, the bottom was silt covered and heavy deposits of slimy silt were found on the artificial substrates. Population densities on both the natural and artificial substrates were low and only three mayfly and caddisfly individuals were found in the quantitative sample. From the data, it was difficult to determine the specific nature of the impact or if it was point or nonpoint source related.

Sunday Creek and Monday Creek

Qualitative sampling in the lower reaches of both streams reflected severe acid mine drainage impacts. Only eight to ten acidophilic taxa were found in each stream and, with few exceptions, their abundance was extremely low.

Little Monday Creek

Little Monday Creek is currently designated LWH with an exemption from specific chemical water quality parameters associated with mine drainage. The ICI of 38 at RM 0.1 slightly exceeded the WWH criterion. Communities were fairly diverse and included numerous, relatively sensitive taxa not typically associated with mine runoff.

Federal Creek Basin

McDougall Branch

Artificial substrate samplers were lost at the RM 2.9 station. Forty five qualitative taxa were collected including nine types of mayflies and caddisflies; this number falls in a range generally associated with good water quality based on scoring for the qualitative EPT ICI metric #10. In 1984 an ICI of 28 (Fair) was recorded at RM 2.9 under nearly intermittent flow conditions.

Sharps Fork

Artificial substrate samplers were also lost at RM 0.3. Numerous high quality organisms were collected in the qualitative sample (49 total taxa; 11 EPT taxa) but in very low densities. Substrate embeddedness, extensive siltation and torrential flows during the 1990 sampling season may have been the major reasons for the low population densities. In addition to surface mine runoff, bank erosion and slumpage observed along the adjacent roadway may have also contributed to the siltation problems.

Federal Creek

Artificial substrates were collected upstream from the confluences with McDougall Branch and Sharps Fork at RM 11.7 and downstream near the mouth at RM 0.9. Federal Creek is currently designated EWH upstream from Sharps Fork and LWH downstream due to mining in the lower watershed. ICI scores from both sites, however, scored in the exceptional range and indicated no significant change in conditions from upstream to downstream.

Fish Community

Hocking River Mainstem

A total of 15,091 fish comprised of 73 species and 4 hybrids were collected from the Hocking River mainstem during the period July 17 through October 4, 1991. The sampling effort included a cumulative total of 37.68 km at 32 locations between RM 95.2 upstream from Lancaster and RM 4.6 near Coolville. The fish community was predominated by numbers by gizzard shad (10.7%), common carp (8.8%), golden redhorse (7.8%), bluegill sunfish (6.7%), northern hog sucker (6.7%), emerald shiner (6.1%), spotfin shiner (5.6%), and creek chub (5.3%). Species that predominated in terms of biomass were common carp (54.2%), silver redhorse (10.4%), golden redhorse (9.8%), and channel catfish (4.2%). Species listed as rare, endangered, threatened, or special status (Ohio DNR 1990) included American brook lamprey (8 individuals), eastern sand darter (5), silver chub (2), and river darter (1).

Based on IBI and MIwb scores and accompanying narrative evaluations, overall fish community performance ranged from good to poor (Table 10; Figure 5). No sites performed at exceptional or very poor levels. IBI and MIwb values were in the good range at RM 95.2 upstream from Lancaster (IBI = 35; MIwb = 8.2) and between RM 73.2 upstream from Logan to RM 51.6 just upstream from Monday Creek. Downstream from Monday Creek at RM 47.9 to RM 16.3 near Stewart, community performance ranged from marginally good to fair. Fair performance was observed in the lower section of mainstem affected by the Ohio River backwater between RM 12.9 and 4.6. The only segment consistently reflecting poor performance was between RM 92.2 and RM 82.0 within and downstream from Lancaster.

Intolerant species were *absent* from 67 of 93 mainstem samples and were in very low abundance in most of the remaining samples. This metric of the IBI scored a "1" (lowest score possible) in 90 of 93 samples. These results attest to the effects of upland erosion and runoff, channel modification, and severe bank erosion, all of which have contributed to the high to moderate embeddedness and heavy to moderate siltation of the mainstem substrates. The total numbers of fish (less tolerants) metric scored a "1" in 44 samples and "3" in 43 samples. Reduced density while maintaining moderate diversity (number of species scored "3" or "5" in 82 samples) appears to be a response signature of sedimentation, particularly where mine runoff is prevalent. Numbers were consistently lower in and downstream from Lancaster, downstream from Nelsonville and Monday Creek, and downstream from Athens.

The number of darter species (applicable only to wading sites; RM 95.2 - 82.0) was 0 or 1 in 15 of 24 samples and scored a "1" in 19 of 24 samples, all of which occurred downstream from RM 95.2 in the Lancaster urban area and downstream from the WWTP. The percentage of round-bodied suckers (the boat site type substitute for the darter metric) scored a "1" or "3" in 51 of 69 boat samples. Most of the "1" scores occurred downstream from the Athens WWTP (RM 32.5).

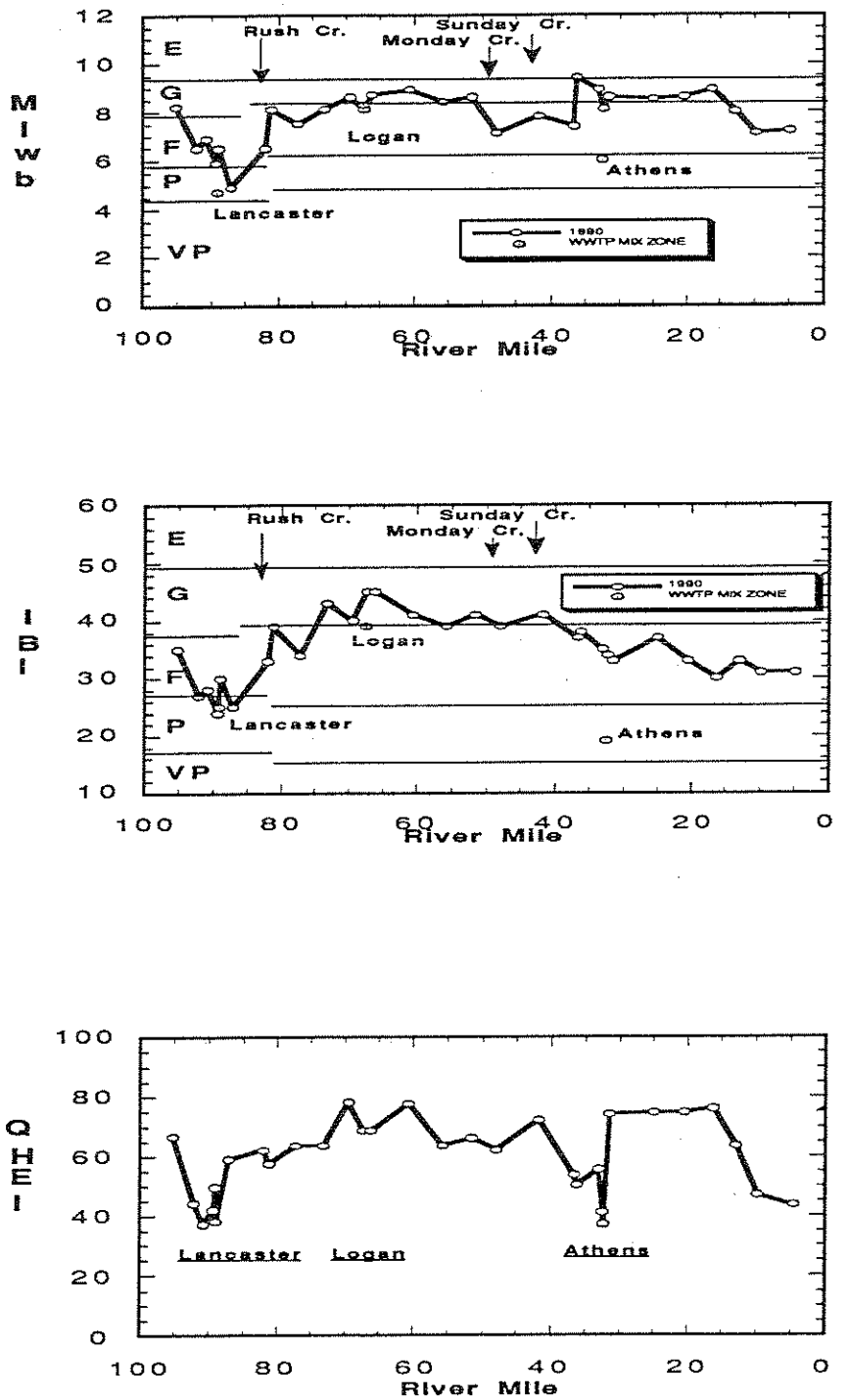

Figure 5. Longitudinal trend of the Modified Index of Well-Being (MIwb), Index of Biotic Integrity (IBI), and Qualitative Habitat Evaluation Index (QHEI) in the upper Hocking River based on electrofishing collections during July - October, 1990. **NOTE:** Changes in criteria limits between the Good (G), Fair (F), Poor (P) and Very Poor (VP) ranges correspond with changes in ecoregions and site type.

