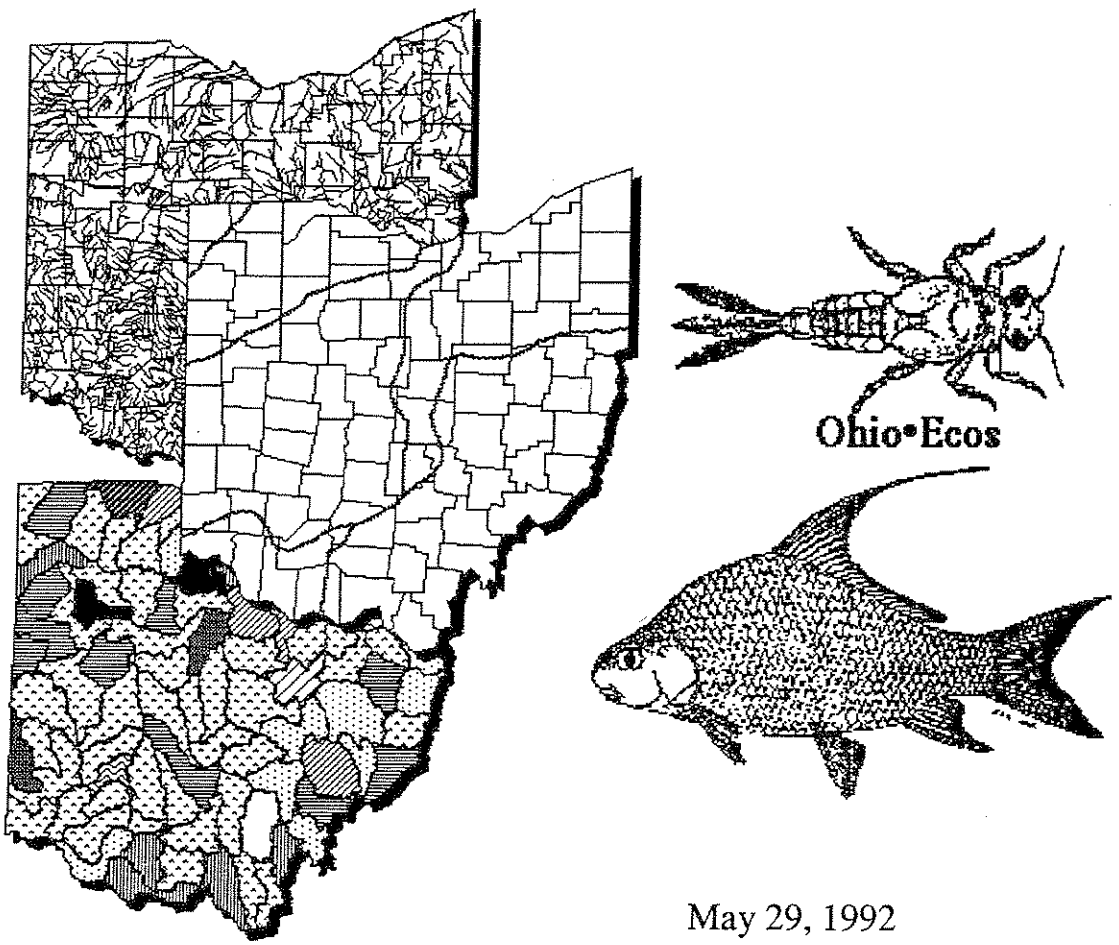
State of Ohio
Environmental Protection Agency

Ecological Assessment Section
Division of Water Quality
Planning & Assessment

Biological and Habitat Investigation of Greater Cincinnati Area Streams: The Impacts of Interceptor Sewer Line Construction and Maintenance

Hamilton and Clermont Counties, Ohio



May 29, 1992

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

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OEPA Technical Report EAS/1992-5-1

prepared by

State of Ohio Environmental Protection Agency
Division of Water Quality Planning and Assessment
Ecological Assessment Section
1685 Westbelt Drive
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NOTICE TO USERS

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

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

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

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

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

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

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

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

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

Ohio EPA - WQP&A
Ecological Assessment Section
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Acknowledgements

Kevin Hinkle, DEFA provided assistance with information about the Taylor Creek Regional project and with the color plates. Steve Malone, DEFA and Rick Shoemaker, DWPC-SWDO provided expertise and information about the Taylor Creek project and other Hamilton Co. MSD activities. Jeff DeShon, WQP&A-EAS provided expertise and input on the macroinvertebrate results. Marc Smith, EAS performed all of the 1988 biological and habitat evaluations, accompanied Ohio EPA and Hamilton Co. MSD personnel on several field visits, and provided input to the fish community and habitat evaluations. Ed Rankin, EAS provided input on the habitat assessments. Data processing support was provided by Dennis Mishne, EAS. Field work (1990 and 1991) was performed by the following EAS staff: Jack Freda, Mike Bolton, Chuck McKnight, Jeff DeShon, Marc Smith, Roger Thoma, Charles Boucher, Randy Sanders, Dave Altfater, Dennis Mishne, and Bernie Counts. Additional assistance was provided by numerous part-time staff. This report was reviewed by Steve Malone, DEFA, Marc Smith, and Jeff DeShon. The report coordinator was Chris Yoder.

Plate 1A. Briarly Creek adjacent to Briarly Creek Road (looking upstream) at RM 1.7 (June 1990). This scene typifies the natural stream and riparian habitat throughout the upper portion of the Taylor Creek subbasin.

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Biological and Habitat Investigation of Greater Cincinnati Area Streams: The Impacts of Interceptor Sewer Line Construction and Maintenance

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1685 Westbelt Drive
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Introduction

The Taylor Creek subbasin, a tributary of the Great Miami River located in western Hamilton County, has been under increasing suburban developmental pressure as the greater Cincinnati metropolitan area expands. A general plan to consolidate a large portion of the separately sewered areas into one regional wastewater treatment plant (WWTP) has existed since 1961. Permit to Install (PTI) applications for this project were submitted to Ohio EPA by the Hamilton Co. Metropolitan Sewer District (MSD) in 1989 and 1990. This was done in response to a consent order which was the result of an enforcement action by Ohio EPA, Division of Water Pollution Control (DWPC) against the non-complying discharges of wastewater from 11 small, package WWTPs operated by the Hamilton Co. MSD. There are an additional 18 privately owned treatment systems that are not part of this proposal. The initial plans call for the construction of an extensive network of interceptor sewers that will regionalize sanitary sewage flows into the Taylor Creek Regional WWTP.

In the greater Cincinnati metropolitan area, the elimination of wastewater flows from small, package WWTP discharges to small, headwater streams has generally been accomplished by the regionalization of those flows. This option has been viewed as being both environmentally and economically more desirable than upgrading and operating the small package WWTPs. Since water quality-based permit limits are generally based on a steady-state, dilution technique using a critical low flow (*e.g.* Q7,10) as a design assumption, effluent limits for such discharges essentially means complying with the Water Quality Standards (WQS) at the "end-of-the-pipe". In addition, the consolidation of sanitary wastewater flows into a larger, presumably more efficient WWTP at a single location not only eliminates a number of perceived pollution problems, but eases the maintenance and administrative burdens in maintaining and tracking compliance.