The frequency of external deformities, eroded fins, lesions, and tumors (DELT anomalies) was highest in the Athens WWTP (37.5%) and Logan WWTP (36.4%) mixing zones.. With the exception of the upstream site at RM 95.2, and 8 individual samples at other sites scattered throughout the mainstem, this IBI metric scored a "1" or "3" indicating the presence of sublethal stress throughout much of the mainstem. Eroded fins and lesions were the predominant DELT anomalies observed and are most frequently associated with organic enrichment type impacts.

Tolerant species predominated within and downstream from Lancaster comprising greater than 50% of the catch between RM 92.2 and RM 87.1 and as evidenced by consistent IBI metric scores of "1" (19 of 22 samples between RM 95.2 and 87.1). These results are consistent with the poor condition of the fish community in this section of the mainstem. Downstream from RM 82.0 this pattern was almost completely reversed with highly tolerant species making up less than 10-20% of the catch at each site. The percent composition by omnivores was somewhat similar to tolerant composition, but was less pronounced with regard to specific segments of the mainstem.

Number of species, sucker species, sunfish species, and simple lithophils scored "3" at most sites while percent composition as insectivores scored "3" or "5" at most sites.

Hocking River Tributaries

Twelve (12) locations in 11 tributaries were sampled for fish during July and September 1991. Overall condition of the fish community in each ranged from very good to very poor. Impacts in each tributary ranged from severe acid mine drainage to moderate siltation.

The influence of urban land use on Hunters Run and the Lancaster combined sewer overflows on Baldwin Run was evident in the fish community results. Of the two streams, Baldwin Run appeared the most impacted with overall community performance in the fair range (Table 10). Tolerant species (blacknose dace, creek chub) predominated with darter species, intolerants, and insectivores in low abundance. Hunters Run had slightly better overall community performance (marginally good), but was likewise predominated by tolerant species.

Rush Creek, Monday Creek, Little Monday Creek, and Sunday Creek all showed varying impacts from acid mine runoff. No fish were collected in Monday Creek and only single individuals of 3 tolerant species were found in Sunday Creek. All 12 IBI metrics scored a "1" resulting in the minimum possible IBI of 12 for each stream and a very poor narrative rating. The effects of severe acid mine runoff mostly from abandoned mine lands were obvious in these three streams. An unnamed tributary to Sunday Creek was sampled once in the latter part of the study period. Although the stream is small (1.0 sq. mi.), the habitat was good (QHEI=67.5). The fish community was, however, comprised of tolerant and pioneering species, the predominance of which correlates with the overlying impact from sedimentation.

Rush Creek yielded 21 species which reflects a considerable degree of improvement over conditions in the headwaters. Although the acidic runoff from the upper watershed is largely

neutralized by alkaline water from Little Rush Creek, sedimentation from this neutralization, upland runoff, and the channelization of the lower mainstem are reflected in the fish community results. Tolerant and moderately tolerant species (carp, bluegill, spotfin shiner) predominate, but the presence of species such as golden redhorse, hog sucker, and silver redhorse indicate that some recovery has occurred in the past decade.

The remaining tributaries reflected at least marginally good performance. Of these, Federal Creek had the best overall performance with high IBI and MIwb scores (Table 10). McDougall Branch, Sharps Fork, and Oldtown Creek followed with IBI scores in the low 40s and MIwb scores generally greater than 8.0.

An exception was Clear Creek which had an MIwb of 7.7. The results were somewhat unusual in that the sunfish metric scored "1" and the darter metric scored likewise in one of the two samples. The former indicates some disturbance to the quality of the pool habitat. The upper watershed is predominated by row crop agriculture and the mainstem has been channelized downstream to near the ECBP/WAP ecoregion boundary. The increased rate of the delivery of upland runoff and siltation result in a higher than normal bank erosion and heavy to moderate siltation (Table 8) similar to that which was previously described for the Hocking River mainstem downstream from Lancaster and Athens. Riffles were highly embedded and the pool substrates were unstable as a result of eroding banks. This was exemplified by the clumps of soil with terrestrial vegetation still attached which were found at the bottoms of the pools. The overall performance of the fish community would likely have been lower if it were not for an overwhelming predominance of warmwater habitat attributes.

McDougall Branch had few intolerant species and scored "3" for each functional metric of the IBI. This stream, too, was affected by heavier than normal siltation. Federal Creek results were similar to the best reference sites of the WAP ecoregion except for an absence of intolerants at RM 11.4. The QHEI matrix (Table 8) revealed no overt indication of substrate or other habitat degradation, however.

Table 10. Fish community indices based on electrofishing at 44 locations sampled by Ohio EPA in the Hocking River basin study area during July to October, 1990.

Stream River Mile	Mean Cum. Species	Mean Rel. Number	Rel. Weight	Index of Biotic Integrity	Modified Index of Well. Being (Iwb)	QHEI[a]	Narrative Evaluation[b]
Hocking River (Warmwater Habitat-WWH)							
95.2	19	1046	15.9	35[ns]	8.2	66.5	Marg. Good
92.2	20	499	122	27*	6.5*	44.0	Poor-Fair
90.8	21	333	6.7	28*	6.9*	37.0	Fair
89.4	24	370	21.9	24*	5.9*	42.0	Poor-Fair
89.1	12	268	22.2	25*	4.7*	49.5	Poor
89.0	16	304	29.6	30*	6.5*	38.0	Fair
87.1	17	149	41.9	25*	4.9*	59.0	Poor
82.0	20	160	18.9	33*	6.5*	62.0	Fair
81.2	21	265	65.5	39[ns]	8.1[ns]	57.5	Marg. Good
77.2	26	277	137.2	34*	7.5*	63.5	Fair
73.2	25	245	53.3	43	8.1[ns]	63.5	Good-Marg. Good
69.5	22	262	65.4	40	8.6	78.0	Good
67.5	17	513	256.6	39[ns]	8.3[ns]		Marg. Good
67.3	27	296	74.0	45	8.1[ns]	68.5	Good-Marg. Good
66.2	23	283	72.9	45	8.7	68.5	Good
60.6	28	292	105.1	41	8.9	77.5	Good
55.7	22	363	84.7	39[ns]	8.4[ns]	63.5	Marg. Good
51.6	20	308	74.8	41	8.6	66.0	Good
47.9	19	76	20.2	39[ns]	7.1*	62.0	Marg. Good-Fair
41.8	19	131	26.1	41	7.8*	72.0	Good-Fair
36.7	20	142	28.0	37[ns]	7.4*	53.5	Marg. Good-Fair
36.2	37	396	150.9	38[ns]	9.4	50.0	Marg. Good-V. Good
33.1	32	354	135.2	35*	8.9	55.5	Fair-Good
32.5	17	205	136.8	19*	6.0*	41.0	Poor
32.3	30	215.4	67.9	34*	8.1[ns]	37.0	Fair-Marg. Good
31.5	29	233.3	80.0	33*	8.6	74.0	Fair-Good
25.0	29	297	94.3	37[ns]	8.5[ns]	74.5	Marg. Good
20.4	22	259.	65.9	33*	8.6	74.5	Fair-Good
16.3	25	309	93.1	30*	8.9	76.0	Fair-Good
12.9	27	412	76.8	33*	8.0*	63.5	Fair
9.8	22	235	14.8	31*	7.1*	47.0	Fair
4.6	25	447	35.6	31*	7.2*	43.5	Fair
Hunters Run (WWH)							
0.5	17	755	9.4	39[ns]	NA	50.0	Marg. Good
Baldwin Run (WWH)							
0.3	15	1942	18.4	31*	NA	50.5	Fair