To assist in their evaluation of the proposed Taylor Creek Regional WWTP sewer system, the Division of Environmental and Financial Assistance (DEFA) requested the Ecological Assessment Section to evaluate specific sections of the Taylor Creek subbasin and elsewhere in Hamilton Co. beginning in 1988. These efforts consisted primarily of site evaluations, which included habitat assessments and limited biological sampling for fish, in the Taylor Creek subbasin and the Mill Creek basin. In 1990, the Ecological Assessment Section was requested by the DEFA to more fully evaluate the Taylor Creek watershed. The request was in response to the Hamilton Co. MSD proposal to regionalize wastewater flows into the Taylor Creek Regional WWTP. The collection system, consisting of a 19 mile network of gravity flow interceptor sewers, is designed to lie under the stream channels and adjacent riparian zones of the major watershed streams - Taylor Creek, Briarly Creek, Steele Creek, and their tributaries. The objective of the 1990 assessment was to

evaluate the present quality of the physical habitat, biological community status, and hence, estimate the impact that such a project would likely have on the physical habitat and the ability of these streams to attain the Ohio WQS, particularly the biological criteria. To this end, biological monitoring of the watershed was conducted between June 26 and August 10, 1990.

The Permit to Install (PTI) applications submitted by the Hamilton Co. MSD for the interceptor sewers were denied in January 1991. The principal basis for the denial was that the proposed project design would necessitate the excavation and modification of many miles of stream channel and adjacent riparian zones. Given the inherent geological features of the streams in the upper two - thirds of the watershed, the proposed construction activities (as has been done in other area streams) would severely damage habitat and permanently prevent the attainment of the WWH use designation, particularly the biological criteria.

As part of the continuing investigation and the search for an alternative to gravity flow sewers, extensive sampling in other Hamilton Co. streams already impacted by sewer line construction and urban development was undertaken in 1991. As a follow-up to the 1988 and 1990 efforts, and in preparation for the then pending appeal of the PTI denial, further field work was performed in several other Hamilton Co. and western Clermont Co. streams in 1991. The entire 1988, 1990, and 1991 study area included 29 different streams and 66 different locations in Hamilton and Clermont Counties sampled for fish and/or macroinvertebrates, and/or physical habitat. The streams sampled included a cross-section of varying impacts from interceptor sewer line construction, urban development, combined sewer overflows (CSO), lift station bypasses, and relatively unimpacted streams. The latter proved very difficult to find in Hamilton County.

Specific objectives of these evaluations were to:

1) Determine the spatial and temporal extent of any environmental damage caused by past interceptor sewer line construction activities in the small, headwater streams (*i.e.* <20 sq. mi. drainage area) of the study area.

2) Evaluate other environmental impacts including combined sewer overflows, point source discharges, and intensive urbanization, and determine the respective roles of each in the aquatic life use attainment status of each stream evaluated.

3) Evaluate the risk posed to the Taylor Creek subbasin by the proposed construction of interceptor sewers utilizing the design submitted to Ohio EPA for PTI approval in 1989 and 1990.

4) Evaluate the appropriateness of existing aquatic life use designations and recommend use designations for streams that are presently not listed in the Ohio Water Quality Standards (WQS; OAC 3745-1).

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

Summary

In 1990, the Ecological Assessment Section was requested to evaluate a proposed interceptor sewer project in the Taylor Creek subbasin in western Hamilton County. Numerous small package WWTPs, many of which are poorly maintained and operated, privately owned WWTPs, and home aeration system and septic tank discharges impact the headwater streams of the subbasin. The 1990 sampling was limited to nine (9) locations in the Taylor Creek subbasin and adjacent Bluerock Creek. The findings of this sampling revealed some moderate degradation to the fish and macroinvertebrate communities at the sites that were in the closest proximity to the package WWTPs. However, FULL attainment of the WWH use designation was found at four of the eight Taylor Creek subbasin locations (Table 1; Ohio EPA 1990c). In addition, the physical habitat at all sites was found to be relatively intact and easily capable of supporting the WWH use. Additional sampling conducted at six (6) sites in 1991 revealed FULL attainment at four (4) sites and PARTIAL attainment at two (2) sites. Some of the results in 1991 were virtually identical to those from 1990. Sampling conducted in 1988 at four sites in Steele Creek, an unnamed tributary, and Taylor Creek revealed **NON** attainment at three (3) sites immediately downstream from WWTPs, and FULL attainment at the one (1) site upstream from the Cedar Ridge WWTP.

Sampling conducted in several greater Cincinnati area streams in 1991 revealed moderate to severe impacts from the construction of gravity flow interceptor sewers in and immediately adjacent to stream channels (Tables 2-7). The most severely impacted stream habitats by sewer construction were in Rapid Run, Wulff Run, and the unnamed tributary to Sycamore Creek. Evidence of raw sewage entering each stream was found with the latter impacted by raw sewage which entered the stream via manhole surcharges during wet weather. Biological sampling results in each stream yielded minimum IBI values (12-14) in the very poor range and qualitative macroinvertebrate results indicative of poor and very poor community performance. Less severe, but nevertheless substantial biological impacts were observed in Sycamore Creek, Shayler Run, and the E. Branch Polk Run. Other streams which failed to attain the applicable biological criteria during 1988 and 1991 were Muddy Creek, Mill Creek, West Fork Creek, W. Fork of Mill Creek, E. Fork of Mill Creek, Sharon Creek, E. Branch Fivemile Creek, Dry Run, and Clough Creek. These streams were impacted by a variety of sources including combined sewer overflows (CSO), urban runoff, flow alterations due to intensive urbanization, and interceptor sewer construction, WWTP and/or lift station bypasses, and illicit industrial discharges mostly via CSOs and storm sewers. Although sewer line construction was evident in some of these streams, the extent of the past construction activities was either less than that evident in the previously mentioned streams or was masked by other equally or more severe impacts. Sampling locations that were in *complete* FULL attainment of the WWH criteria included Shayler Run (upstream and downstream sites), the unnamed tributary to Shayler Run (upstream site), Hall Run (dst. I-275), and Polk Run (at mouth).

Using the Area of Degradation Value (ADV; Rankin and Yoder 1991) program in Ohio ECOS, a total of 57.6 stream miles were assessed (includes extrapolated miles) in the greater Cincinnati streams study area between 1988, 1990, and 1991. A total of 37.9 miles (65.8%) were either in **NON** (36.8 mi.) or PARTIAL (1.1 mi.) attainment of the WQS. FULL attainment was observed in the remaining 19.7 miles (34.2%). The **NON** attaining miles increase to 41.7 miles (72%) when Shayler Run is evaluated against the Exceptional Warmwater Habitat (EWH) biocriteria. Of these totals 20.9 miles (56.8%) of the **NON** attainment were from streams that were impacted by past interceptor sewer line construction. Of the poor and very poor performing miles, 18.4 miles (58.4%) were from sewer line impacted streams. Area of Degradation (ADV) units/mile for the Index of Biotic Integrity (IBI) showed that a cumulative total of 1422.8 ADV/mile (58.4% of a total of 2452.7 ADV/mi.) were from streams that have been impacted by the construction of

interceptor sewers. Streams concurrently or independently impacted by intensive urbanization yielded 1174 ADV/mile (47.9%), CSO impacts yielded 997 ADV/mile (40.6%), and WWTP and other sewage discharges yielded 393.9 ADV/mile (16.1%). Although the study does not represent a randomized sample design, the results indicate that the severity of the impacts to the streams of the area rank in the order of importance noted in the preceding estimates.

The habitat disturbance caused by the construction of sewers in and immediately adjacent to the stream channels appears to take place in two phases. The initial construction results in damage that is reflected in either a moderate, but substantial decline of biological performance (usually into the fair range) or, at best, partial attainment of the WWH criteria. This was evident in Sycamore Creek and Shayler Run. However, both streams have lateral space available so that the construction did not impact the stream channels continuously. Also, and more importantly the 1991 sampling was conducted under average summer rainfall and stream flow conditions. Under periodically recurring lower flow periods the biological performance would likely be poorer due to the restricted habitat space available during those periods. The 1991 results for the fish community were typified by young-of-the-year and juveniles with very few if any adults of most species, a further indication of the precarious nature of the observed marginal attainment at some of the sites in each stream. Also, the true potential of Shayler Run is in the Exceptional Warmwater Habitat (EWH) range of performance based on analysis of U.S. EPA (1976) survey results from the years 1969 through 1971.