Table 10. (continued)

Stream River Mile	Mean Cum. Species	Mean Rel. Number	Rel. Weight	Index of Biotic Integrity	Modified Index of Well. Being (Iwb)	QHEI[a]	Narrative Evaluation[b]
Clear Creek (WWH)							
2.0	18	384	19.2	42[ns]	7.7[ns]	78.0	Marg. Good
Oldtown Creek (WWH)							
0.6	16	1512	NA	44	NA	69.5	Good
Rush Creek (Limited Resource Water-LRW)							
2.0	21	188	97.1	28*	6.3	41.5	Fair-Poor
Little Monday Creek (Limited Warmwater Habitat-LWH)							
1.0	12	186	1.6	26*	5.7*	50.0	Poor
Sunday Creek (LWH)							
0.2	3	6	0.1	12*	2.4*	50.0	V. Poor
U.T. to Sunday Creek (Undesignated)							
0.2	5	116	NA	22*	NA	67.5	Poor
Monday Creek (LRW)							
1.8	0	0	0	12*	0.0*	40.0	V. Poor
McDougall Branch (Exceptional Warmwater Habitat-EWH)							
2.5	30	307	13.1	42*	9.1[ns]	52.0	Marg.Good-V.Good
Sharps Fork (EWH)							
0.3	20	255	4.0	44*	8.1*	59	Good
Federal Creek (EWH)							
11.4	25	447	6.7	48[ns]	9.0[ns]	81.5	V. Good
Federal Creek (LWH)							
1.3	29	226	2.8	46[ns]	8.7*	75.5	V. Good-Good

Ecoregion Biocriteria:

Erie/Ontario Lake Plain (EOLP; RM 95.2-87.1)

INDEX - Site Type	EWH	WWH[c]	MWH[d]	LRW[e]
IBI - Headwaters	50	40	N/A	18
IBI - Wading (RM 95.2-87.1 and tributaries)	50	38	N/A	18
Mod. Iwb - Wading	9.4	7.9	N/A	4.5

Western Allegheny Plateau (WAP; RM 82.9-4.6)

INDEX - Site Type	EWH	WWH[c]	MWH[d]	LRW[e]
IBI - Wading (RM 82.0 and tributaries)	44	44	24	18
IBI - Boat (RM 81.2-4.9; Rush Cr. RM 2.0)	40	40	24	16
Mod. Iwb - Wading (RM 82.0 and tributaries)	9.4	8.4	5.5	4.5
Mod. Iwb - Boat (RM 81.2-4.9; Rush Cr. RM 2.0)	9.6	8.6	5.5	5.0

* Significant departure from ecoregion biocriteria; poor and very poor results are underlined.

ns Nonsignificant departure from biocriterion (4 IBI or ICI units; 0.5 Iwb units).

NA Headwater site - MIwb not applicable.

a Qualitative Habitat Evaluation Index (QHEI) values based on the most recent version (Rankin 1989); [b] Based on IBI and MIwb scores; [c] Applies to LWH use designation; [d] MWH for mine affected streams - WAP ecoregion only; [e] Interim criteria for Limited Resource Water streams.

Trend Assessment: 1982 through 1990

Chemical/Physical Water Quality

Upper Hocking River - Lancaster Area

Historically, the Hocking River between Lancaster and Rush Creek has been one of the most severely degraded river segments in the state (Ohio EPA 1982). Inadequate treatment and bypassing at the Lancaster WWTP, wet and dry weather CSOs and a heavy contribution of industrial effluents (30 - 35%) resulted in gross enrichment and heavy metals contamination, significant levels of in-stream toxicity, and periodic fish kills. Chemical and biological data from 1990 reflect significant improvement in this segment as a result of pollution control efforts in Lancaster including plant expansion, implementation of a sewer user pretreatment ordinance and the active monitoring by the wastewater plant personnel. Both the bulking of sludge and the toxic conditions which inhibited treatment of the waste stream during the 1980s have been eliminated. A listing of major facility changes at Lancaster since 1986 can be found in Table 11.

Table 11. Significant construction and operational improvements instituted in the City of Lancaster sewerage system since 1986.

Year/Month	Wastewater Treatment System Improvements
1986 / April	Construction began on WWTP upgrades.
1987 / Mid Year	Lancaster Electroplating (LEP) installed metals treatment in Buildings #1 and #2 as part of Lancaster pretreatment program. Occasional problems with copper remained.
1988 / December	Construction began on lift station rehabilitation
1989 / --	LEP installed treatment for cyanide to remedy copper problem
1989 / January	WWTP upgrades operational except for flow equalization tank, chlorination and dechlorination tanks
1989 / March	Sewer rehab. completed; work to remove I/I identified as cost effective.
1989 / August	Began operation of upgraded WWTP with exception of dechlorination tank.
1989 / Summer	Ended use of dedicated sludge site. Difficulty experienced meeting ammonia, chlorine and fecal coliform limits. Access to farm sites for land application of sludge in late summer resulted in control of solids and ammonia limit compliance.
1989 / Nov.	Lift station upgrades were completed resulting in bypass elimination.
1990 / Winter	LEP in compliance with all applicable pretreatment limits from early 1990 to the present.
1990 / Summer	Began operation of dechlorination equipment.

Monthly monitoring data for selected parameters collected from the Hocking River fixed station at RM 87.3 during the past two decades was reviewed for trend analysis. The site was located 1.7 miles downstream from the Lancaster WWTP and the Lancaster urban area. Between 1970 and 1980, all selected chemical parameters showed random variability while the period from 1980 to 1987 exhibited marked decreases in water quality. Third quarter max.-min. trends for ammonia, BOD and cyanide (Figure 6) and box and whisker plots of annual D.O. data (Figure 7) are representative of recent water quality improvements downstream from Lancaster. All parameters improved significantly following the upgrade of the Lancaster WWTP in 1988 and most showed some additional improvement during 1989 and 1990.

1990 results show almost no exceedences of WWH criteria compared to the highly degraded conditions encountered prior to 1988. As recently as 1986-87, the majority of D.O. concentrations were well below the 4 mg/l acute criteria and third quarter ammonia levels consistently exceeded the WWH criterion. A comparison of the 1990 and 1982 intensive survey results for ammonia and zinc show substantial reductions in mainstem concentrations since 1982, particularly downstream from the Lancaster WWTP (Figure 8).

Lancaster WWTP Loadings Trends

Due to inadequacies in the quantity and quality of self-monitoring data from the LEAPS database it was not possible to develop precise historical loadings information for the Lancaster sewerage system. However data available from the 1975-90 period of record do suggest significant changes in effluent quality over the past decade.

Third quarter effluent loading trends for flow, BOD, zinc, and oil and grease were selected to represent wastewater quality during the period of record (Figure 9). With the exception of flow, most loadings have been substantially reduced since 1988 as a result of WWTP upgrades and improvements in pretreatment and plant monitoring.

Flow data plotted with BOD loadings in Figure 9 show a general increase in flow over the period of record; 1990 discharges were over 60% higher than in 1975. However, a best fit line for flow suggests significant under-reporting between 1983 and 1988. Flow monitoring improved following the 1988 facilities upgrade.

Wastewater bypassing and CSO discharges could not be precisely quantified but have occurred frequently at the Lancaster facilities during the past decade. Historical D.O. trends from the fixed monitoring station at RM 87.4 was considered an indirect measurement of the total system performance (Figure 7). In general, median oxygen concentrations decreased from 1980 to 1988 but have increased since the 1988 upgrades. Overall, during the past 15 years, the impact of Lancaster wastewater treatment effluents on the mainstem has been significantly reduced. Most improvements however, have occurred only recently, following major upgrades in the late 1980s. Discharges of "greywater", while not completely eliminated, have declined both in frequency and duration and data from the ambient monitoring location suggests recovery of the mainstem is in progress. In addition, urban nonpoint source impacts may need to be evaluated in the future if recovery to the full aquatic use is not complete.

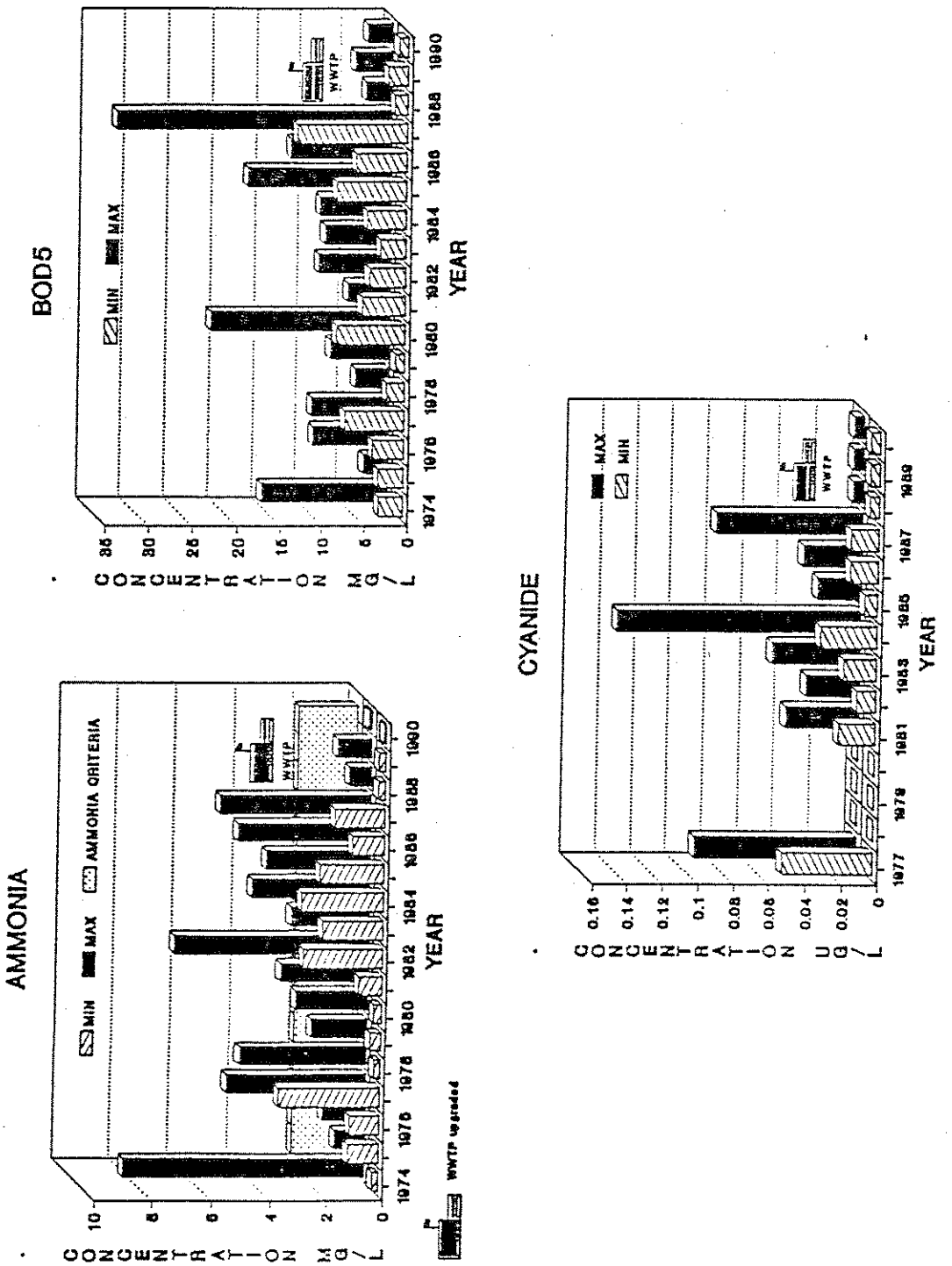

Figure 6. Third Quarter maximum and minimum concentrations of ammonia, BOD5 and cyanide collected from the Hocking River National Ambient Water Quality Monitoring Network (NAWQMN) station at RM 87.4 from 1974-90 (ammonia, BOD5) and 1977-90 (cyanide).

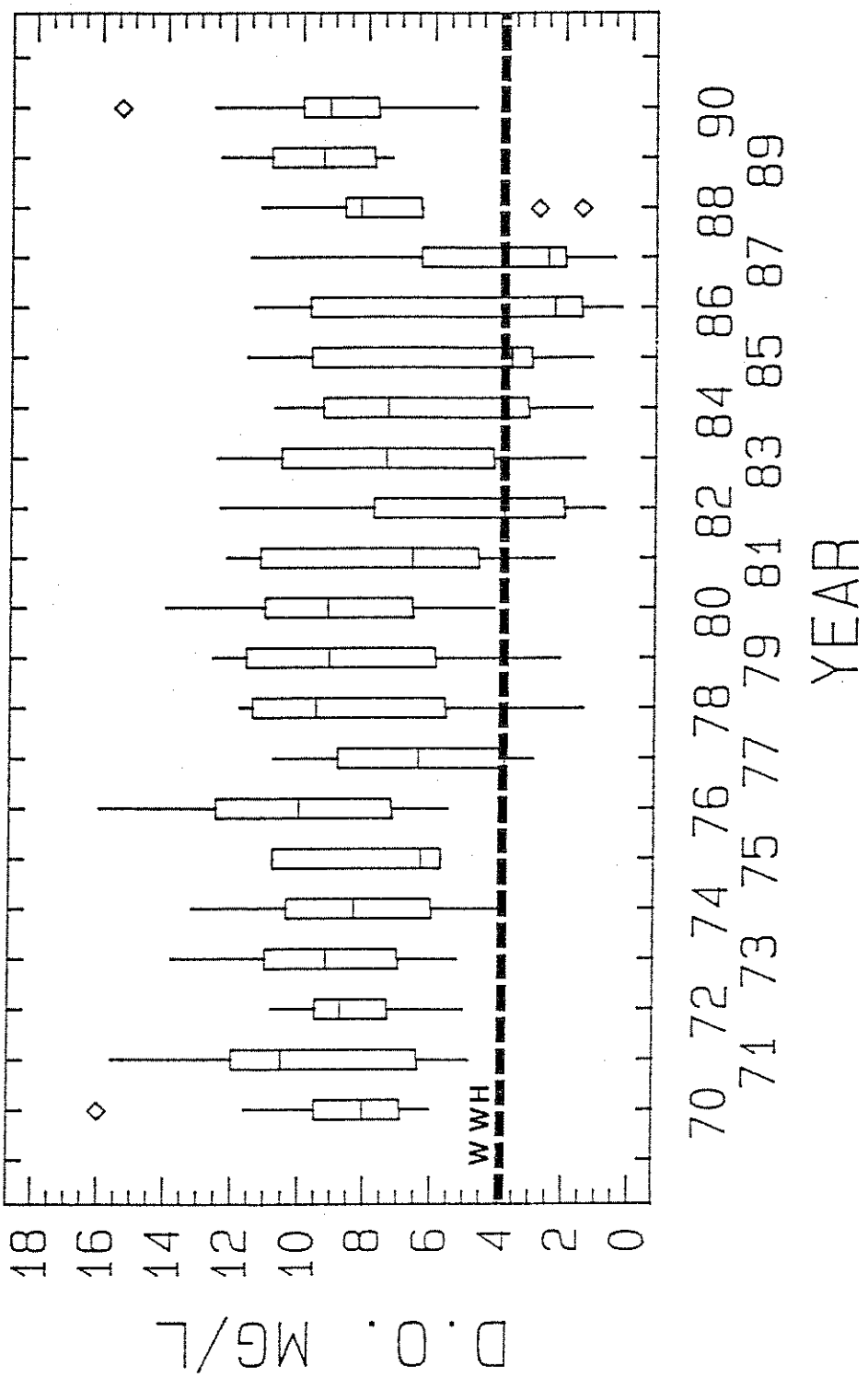

Figure 7. Box and Whisker plots of D.O. concentrations measured monthly at the Hocking River NAWQMN station at RM 87.4, 1970-90. Minimum criteria for the WWH use designation (4 mg/l) is indicated.