Based on observations throughout the study area, it is a virtual certainty that interceptor sewers will eventually require rehabilitation and replacement due to the substantially increased channel erosion which is further exacerbated by the naturally "flash flow" characteristics of Interior Plateau streams. It is seemingly the rehabilitative construction (second phase) that results in the severe impacts and total collapse of biological community performance that was noted in Rapid Run, Wulff Run, and the unnamed tributary to Sycamore Creek. In addition to the further fragmentation of the limestone and soft shale bedrock substrates, a "debris torrent" composed of the fragments of limestone embedded in the shale derived clayey silts is created. This literally buries the stream in the rock derived debris which essentially obliterates the natural pool-run-riffle complexes and extensive ledges and crevices formerly provided by the layers of limestone bedrock. Bank erosion is also greatly accelerated by the abrasive action of the debris torrents. Except for brief periods following significant rainfall events, the streams are essentially dry even during periods of normal rainfall such as was observed in 1991. Because of the highly dissected topography and steep slopes of the upper two-thirds of the Taylor Creek subbasin the initial construction of gravity flow sewers is expected to result in a much greater impact than that noted in either Shayler Run or Sycamore Creek.

Interior Plateau streams are "perched" on limestone bedrock layers that may range from a few inches to more than one feet thick. Thicker layers of soft, blue-grey shale are "sandwiched" between the alternating limestone layers. The limestone bedrock layer provides an insulating buffer against the naturally high erosive forces thus maintaining a stable stream habitat. The removal or disturbance of this layer makes the stream channel vulnerable to catastrophic erosion both vertically and laterally, which results in extensively degraded habitat and a loss of the ability to support a community of aquatic life consistent with the criteria prescribed by the Ohio WQS. The concern about interceptor sewer alignments exists not only with the actual contact of the sewer line with the stream channel, but extends as well to the area occupied by the construction easement and access roads for heavy construction equipment. The mere movement of the heavier treaded equipment can fracture the surface bedrock substrate and make it vulnerable to erosion by subsequent high flow and weathering processes.

Table 1. Aquatic life use attainment status for the Warmwater Habitat (WWH) use designation in Taylor Creek and tributaries based on data collected during July - September 1990 and 1991.

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Attainment Status	Comment
			Interior Plateau - WWH Use Designation (Existing)			
Taylor Creek (1990)						
3.5/3.5	44	N/A	G	85	FULL	Ust. Briarly Cr.
1.6/1.8	44	N/A	42	60	FULL	Adjacent I-74
0.5/0.4	28*	7.4*	30	64	PARTIAL	Dst. Wesselman Cr.
Briarly Creek (1990)						
1.8/1.7	22*	N/A	F*	64	**NON**	Ust. Steele Cr.
1.3/1.4	34*	N/A	F*	70	**NON**	Dst. Steele Cr.
0.5/0.1	36ns	N/A	46	80.5	FULL	Ust. Taylor Cr. @ Mouth
Steele Creek (1990)						
0.2/0.2	20*	N/A	MG	70	**NON**	Impacted by WWTPs
Wesselman Creek (1990)						
0.3/0.3	44	N/A	46	67	FULL	Background WQ
Bluerock Creek (1990)						
0.5/0.5	50	N/A	42	70	FULL	Dst. Colerain Hts. WWTP
Taylor Creek (1991)						
3.4/3.5	44	N/A	36	65.5	FULL	Ust. Briarly Cr.
1.6/1.8	44	N/A	40	66.5	FULL	Adjacent I-74
Briarly Creek (1991)						
1.3/1.4	34*	N/A	30	61.5	PARTIAL	Dst. Steele Cr.
0.5/0.1	36ns	N/A	46	67	FULL	Ust. Taylor Cr. @ Mouth
Steele Creek (1991)						
0.2/0.2	30*	N/A	28ns	69	PARTIAL	Impacted by WWTPs
Wesselman Creek (1991)						
0.3/0.3	52	N/A	38	63.5	FULL	Background WQ

Ecoregion Biocriteria: Interior Plateau (IP)

INDEX - Site Type	WWH	EWH	MWH[c]
IBI - Headwaters/Wading	40	50	24
Mod. Iwb - Wading	8.1	9.4	5.8
ICI	30	46	22

c - Modified Warmwater Habitat for channel modified areas.

* - significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns - nonsignificant departure from ecoregional biocriteria for WWH or EWH (4 IBI or ICI units; 0.5 Iwb units).
a - Narrative evaluation used in lieu of ICI (E=Exceptional; G=good; MG=Marginally good; F=Fair; P=Poor; VP=Very Poor).
b - Qualitative Habitat Evaluation Index (QHEI) values based on the new version (Rankin 1989).
N/A - MIwb not applicable at headwater sites.

Table 2. Aquatic life use attainment status for the Warmwater Habitat (WWH) use designation in Steele Creek, a tributary to Steele Creek, and Taylor Creek based on data collected during August - September 1988.

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI	QHEI[a]	Attainment Status	Comment
			Interior Plateau - WWH Use Designation (Existing)			
Steele Creek (1988)						
1.0/ -	18*	N/A	-	70	**NON**	WWTP Impacts
Tributary to Steele Creek (1988)						
0.3/ -	20*	N/A	-	70	**NON**	Ust. Oakview Estates
Taylor Creek (1988)						
4.7/ -	36[ns]	N/A	-	68.5	FULL	Ust. Cedar Ridge WWTP
4.6/ -	30*	N/A	-	69.5	(NON)	Dst. Cedar Ridge WWTP

Ecoregion Biocriteria: Interior Plateau (IP)

INDEX - Site Type	WWH	EWH	MWH[c]
IBI - Headwaters/Wading	40	50	24
ICI	30	46	22

[c] - Modified Warmwater Habitat for channel modified areas.

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ns - nonsignificant departure from ecoregional biocriteria for WWH or EWH (4 IBI or ICI units; 0.5 Iwb units).
[a] - Qualitative Habitat Evaluation Index (QHEI) values based on the new version (Rankin 1989).
N/A - MIwb not applicable at headwater sites.

Table 3. Aquatic life use attainment status for the Warmwater Habitat (WWH) use designation in Rapid Run, Wulff Run and Muddy Creek based on data collected during August - September 1991.

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Attainment Status	Comment
Interior Plateau - WWH Use Designation (Existing)						
Rapid Run (1991)						
1.1/1.2	12*	N/A	P*	36.5	**NON**	Extensive disturbance
Wulff Run (1991)						
0.6/0.7	12*	N/A	P*	30.5	**NON**	Extensive disturbance
Muddy Creek (1991)						
5.3/5.3	12*	N/A	VP*	48	**NON**	Impacted by CSOs
2.7/2.6	36ns	N/A	P*	44	**NON**	Exposed sewer line

Ecoregion Biocriteria: Interior Plateau (IP)

INDEX - Site Type	WWH	EWH	MWH[c]
IBI - Headwaters/Wading	40	50	24
ICI	30	46	22

c - Modified Warmwater Habitat for channel modified areas.

* - significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns - nonsignificant departure from ecoregional biocriteria for WWH or EWH (4 IBI or ICI units; 0.5 Iwb units).
a - Narrative evaluation used in lieu of ICI (E=Exceptional; G=good; MG=Marginally good; F=Fair; P=Poor; VP=Very Poor).
b - Qualitative Habitat Evaluation Index (QHEI) values based on the new version (Rankin 1989).
N/A - MIwb not applicable at headwater sites.