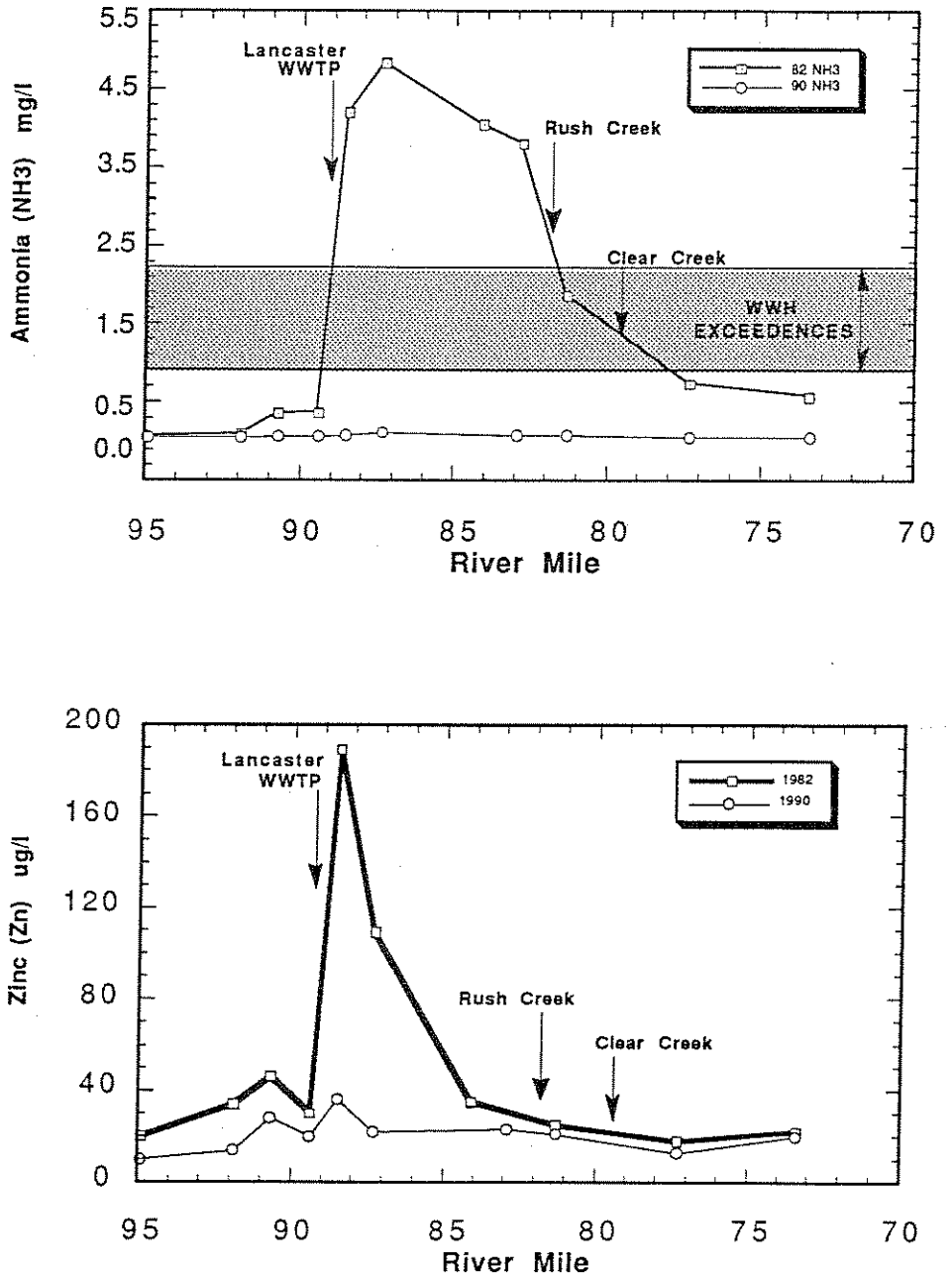

Figure 8. Mean concentrations of ammonia and zinc collected from chemical sampling locations in the upper Hocking River mainstem during the summers of 1982 and 1990. Exceedence range for ammonia is based on the WWH outside mixing zone-30 day average criteria using 25th and 90th percentile values for temperature and pH found in chemical grabs collected from 1982-90.

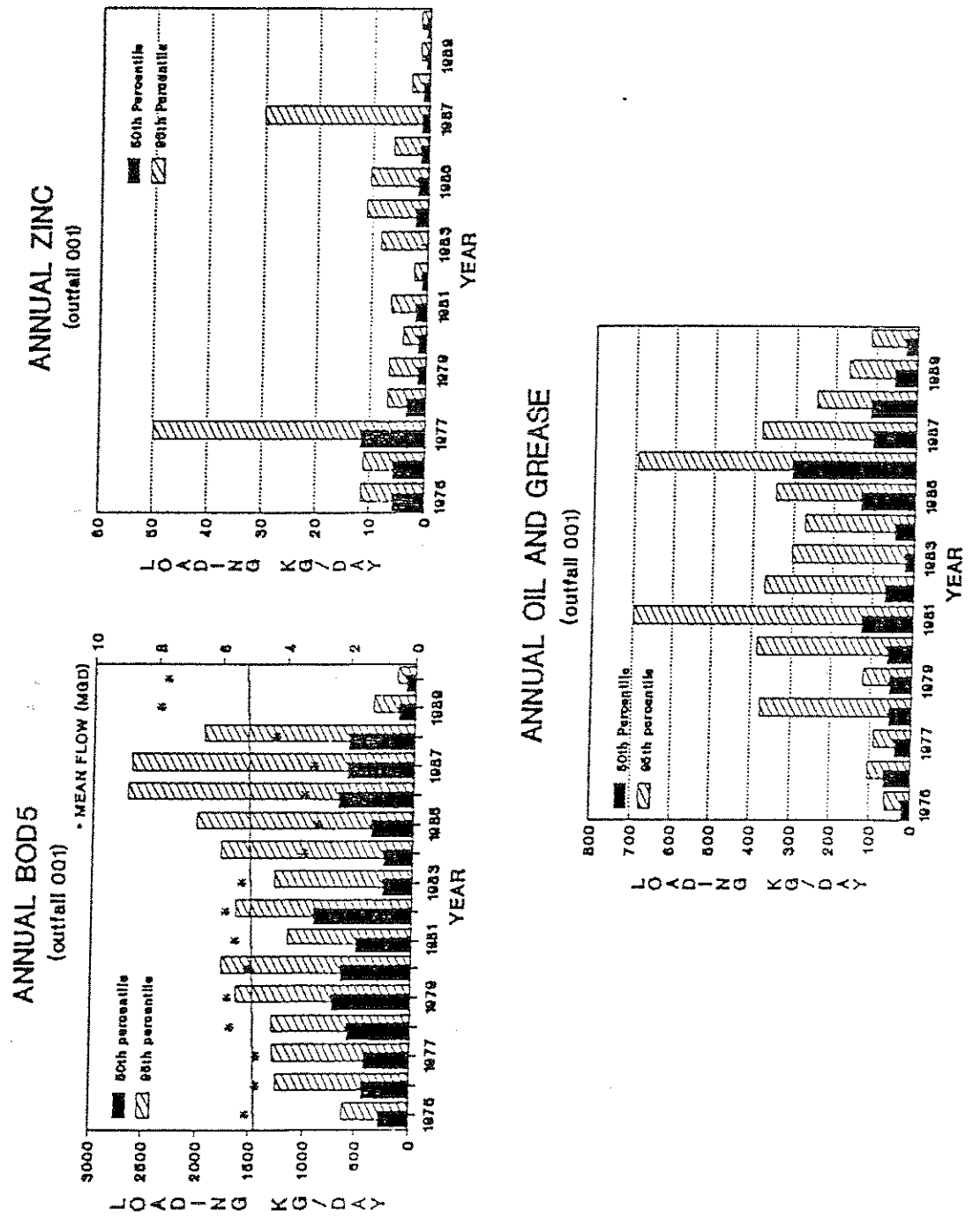

Figure 9. Annual mean and 95th percentile loadings in kg/day for BOD5, Oil and Grease and Zinc discharged from the Lancaster WWTP 001, 1975-90.