Table 4. Aquatic life use attainment status for the Warmwater Habitat (WWH) use designation in W. Fork Mill Creek, West Fork Creek, tributary to West Fork Cr., Sharon Creek, and E. Fork Mill Creek based on data collected during August - September 1988, 1990, and 1991.

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Attainment Status[c]	Comment
Interior Plateau - WWH Use Designation (Existing)						
Mill Creek (1988)						
17.7/ -	20*	6.1*	-	59.5	**NON**	
14.8/ -	20*	2.5*	-	65	**NON**	
13.3/ -	22*	5.6*	-	63.5	**NON**	
12.2	20*	3.7*	-	71	**NON**	
W. Fork Mill Creek (1991)						
13.9/ -	-	-	-	61.5	-	Intensive urbanization
10.2/10.0	-	-	4*	55	**NON**	Intensive urbanization
W. Fork Mill Creek (1988)						
13.9/ -	16*	N/A	-	48	**NON**	Intensive urbanization
12.6/ -	16*	N/A	-	60.5	**NON**	Intensive urbanization
10.2/ -	14*	N/A	-	64.5	**NON**	Ust. Winton Lake
6.4/ -	24*	4.8*	-	59	**NON**	Dst. Winton Lake
4.1/ -	22*	5.2*	-	69	**NON**	CSO impacted
2.6/ -	24*	6.2*	-	64.5	**NON**	CSO impacted
1.1/ -	22*	5.5*	-	-	**NON**	Multiple impacts
West Fork Creek (1991)						
2.7/ -	12*	N/A	-	61.5	**NON**	Mt. Airy Forest
2.5/ -	12*	N/A	-	56.5	**NON**	Sanitary overflows
Tributary to West Fork Creek (1991)						
0.1/ -	12*[d]	N/A	-	46.5	**NON**	Mt. Airy Forest
E. Fk. Mill Creek (1991)						
- /3.3	-	-	20*	-	(NON)	Background WQ?
E. Fk. Mill Creek (1988)						
3.3/ -	44	N/A	-	45.5	(FULL)	Background WQ?
Sharon Creek (1991)						
4.3/4.3	34*	N/A	12*	77.5	**NON**	Upstream impacts
Sharon Creek (1988)						
4.3/ -	38	N/A	-	74	(FULL)	Background WQ
0.2/ -	18*	N/A	-	52.5	**NON**	Dst. WWTP; urbanized

Ecoregion Biocriteria: Interior Plateau (IP)

INDEX - Site Type	WWH	EWH	MWH[e]
IBI - Headwaters/Wading	40	50	24
Mod. Iwb - Wading	8.1	9.4	5.8
ICI	30	46	22

[e] - Modified Warmwater Habitat for channel modified areas.

* - significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns - nonsignificant departure from ecoregional biocriteria for WWH or EWH (4 IBI or ICI units; 0.5 Iwb units).
[a] - Narrative evaluation used in lieu of ICI (E=Exceptional; G=good; MG=Marginally good; F=Fair; P=Poor; VP=Very Poor).
[b] - Qualitative Habitat Evaluation Index (QHEI) values based on the new version (Rankin 1989).
[c] - Attainment status based on one organism group is parenthetically expressed, except if index is Poor or V. Poor.
[d] - No fish collected; N/A - MIwb not applicable at headwater sites.

Table 5. Aquatic life use attainment status for the Warmwater Habitat (WWH) use designation in E. Br. Fivemile Creek, Clough Creek, and Dry Run based on data collected during August - September 1991.

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Attainment Status	Comment
Interior Plateau - WWH Use Designation (Existing)						
E. Br. Fivemile Creek (1991)						
0.4/0.4	12*[c]	N/A	F*	45	**NON**	Habitat disturbance; toxicity?
Clough Creek (1991)						
3.2/0.7	26*	N/A	F*	36	**NON**	Habitat/flow alteration
Dry Run (1991)						
4.2/4.2	26*	N/A	MG	50.5	**NON**	Moderate habitat alteration

Ecoregion Biocriteria: Interior Plateau (IP)

INDEX - Site Type	WWH	EWH	MWH[c]
IBI - Headwaters/Wading	40	50	24
ICI	30	46	22

c - Modified Warmwater Habitat for channel modified areas.

* - significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns - nonsignificant departure from ecoregional biocriteria for WWH or EWH (4 IBI or ICI units; 0.5 Iwb units).
a - Narrative evaluation used in lieu of ICI (E=Exceptional; G=good; MG=Marginally good; F=Fair; P=Poor; VP=Very Poor).
b - Qualitative Habitat Evaluation Index (QHEI) values based on the new version (Rankin 1989).
c - No fish collected.
N/A - MIwb not applicable at headwater sites.

Table 6. Aquatic life use attainment status for the Warmwater Habitat (WWH) use designation in Sycamore Creek, tributary to Sycamore Creek, Polk Run, and E. Br. Polk Run based on data collected during August - September 1991.

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Attainment Status	Comment
Interior Plateau - WWH Use Designation (Existing)						
Sycamore Creek (1991)						
1.4/1.2	38[ns]	N/A	G	51.5	FULL	Ust. trib.; mod. disturb.
0.7/1.0	38[ns]	N/A	22*	53.5	PARTIAL	Dst. trib.; mod. disturb.
Tributary to Sycamore Creek (1991)						
1.9/ -	-	-	-	29.5	-	Severe habitat alteration
1.0/ -	-	-	-	31	-	Sewer rehab. project
0.1/0.1	14*	N/A	VP*	43.5	**NON**	Raw sewage overflows
Polk Run (1991)						
0.3/0.3	52	N/A	46	80	FULL	Exceptional performance
E. Br. Polk Run (1991)						
1.5/1.4	34*	N/A	MG	71.5	**NON**	Minor habitat alteration

Ecoregion Biocriteria: Interior Plateau (IP)

INDEX - Site Type	WWH	EWH	MWH[d]
IBI - Headwaters/Wading	40	50	24
ICI	30	46	22

[d] - Modified Warmwater Habitat for channel modified areas.

* - significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns - nonsignificant departure from ecoregional biocriteria for WWH or EWH (4 IBI or ICI units; 0.5 Iwb units).
[a] - Narrative evaluation used in lieu of ICI (E=Exceptional; G=good; MG=Marginally good; F=Fair; P=Poor; VP=Very Poor).
[b] - Qualitative Habitat Evaluation Index (QHEI) values based on the new version (Rankin 1989).
[c] - No fish collected.
N/A - MIwb not applicable at headwater sites.

Table 7. Aquatic life use attainment status for the Warmwater Habitat (WWH) use designation in Shayler Run, tributary to Shayler Run, and Hall Run based on data collected during August - September 1991.

RIVER MILE Fish/Invert.	IBI	Modified Iwb	ICI[a]	QHEI[b]	Attainment Status[c]	Comment
Interior Plateau - WWH Use Designation (Existing)						
Shayler Run (1991)						
7.3/ -	42	N/A	-	69.5	(FULL)	Background WQ
5.8/5.8	32*	N/A	28*	71	**NON**	Organic enrichment
5.2/5.2	36ns	N/A	G	61	FULL	Adj. sewer line
4.2/ -	36ns	N/A	-	53	(FULL)	Extensive disturbance
3.3/ -	-	-	-	38	-	Extensive disturbance
3.0/3.4	40	N/A	G	46.5	FULL	Extensive disturbance
2.3/2.1	46	N/A	40	50	FULL	Lower end of disturbance
0.6/ -	50	N/A	-	73	(FULL)	Exceptional performance
Interior Plateau - WWH Use Designation (Recommended)						
Tributary to Shayler Run (1991)						
0.6/0.7	40	N/A	G	79.5	FULL	Natural bedrock habitat
0.1/0.1	36ns	N/A	G	67	FULL	Moderate disturbance
Hall Run (1991)						
0.5/0.5	44	N/A	G	48.5	FULL	Dst. I-275; Mod. dist.

Ecoregion Biocriteria: Interior Plateau (IP)

INDEX - Site Type	WWH	EWH	MWH[d]
IBI - Headwaters/Wading	40	50	24
ICI	30	46	22

[d] - Modified Warmwater Habitat for channel modified areas.

* - significant departure from ecoregional biocriteria; poor and very poor results are underlined.
ns - nonsignificant departure from ecoregional biocriteria for WWH or EWH (4 IBI or ICI units; 0.5 Iwb units).
[a] - Narrative evaluation used in lieu of ICI (E=Exceptional; G=good; MG=Marginally good; F=Fair; P=Poor; VP=Very Poor).
[b] - Qualitative Habitat Evaluation Index (QHEI) values based on the new version (Rankin 1989).
[c] - Attainment status based on one organism group is parenthetically expressed.
N/A - MIwb not applicable at headwater sites.

The most appropriate analogs to what could take place in the Taylor Creek subbasin are represented by Rapid Run, Wulff Run, and the unnamed tributary to Sycamore Creek. These streams occur in similar topographical and geologic settings and are inundated by interceptor sewer alignments similar to that proposed for the Taylor Creek subbasin. The Taylor Creek Regional project, as proposed, will have a result similar to that observed in these streams.

The purpose in regulating water discharges and their attendant infrastructure is to meet WQS. The Director cannot approve projects that result in the loss of an existing designated use (*e.g.* Warmwater Habitat). This means more than achieving chemical water quality criteria alone, and includes the maintenance of biological and physical integrity as well. Besides the requirements of the Ohio WQS to take a broad based water resource approach, the definition of pollution in the 1987 Clean Water Act follows:

> *"(19) The term 'pollution' means the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water". (Section 502)*

This clearly goes beyond a focus on chemical water quality alone, which means that the impetus for interceptor sewer projects needs to be reviewed as well. Regionalization will not be a viable option if it requires the construction of interceptor sewers that will cause the types of impairments observed in several streams in the greater Cincinnati study area.

The Taylor Creek subbasin and adjacent Great Miami River tributaries represent the only appreciable, intact stream habitats remaining in Hamilton County. The existing water quality problems in these streams are correctable through means other than the construction of gravity flow interceptor sewers in stream corridors. The use of alternatives is essential in order to preserve the remaining stream habitats of the Taylor Creek subbasin and prevent the types of impairments observed in other greater Cincinnati area streams.

Conclusions

The results of the three years of sampling and analysis indicate the following:

- The construction of gravity flow sewers in the stream beds of the Taylor Creek watershed will cause permanent non-attainment of the WWH use designation. Areas that are presently in **NON** attainment of WWH due to substandard water quality alone will be further degraded and prevented from ever attaining WWH.

- The impact of constructing gravity flow sewers in the manner proposed for Taylor Creek will be much more severe than the existing impact of poorly operated WWTPs alone, and will be similar to the impacts observed in other area streams (*e.g.* Rapid Run, Wulff Run). Bringing the Taylor Creek subbasin WWTPs to advanced secondary treatment standards (*e.g.* 10 mg/l BOD_5, 1.5 mg/l NH_3-N) would have substantial benefits as opposed to the substantial detriment that would be caused by the proposed sewer construction in the stream corridor.

- The Taylor Creek subbasin and adjacent Great Miami River tributaries are the last remaining and viable headwater stream habitats in Hamilton Co. A combination of interceptor sewer construction, intensive urbanization, and combined sewer overflows have substantially and, in some cases, irretrievably impacted most of the remaining Hamilton Co. streams.

- The concept of "collecting" package WWTP and lift station sewage flows, utilizing a gravity flow collection system with interceptor sewers located in the stream corridors, and consolidating flows into one regional location for the purpose of improving chemical water quality has resulted in environmental degradation and use impairment more serious than the original problem (or at least beyond the ability to mitigate the degradation) in at least four greater Cincinnati area watersheds.

- Extensive disturbance of the limestone bedrock layer on which the area streams are "perched" is the primary detrimental impact that results in the permanently degraded habitat. The crisscrossing routes used in the construction of the gravity flow interceptor sewers results in the disruption of the entire stream habitat due to the width required for the construction activities. In addition to the effects of excavation and back filling, the moving of modern, heavy treaded construction equipment across these surfaces can fracture the surface limestone bedrock layer. Subsequent high flow events result in the displacement of the limestone fragments and the exposure of the soft, underlying layer of calciferous shale. The resulting stream bed erosion is both lateral and vertical with the rate of deepening and widening being on the order of several feet per year. The project proposed for Taylor Creek will result in similar effects including the eventual creation of debris torrents like those observed in Rapid Run, Wulff Run, and the unnamed tributary to Sycamore Creek.

- The limestone bedrock substrate is the most critical and limiting component of the habitat of the greater Cincinnati area streams because of the primary importance to stream channel stability. Once this layer is disturbed, degradation to other habitat features (*e.g.* riparian habitat, stream banks) are inevitable, will worsen with time, and are essentially permanent. Post-construction mitigation is not a viable option for these streams. This may be quite different from how the same activity might be managed in other Ohio ecoregions (*e.g.* E. Corn Belt Plain) where woody riparian vegetation is the most important factor because it is of primary importance in providing stream channel stability. This is not intended to indicate that restrictions on the amount of disturbance to either the riparian zone or substrate in either of these ecoregions will not be necessary.

Recommendations

Principal Recommendations

The following are the principal recommendations for the Taylor Creek Regional project, but also apply to the development and refinement of existing and emerging policies with regard to PTI review and approval statewide. Details of certain recommendations may be subject to change pending further consideration by the Stream Protection Committee.

- For the portions of Hamilton and Clermont Counties with a highly dissected, high relief landscape (with little or no space to construct in the adjacent floodplain without crisscrossing the stream corridor) gravity flow sewers in the stream corridor is an *unacceptable* option. This is due to the inability to avoid degrading stream beds with the construction equipment and the need for construction easements that occupy much of the stream widths for the entire stream length. Furthermore, due to the geological and hydrological realities of the Interior Plateau ecoregion, periodic rehabilitation and/or replacement of sewers will be necessary which will assure the worsening and permanence of the initial disturbance. This would effectively relegate the subject streams (most all of which are designated WWH) to a Limited Resource Water (LRW) use designation status. Allowing this to take place is in clear violation of the Ohio WQS.

- Other alternatives to gravity flow sewers (force mains, mini-regionals, existing WWTP or lift station upgrades) will need to be employed and located outside of the stream corridors. Post-construction mitigation is not likely to be an acceptable substitute for avoidance since techniques to effectively restore the equivalent function of the surface bedrock layer either do not exist or have not been widely and successfully employed.

- A review and analysis of the initial impetus for sewer construction should be conducted for each project. Expanding or upgrading existing WWTPs and/or lift stations should be carefully considered prior to accepting regionalization as the only viable option to meet WQS. OAC 3745 - 1-01[G][c] can be used as a legitimate variance in cases where advanced secondary treatment may not provide the effluent quality to meet numerical chemical water quality criteria based on predictive modeling using critical low flow and high WWTP flow assumptions. This clause states . . . "Human caused conditions or sources of pollution prevent the attainment of the criteria and cannot be remediated *or would cause more damage to correct than leave in place*" (emphasis added). This clause would permit the discharge of good quality WWTP effluent that may not attain the numerical WQS under restrictive design conditions, but which would be a much more preferred alternative to constructing and maintaining interceptor sewers in the stream corridors.