Hocking River - Athens Area

Extensive data for chemical trends in the lower Hocking are limited but a qualitative assessment of historical data from the USGS continuous monitor at RM 27.3 (1970s) and Ohio EPA drought sampling from 1988 suggest a large improvement in D.O. content downstream from Athens. Periodic summertime exceedences of the 4 mg/l WWH criterion were common throughout most of the 1970s and were particularly severe in 1978 when D.O. maxima on 50 of 81 recording days from June through August were below 4 mg/l. In contrast, 1988 Datasonde sampling recorded no WWH exceedences for D.O. with all minimum daily values from August 22-26 above 5 mg/l. The USGS data also indicated occasional slugs of acidic water impacted the mainstem and resulted in ph exceedences as late as 1975 (min. 3.3 S.U. pH).

Plant operation at the Athens WWTP has improved substantially since upgrades were completed in late 1989. Plant staff now admit that, prior to upgrading, sludge was often dumped in the river instead of being removed and land applied. In 1990 approximately 325 dry tons were removed; in contrast it is estimated only a small fraction of the load was handled in the early 1980s (SEDO-DWPC, IOC, 1991). Collection system improvements have resulted in greater flows to the plant and fewer overflows and bypasses (often unreported) to the Hocking River.

Rush Creek

Rush Creek continues to reflect significant mine drainage influences but there are indications of some improvements in mining and nutrient related parameters since 1982 (*e.g.* pH, manganese, sulfate, ammonia). These improvements may result from the completion of several large reclamation projects, the cessation of at least two active mining operations and upgrading of the Bremen WWTP since the OEPA 1982 survey. Also, anecdotal information from the Rush Creek Conservancy District suggests fewer slugs of "red water" coming downstream from mine lands in the headwaters. However, recent observances of slugs of acidic water in the Sugar Grove area during the late summer of 1991 are evidence of continued acid mine drainage problems in the lower mainstem. Preliminary investigations suggest these slugs were associated with extended periods of drought followed by localized or light rainfalls which were sufficient to wash accumulated surface acid into the creek but did not result in significant dilution. Additional field investigations should be conducted in the headwaters to determine if the slugs are related to a specific area or source.

Biological Results

A summary of aquatic life use attainment for historical data and 1990 survey data from similar sampling locations in the Hocking River basin can be found in Table 12.

Upper Hocking River- Lancaster Area

Plots of IBI, Miwb and ICI scores for the 1990 and 1982 surveys in the upper Hocking River mainstem can be found in Figures 10 and 11. Since 1982, the upper Hocking River has

exhibited some of the greatest improvement in biological performance of any river system in the state. However, the recovery from the severely degraded conditions observed in 1982 was not complete in 1990. In 1982, none of the 20.5 mile section between Lancaster and Logan attained the WWH use and approximately 75% of these river miles fell in the poor or very poor range. Biological communities reflected the grossly polluted and acutely toxic conditions present in portions of the mainstem downstream from the Lancaster WWTP and CSOs. In 1990, 13.4 of the 22.1 comparable river miles either attained or partially attained WWH. River miles in the poor-very poor range were reduced from 15.7 in 1982 to 5.0 in 1990.

Following large scale upgrades in the Lancaster sewer system and pronounced improvements in chemical water quality conditions, total ADV scores for 1990 in the upper mainstem were reduced by over 85% (Table 13). Macroinvertebrates reflected the most improvement with the ICI ADV almost entirely eliminated (3,147 in 1982 compared to 5 in 1990). Fish communities improved considerably, but not to the same high levels shown in the macroinvertebrates. This may have been the result of several factors including lower habitat quality due to channelization, residual contamination in the Lancaster urban area, and inadequate recovery time following improvement and stabilization of effluent quality from Lancaster. As was noted in the analysis of the chemical data, concentrations of some parameters have only recently begun to stabilize. Conversely, ICI scores may reflect some positive influences from the higher than normal stream flow in 1990 and associated dilution effects. Both organism groups showed evidence, to varying degrees, of continued impacts in the Lancaster urban area and downstream from the WWTP.

Hocking River: Nelsonville Area

Fish community data was collected in 1988 from two sites in the vicinity of Nelsonville for the purpose of addressing a 404/401 dredge and fill permit application. The results of multiple sampling passes at RM 54.0 (IBI=47; MIwb=9.1) and 52.6 (IBI=42; MIwb=9.2) showed very good community performance. Results in 1990 from nearby sampling locations at RM 55.7 (IBI=39;MIwb=8.4) and RM 51.6 (IBI=41;MIwb=8.6) demonstrated a slightly lowered performance in the good range. The differences are likely the result of the somewhat impacted condition of this section of the mainstem by moderate bank instability, sedimentation, and a moderate to extensive embeddedness of the riffle/run areas, some of which is due to previous attempts to manipulate the river channel in the Nelsonville area. Some annual variation in the biological results can be expected in rivers subjected to these types of habitat impacts.

Hocking River: Athens Urban Area

Historical biological data for the lower mainstem near Athens is limited. Compared to collections in the Athens urban area (RM 32.7/33.1) during the 1988 drought, ICI scores in 1990 improved from the poor to the very good range (12 to 42) while fish communities declined from the very good to the fair-good range during the same interval. However, the 1988 fish results are represented by a single sampling pass at RM 32.7, just upstream from the Athens WWTP. The more comprehensive sampling in 1990 represents a more complete assessment of the fish community in the Athens area. In addition to the elevated flows in 1990, the macroinvertebrate data suggests a positive response to upgrades in the Athens sewer

system and the elimination of some dry weather CSOs since 1988.

Hunters Run / Baldwin Run

Biological communities in Hunters Run improved from NON to FULL attainment of the WWH criteria from 1982-90. This appears to represent continued recovery following cessation of the Anchor Hocking discharge in 1978. Baldwin Run continues to be impacted by CSO discharges in Lancaster and remained in NON attainment in 1990. Some chemical and biological improvement has occurred since 1982 however, and the extremely dense growths of "sewage fungus" which covered the stream bottom in 1982 were not present in 1990.

Rush Creek

Fish and macroinvertebrate community performance showed improvement in lower Rush Creek (RM 2.0-2.1) compared to the severely degraded conditions observed in 1982. ICI values increased from the fair to the lower exceptional range while fish index scores in the fair-poor range were 2-3 times higher than the results obtained in 1982. The predominant influences in the lower mainstem continue to be excessive sediment loads and channelization, the latter of which will likely limit community performance for some time. Additional macroinvertebrate sampling was conducted in 1991 following reports of slugs of acid mine drainage reaching the lower section of Rush Creek. The ICI score dropped to the marginally good range but still represented an improvement over the 1982 results.

Clear Creek

Biological data from four years of sampling near the mouth of Clear Creek (RM 2.1/2.0) in the WAP ecoregion indicate little significant variation in performance over the past decade, with the MIwb being an exception. MIwb scores have declined steadily from 9.4 in 1982 to 7.7 in 1990. Conversely IBI scores have increased from 35 in 1982 to 42 in 1990. This combination of trends in MIwb and IBI scores is rare, but is most often associated with non-chemical impacts such as increased siltation. The macroinvertebrates have ranged from good to exceptional, a further indication that chemical water quality has been good to excellent. The consistently lower performance of the fish community appears primarily related to extensive agricultural land use and channel modifications in the upper watershed which is located in the ECBP ecoregion.

Table 12. Aquatic life use attainment status in the Hocking River basin based on data collected from similar sampling locations during July-October 1982-1991.