- In those limited cases where sewer construction adjacent to stream corridors is deemed an environmentally acceptable alternative by Ohio EPA, a wide range of stream protection measures must be incorporated into the detailed design as part of the PTI process. For example, stream crossings, if deemed acceptable at all, should be no more frequent than absolutely necessary and will be permitted only when all other alternatives have been exhausted. The long, diagonal crossings used frequently in past Hamilton and Clermont County projects is not acceptable. The latest version of the Recommended Standards for Wastewater Facilities (Great Lakes - Upper Mississippi River Board of State Public Health and Environmental Managers 1990) recommends sewers to be located outside of the stream bed and sufficiently removed therefrom to provide for possible stream widening and to prevent pollution by siltation during construction (section 36.12; pp. 30-8). The manual further specifies that stream crossings be designed to cross perpendicular to stream flow (section 36.14; pp. 30-8).

- Where adjacent valley widths and flatter topography allow, gravity flow sewers may be a viable option provided the construction easement does not approach within two stream widths of the stream riparian zone. The actual stream habitat should be regarded as being "wider than the wet part" which includes the adjacent riparian vegetative zone. A width of two times the stream channel width has been used as a "rule-of-thumb" indication of the *minimum* width of the riparian zone. Other factors such as the degree of slope will determine how wide the riparian zone should be in a given situation. The experiences of other states (*e.g.* logging practices and BMPs in the western U.S.) may prove useful in formulating best management practices (BMP). In addition, BMPs (*e.g.* silt fences, buffers, set backs) for preventing excess sediment in runoff from entering the streams should be required.

- The Taylor Creek watershed supports high quality, diverse habitat conditions and easily demonstrates full attainment of the WWH aquatic life use at the sites most removed from the WWTPs. The ecological impact of a project such as that proposed (*e.g.* 60'-100' wide construction easements, etc.) would result in irreparable environmental degradation in the form of habitat modification and destruction of stream channels and adjacent riparian zones. An examination of two area streams affected by past sewage line construction (Wulff Run and

Rapid Run) revealed extensive, permanent disturbance of the natural substrates, pool modification, partial de-watering of the streams, and degradation of the aesthetic qualities. The WWH aquatic life use could not be attained under these conditions even if given a "reasonable" amount of time to recover from the initial disturbance. This would result in a significant violation of the Ohio Water Quality Standards, specifically the State's biological criteria (OAC 3745-1-07) and anti-degradation policy (OAC 3745-1-04).

- Impending suburban development in the Taylor Creek watershed will affect the ability of the streams to support community performance consistent with the WWH use unless the development is planned and stormwater flows are controlled from an integrated, watershed perspective. The natural stream habitats, including the limestone bedrock substrates, are critical in providing a buffer against the expected hydrologic changes. Therefore it is critical that these habitats be maintained. Failure to do so could result in the type of stream channel and bank erosion that was observed in the Rapid Run and W. Fk. Mill Creek watersheds.

Status of Aquatic Life Uses

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 standardized approaches to the collection of instream biological data or numerical biological criteria. Therefore, because this study represents a first use of this type of biological data to evaluate and establish aquatic life use designations, several revisions are recommended. While some of the changes may appear to constitute "downgrades" (*i.e.* EWH to WWH, WWH to MWH, etc.) or "upgrades" (*i.e.* LWH to WWH, WWH to EWH, etc.), any changes should not be construed as such because this constitutes the first use of an objective and robust use evaluation system and database. Ohio EPA is under obligation by a 1981 public notice to review and evaluate all aquatic life use designations outside of the WWH use prior to basing any permitting actions on the existing, unverified use designations. Thus some of the following aquatic life use recommendations constitute a fulfillment of that obligation.

- Taylor Creek, Bluerock Creek, Wesselman Creek, Briarly Creek, Steele Creek, and all unnamed tributaries to each should receive the State Resource Waters (SRW) classification. This recommendation is justified by the fact that these streams represent the last relatively undisturbed, headwater stream habitats in Hamilton Co.

- Rapid Run is presently designated WWH in the Ohio WQS. Due to the essentially irretrievable modifications made to the stream channel habitat by the construction and maintenance of interceptor sewers it is recommended that the use designation be revised to the Limited Resource Waters (LRW) designation.

- Wulff Run is presently undesignated. The LRW use designation is recommended for the same reasons cited for Rapid Run.

- The unnamed tributary to Sycamore Creek is presently undesignated. The LRW use designation is recommended for the same reasons cited for Wulff Run.

- The unnamed tributary to Shayler Run is presently undesignated. Due to the demonstrated ability to attain the WWH criteria the WWH use designation is recommended.

Study Area Description

Forty-two (42) sites on 23 streams were biologically sampled (macroinvertebrates and/or fish) and/or the physical habitat evaluated in 1990 and 1991. Fish community data from an additional 22 sites on seven (7) streams is available from 1988. Habitat evaluations were conducted at 14 sites in the upper Taylor Creek subbasin in 1988, as well. All of this is in addition to the eight (8) sites sampled in the Taylor Creek subbasin and one (1) site on Bluerock Creek in 1990 and 1991. In all, a total of 49 sites have been biologically sampled. Habitat evaluations have been conducted at a total of 66 sites throughout the study area. All of the streams sampled, with the exception of Hall Run, Shayler Run, and the unnamed tributary to Shayler Run (eastern Clermont County) are in Hamilton County (Figure 1).

The greater Cincinnati study area lies in the Interior Plateau ecoregion. The principal characteristics of this ecoregion include a north to south transition from till plains of low topographic relief formed from Illinoisan glacial drift to rolling and moderately to deeply dissected plateaus that are underlain by shale and limestone (Omernik and Gallant 1988). The bedrock underlying Hamilton County is comprised of nearly horizontal layers of fossiliferous limestone and calcareous shale which is evident in outcroppings on steep slopes and at the numerous waterfalls and ledges in area streams. The limestone layers are generally two to six inches thick, but may approach one foot in thickness in certain instances (Stout *et al.* 1943) In other areas, particularly near the major rivers, the bedrock is overlain by glacial deposits which may be up to 400 feet thick. The Taylor Creek subbasin and adjacent watersheds are underlain by the Kope bedrock formation which is composed of Ordovician gray shale with interbedded thin layers of limestone. Shale comprises more than 75 percent of the bedrock which, upon exposure, weathers rapidly by slaking into a highly plastic, clayey mass that is very unstable (U.S. Dept. of Agriculture 1982). The Interior Plateau is also the area with the highest rate of gross erosion in the state (Antilla and Tobin 1978).

Taylor Creek and its tributaries are impacted by a number of permitted and unpermitted point source discharges, in addition to an unspecified number of home aeration systems and septic systems. Figure 2 shows the locations of the proposed Taylor Creek Regional WWTP (under construction) and the existing permitted and some of the unpermitted WWTPs in the Taylor Creek subbasin and along with a number of the lift stations located in the watershed. Much of the suburban development is located in the upper watershed and along the lower tributaries.

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 Water Quality Standards (WQS; 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. When macroinvertebrate data from qualitative sampling only is available a narrative evaluation (Exceptional, Good, Fair, Poor, and Very Poor) is used in lieu of the ICI. The IBI and ICI are multi-metric indices patterned after an original IBI described by Karr (1981) and Fausch *et*

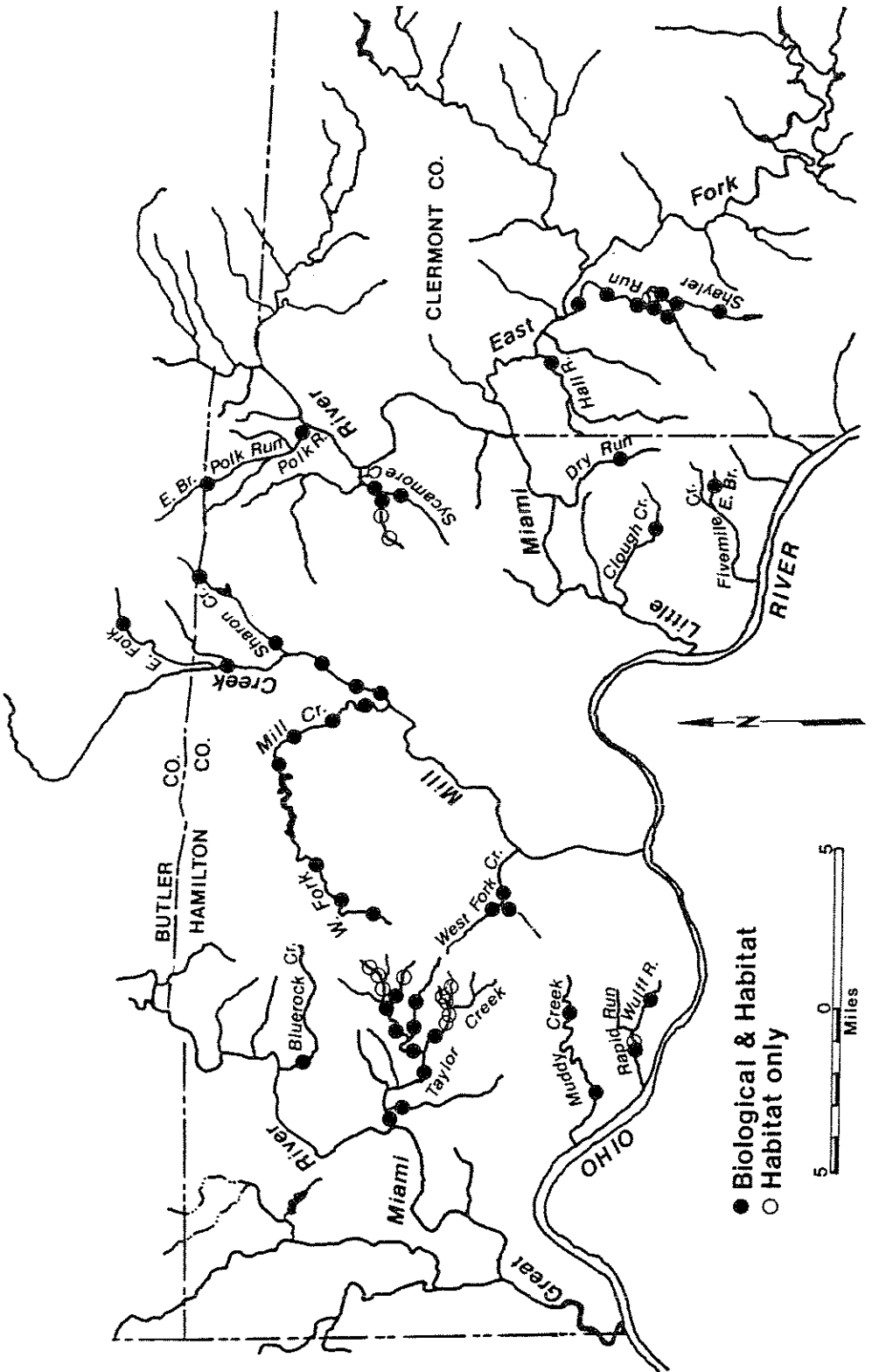

Figure 1. The greater Cincinnati streams study area showing principal river and stream drainages, county boundaries, and the 1988, 1990, and 1991 biological and habitat sampling locations (solid circles indicate locations sampled for fish and/or macroinvertebrates, and physical habitat; open circles indicate locations evaluated for physical habitat quality only).

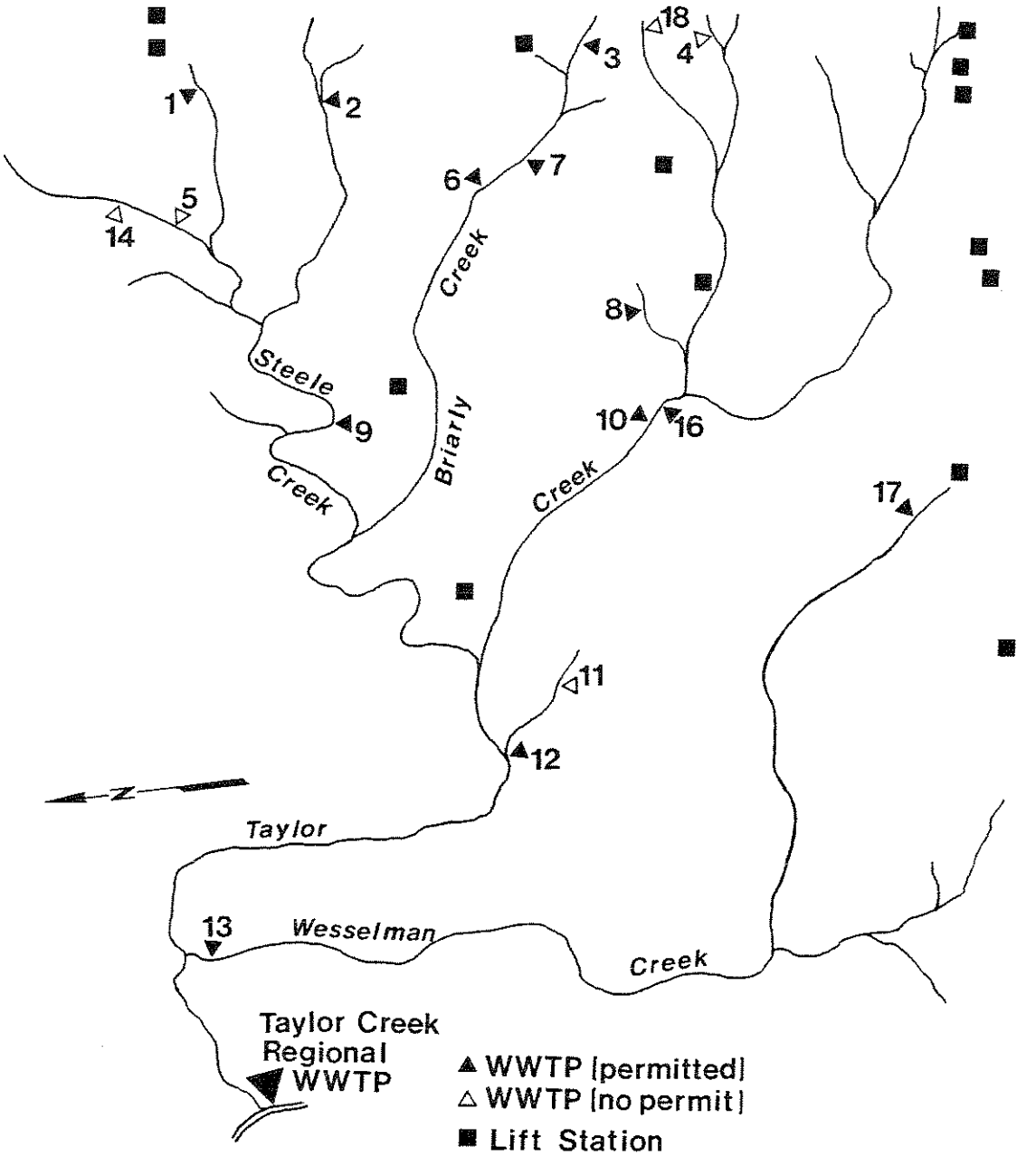

Figure 2. The Taylor Creek subbasin study area showing principal study streams, locations of some of the permitted and unpermitted package wastewater treatment plants, and lift station locations. A partial listing of WWTPs follows (* unpermitted source): 1 - Oak Hollow Estates; 2 - Brunswick Village; 3 - Monfort Heights; 4 - Arrow Street*; 5 - Peach Tree*; 6 - Farlook Hills; 7 - Frontier Park; 8 - West Fork Acres; 9 - White Oak Estates; 10 - Cedar Ridge; 11 - Eagles Nest Condominiums*; 12 - West Hills Apts.; 13 - Taylor Creek Condominiums; 14 - Peach Grove Manor*, 15 - Audobon Woods, 16 - Chateau Lakes, 17 - Diamond Oaks, 18 - Shoneys* (Source: Taylor Creek - Miamitown Drainage Area Proposed and Future Sanitary Sewers, Figure No. 1).