Stream Name River Mile Fish / Invertebrate.	IBI	Modified Iwb	ICI[a]	QHEI[b]	WWH Attainment Status[c]	Comment
Upper Hocking River (1990)						
95.2[c] / 95.1	35[ns]	8.2	50	66.5	FULL	Ambient
92.2[c] / 91.9	27*	6.5*	52	44.0	NON	Channelized
90.8[c] / 90.7	28*	6.9*	46	37.0	PARTIAL	Dst. CSO's; urban
89.4[c] / 89.4	24*	5.9*	38	42.0	NON	Dst. Wheeling Lift Sta.
89.1[c] / 89.1	25*	4.7*	26*	49.5	**	Lanc. WWTP mix zone
89.0[c] / 88.9	30*	6.5*	32[ns]	38.0	PARTIAL	Dst. WWTP mix zone
87.1[c] / 87.2	25*	4.9*	MG	59.0	NON	Dst. Lancaster
82.0 / 82.9	33*	6.5*	46	62.0	PARTIAL	Dst. Lancaster
81.2 / 81.3	39[ns]	8.1[ns]	44	57.5	FULL	Dst. Rush Creek
77.2 / 77.1	34*	7.5*	G	63.5	PARTIAL	@ Rockbridge
73.2 / 73.4	43	8.1[ns]	G	63.5	FULL	@ Enterprise
69.5 / 69.4	40	8.6	46	78.0	FULL	@ West Logan
Upper Hocking River (1982)						
94.9 / --	27*	6.1*	G	46	PARTIAL	Old channelization
93.2 / --	23*	5.5*	–	-	(NON)	Channelization
92.0 / 92.0	17*	4.5*	44	48	NON	Urban development
- / 91.2	-	-	8*	-	(NON)	Raw sewage evident
90.7 / 89.3	17*	4.0*	2*	40	NON	dst. Wheeling lift sta.
88.8 / 88.5	12*	0.6*	0*	48	NON	dst. Lancaster WWTP
- / 87.3	-	-	0*	-	(NON)	dst. Lancaster
85.7 / 85.4	12*	1.8*	0*	62	NON	dst. Lancaster
83.1 / 82.9	20*	4.0*	0*	67	NON	ust. Rush Cr./Sugar Gr.
- / 81.8	-	-	0*	-	(NON)	ust. Rush Cr./Sugar Gr.
81.4 / 81.3	17*	2.4*	12*	84	NON	dst. Sugar Gr, Rush Cr.
77.2 / 77.3	29*	6.8*	22*	63	NON	dst. Clear Cr.
73.3 / 73.5	31*	7.3*	18*	66	NON	@ Enterprise
Hocking River-Nelsonville & Athens Areas 1990						
55.7 / 55.3	39[ns]	8.4[ns]	44	63.5	FULL	Dst. Landfill
51.6 / 51.4	41	8.6	52	66.0	FULL	Dst. Nelson. WWTP
33.1 / 32.6	35*	8.9	40	55.5	PARTIAL	Ust. Athens WWTP
1988						
54.0 / ---	47	9.1	NA	67	(FULL)	Ust. Nelsonville
52.6 / ---	42	9.2	NA	NA	(FULL)	Nelsonville urban area
32.7 / 33.1	42[ns]	9.4	12*	NA	NON	Ust Athens WWTP; drought
Hunters Run (1990-82)						
0.5[c] / 0.5	39[ns]	NA	38	50.0	FULL	1990; channelized urban
0.6 / 0.4	28*	NA	F-P	NA	NON	1982; Anchor Hocking discharge ceased in 1978
Baldwin Run (1990-82)						
0.3 / 0.2	31*	NA	16*	50.5	NON	1990; CSO's; urban
0.5 /0.2	27*	NA	VP	NA	NON	1982; CSO's; urban
Clear Creek (1990-82)						
2.0 / 2.0	42[ns]	7.7*	50	78.0	PARTIAL	1990; Reference site
2.0 / 2.1	40[ns]	8.1[ns]	46	84.0	FULL	1984
2.0 / 2.1	39*	8.2[ns]	52	84.0	FULL	1983

Table 12 (continued).

Stream Name RIVER MILE Fish / Invertebrate.	IBI	Modified Iwb	ICI[a]	QHEI[b]	WWH Attainment Status[c]		Comment
Clear Creek (continued)							
2.3 / 2.0	35*	9.4	42	NA	PARTIAL		1982
					Use Attainment Status Existing / Recommended		
Rush Creek (1991-82)					LRW[d]	MWH[e]-Mine Affected	
---- / 2.1	–	–	34 / 34	–	FULL	FULL	1991; AMD slugs
2.0 / 2.1	28 / 28	6.3 / 6.3	46 / 46	41.5	FULL	FULL	1990; sedimentation, mining
2.0 /2.1	13* / 13*	3.7* /3.7*	16 / 16*	40.0	NON	NON	1982; Recent channelization
McDougall Branch (1990-83)					EWH[f]	WWH	
2.5 / 2.9	42* / 42[ns]	9.1[ns] / 9.1	G* / G	52.0	PART.	FULL	1990; Reference Site
2.4 / 2.9	42* / 42[ns]	8.7* / 8.7	28* / 28*	63.0	NON	PARTIAL	1983 & 1984 sampling
Federal Creek (1990-84)					LWH[g]	EWH[h]	
1.3 / 0.9	46 / 46[ns]	8.7 / 8.7*	54 / 54	75.5	FULL	PARTIAL	1990; Reference Site
1.3 / 0.9	50 / 50	10.3 / 10.3	38 / 38*	71.0	FULL	PARTIAL	1984

Ecoregion Biocriteria:

Erie/Ontario Lake Plain (EOLP; RM 95.2-87.1)

INDEX - Site Type	WWH	EWH	MWH[h]	LRW[i]
IBI - Headwaters	40	50	24	18
IBI - Wading (RM 95.2-87.1 and tributaries)	38	50	24	18
Mod. Iwb - Wading	7.9	9.4	6.2	4.5
ICI (RM 95.1-87.2 and tributaries)	34	46	22	14

Western Allegheny Plateau (WAP; RM 82.9-4.6)

INDEX - Site Type	WWH	EWH	MWH[h]	LRW[i]	Mine MWH-Affected
IBI - Wading (RM 82.0 and tributaries)	44	50	24	18	24
IBI - Boat (RM 81.2-4.9; Rush Cr. RM 2.0)	40	48	24	16	24
Mod. Iwb - Wading (RM 82.0 and tributaries)	7.9	9.4	6.2	4.5	5.5
Mod. Iwb - Boat	8.6	9.6	5.8	5.0	5.4
ICI (RM 82.9-4.6 and tributaries)	36	46	22	14	30

* - Significant departure from ecoregion biocriteria; poor and very poor results are underlined.

ns - Nonsignificant departure from biocriterion (4 IBI or ICI units; 0.5 Iwb units).

a - Narrative evaluation is used in lieu of ICI for sites with qualitative samples only (MG= Marginally good, G=Good; F=Fair, P=Poor, VP= Very Poor).

b - Qualitative Habitat Evaluation Index (QHEI) values based on the most recent version (Rankin 1989).

c Use attainment status based on one organism group is parenthetically expressed.

d LRW-- Limited Resource Water / Acid Mine Drainage

e MWH-- Modified Warmwater Habitat for channelized and/or non-acidic mine affected streams.

f LWH- Limited Warmwater Habitat-Streams; these streams are exempted from specific chemical standards but all other WWH criteria apply.

g EWH- Exceptional Warmwater Habitat

h MWH biocriteria for channel modification type.

i Interim criteria for Limited Resource Water / Acid Mine Drainage streams.

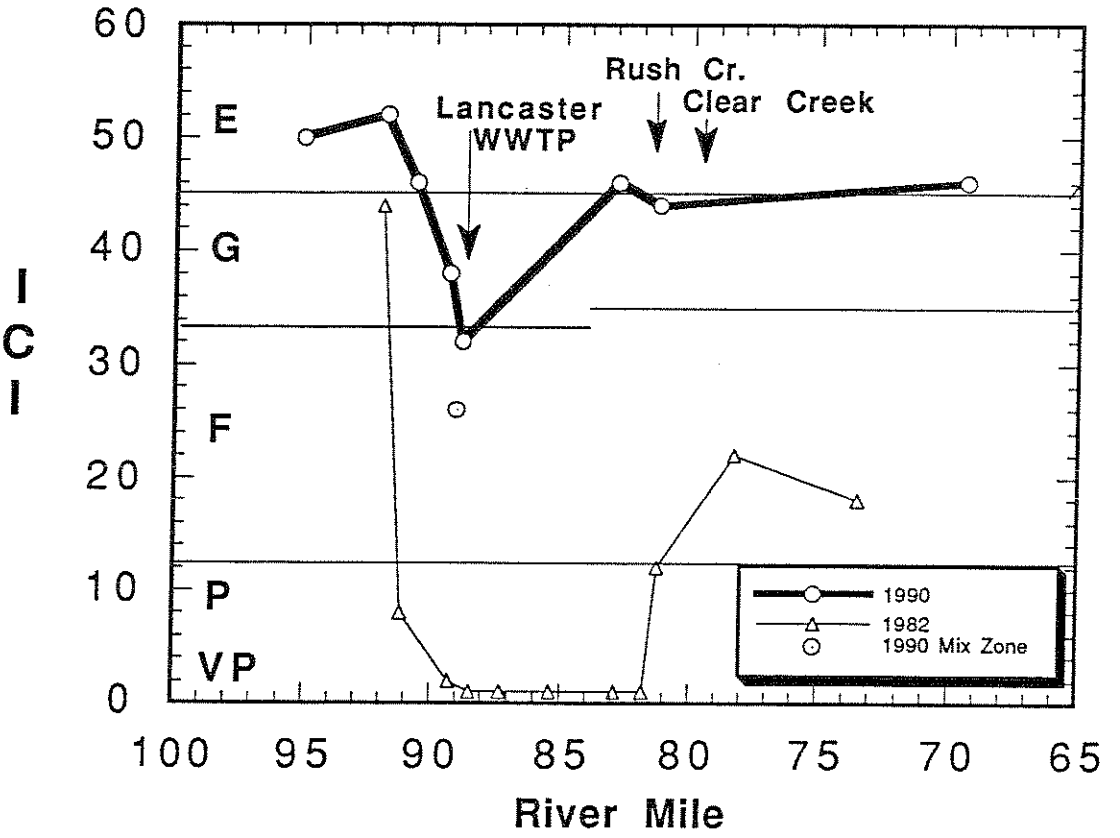

Figure 10. Longitudinal trend of the Invertebrate Community Index (ICI) in the Hocking River mainstem, 1982 and 1990. E denotes exceptional invertebrate communities (meets EWH criteria), G denotes good invertebrate communities (meets WWH criteria), and F, P, and VP denote fair, poor, and very poor invertebrate communities (non-attainment of aquatic life use). **NOTE:** Changes in criteria limit between the Good (G) and Fair (F) range corresponds to a change in ecoregion.

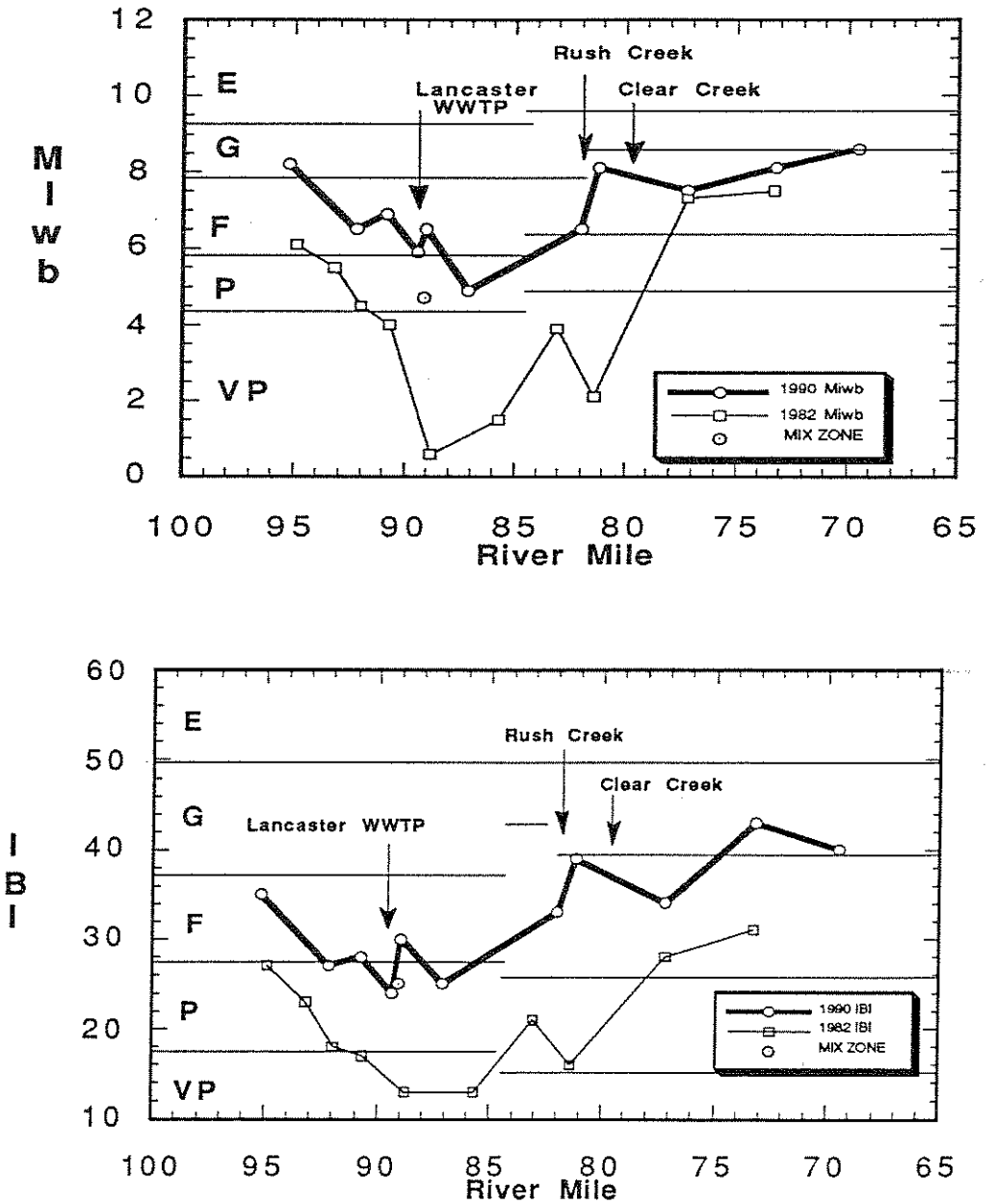

Figure 11. Longitudinal trend of the Modified Index of Well-Being (MIwb) and Index of Biotic Integrity (IBI) in the upper Hocking River based on electrofishing collections during July-September, 1982 and 1990. **NOTE:** Changes in criteria limits between the Good (G), Fair (F), Poor (P) or Very Poor (VP) ranges correspond with changes in ecoregions or sampling methodologies.

Table 13. Area of Degradation Value (ADV) statistics for the Hocking River mainstem, 1982-90 (calculated using ecoregion criteria).

Index	Upper RM	Lower RM	Year	Mini-mum	Maxi-mum	ADV	Poor-VP ADV	Miles Meeting	Partial	Non	Poor-VP
Hocking River (entire mainstem)											
IBI	95.2	0.0	**1990**	19	45	**1788**	54	31.3	43.8	16.1	5.3
MIwb				4.6	9.4	**1735**	22				
ICI				26	56	**5**	0				
Upper Hocking River (RM 95.2 - 73.2)											
IBI	95.2	73.2	**1990**	24	43	**816**	44	1.3	12.1	8.7	5.0
Miwb				4.6	8.2	**955**	22				
ICI				26	52	5	0				
Upper Hocking River (RM 94.9 - 73.3)											
IBI	94.9	73.3	**1982**	12	31	**3198**	1277	0.0	0.0	20.5	15.7
MIwb				0.6	7.5	**3870**	453				
ICI				0	44	**3147**	953				

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List of Appendix Tables*

APPENDIX B - MACROINVERTEBRATE DATA

APPENDIX F - FISH DATA

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* - available on request from Ohio EPA, WQP&A-Ecological Assessment Section, 1685 Westbelt Drive, Columbus Ohio 43228