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). The median and lower quartile (25th percentile) Qualitative Community Tolerance Value (QCTV) are also calculated from the qualitative data. The QCTV is the median value of the weighted ICIs for each individual taxon in the qualitative sample. Although no formal criteria for the QCTV have been established, it is useful for making comparisons between sites. Higher QCTVs indicate a preponderance of taxa that have been associated with higher ICIs, while low QCTVs indicate a predominance by tolerant taxa.

Performance expectations for the basic aquatic life uses (Warmwater Habitat [WWH], Exceptional Warmwater Habitat [EWH], and Modified Warmwater Habitat [MWH]) were developed using the regional reference site approach (Hughes *et al.* 1986) and Omernik's (1988) ecoregions. 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 indices 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

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989). Various attributes of the available habitat are scored based on their overall importance to the establishment of viable, functional, and diverse aquatic faunas. Evaluations of the 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 10s to the 90s. 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. A matrix of QHEI habitat attributes that typify both warmwater habitats and modified habitats is also used to evaluate habitat quality and to assist in determining the attainability of aquatic life use designations. (Rankin 1989, 1990).

Macroinvertebrates

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 several locations where the artificial substrate samplers were lost or where qualitative samples only were collected. For this investigation, macroinvertebrate sites in the study area were also evaluated using an assessment tool currently in the developmental phase. This method utilizes the qualitative, natural substrate collections available from each site and relies on tolerance values derived for each macroinvertebrate taxon collected. These tolerance values, unlike other tolerance values used in common indices (*e.g.* the Hilsenhoff Biotic Index), utilizes the abundance data for a given taxon collected with artificial substrates at sites around Ohio. To determine the tolerance value of a given taxon, ICI scores at all locations where the taxon has been collected with artificial substrates were weighted by the abundance data of that taxon at those sites.

The median of the weighted ICI scores for a taxon results in the tolerance value of that taxon. Thus, a taxon's tolerance value represents its relative level of position on the ICI scale of 0 to 60. High tolerance values are calculated for the more intolerant taxa which tend to reach their greatest abundance at least disturbed sites (*i.e.* sites with the highest ICI scores). Conversely, the more pollution tolerant taxa attain their greatest abundances at highly disturbed sites that have low ICI scores, which results in a lower tolerance value. For the qualitative macroinvertebrate collections in the greater Cincinnati study area, the median tolerance value, based on all tolerance values of the organisms collected at a site, resulted in what has been termed the Qualitative Community Tolerance Value (QCTV). Though presently in the developmental stage, the QCTV shows potential as a method to supplement the existing narrative assessment methods using the qualitative macroinvertebrate information. Its use in evaluating sites in the study area was restricted to relative comparisons between sites with no direct attempt to interpret the quality of the sites or aquatic life use attainment status. The median (50th percentile) $QCTV_{50}$ and 25th percentile $QCTV_{25}$ were used to evaluate the results.

Fish Community

Fish were sampled 1 time at most sites using pulsed DC electrofishing gear using wading methods. In the smallest streams a Michigan DNR battery-powered back pack unit which produces 100-200 VDC at 2-3 amperes was used. A T&J generator/pulsator electrofishing unit which produces 150-300 VDC at 3-4 amperes was used at sites that were deeper and wider, but wadable. Sampling sites were 150-200m in length and were fished in an upstream direction (Ohio EPA 1989b). All habitat and biological sampling locations are located on Figure 1.

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. 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 streams. For stream segments with a single sampling site, the ADV is based on an extrapolation of the results of approximately 0.5-1.0 mile on either side of the site.

Results and Discussion

Chemical Water Quality

Water chemistry samples were not collected in association with the biological samples and habitat evaluations during the 1988, 1990, and 1991 field work. Some chemical data does exist, however. The U.S. EPA STORET system was used to access any chemical data collected by Ohio EPA in the greater Cincinnati study area. Data is relatively sparse and was available from only 10 of the study area streams with most dating from the 1970s and early 1980s. Contamination from organic enrichment and domestic sewage was evident in Taylor Creek at RM 3.1 (1976-77; elevated NH_3-N, total P, marginal D.O., elevated fecal coliform, elevated BOD_5), Hall Run at RM 0.23 (1974; elevated NH_3-N, total P, and BOD_5), Dry Run at RM 3.37 (1983; elevated NH_3-N, total P, and BOD_5), Sharon Creek at RM 0.2 (1973; elevated fecal coliform and BOD_5), E. Fork Mill Creek at RM 1.9 (1976; elevated NH_3-N, fecal coliform, and low D.O.), and Muddy Creek at RM 2.0 (1976; elevated fecal coliform). These results reflect water quality conditions prior to the upgrading or removal of domestic sewage discharges and likely reflect present conditions, particularly those areas impacted by combined sewer overflows.

Physical Habitat for Aquatic Life

Physical habitat for aquatic life was assessed using the Qualitative Habitat Evaluation Index (QHEI) at 66 sites in the study area. The QHEI results are summarized in Appendix Tables 1A through 6A in a matrix form which compares warmwater attributes with modified habitat attributes following Rankin (1989). The results are also graphically depicted in Figures 3 and 4.

For comparison purposes the QHEI results at the 66 sites in the study area were lumped into five groupings that reflect major subbasin aggregations and similarities of habitat impact. The Taylor Creek subbasin streams sampled in 1990 and 1991 reflect good to excellent habitat at all sites (Figure 3). This is despite the relocation and modification of the Taylor Creek mainstem by the construction of I-74 and I-275. Based on an inspection of the construction plans at the Ohio Department of Transportation a cumulative total of 1.14 miles of original stream channel was relocated into 1.04 miles of existing channel. This construction which took place between 1961 and 1968 was confined to the lower 3-4 miles of Taylor Creek with the most extensive channel modification work taking place along Harrison Avenue under the I-275 overpass. The substrate in this section of Taylor Creek is primarily composed of alluvial materials which are better able to recover than are the bedrock substrates in the upper portions of the subbasin. The types of impacts due to the highway construction activities were not similar in effect to those for the proposed construction of gravity flow interceptor sewers in Taylor Creek and tributaries. Despite this work the QHEI values exceed 60 at all sites evaluated in 1990 and 1991 (Figure 4) It is important to note that the overall performance of aquatic communities is correlated with segment or subbasin wide habitat quality and does not vary with site specific habitat (Rankin 1989). The habitat quality in the upper headwater tributaries was likewise good with some of the QHEI scores in the 55-60 range. However the median value of 14 sites exceeded 60 which is adequate to support the WWH use designation. All of the Taylor Creek subbasin sites were predominated by warmwater habitat attributes with MWH:WWH ratios of less than 0.5. The only site with a conspicuously high ratio was RM 1.6 (MWH:WWH = 2.25) in Taylor Creek which was affected by the I-74/I-275 construction (Appendix Tables 1A and 2A). MWH:WWH ratios of less than 1.0 generally indicate the presence of enough warmwater attributes to attain the WWH use, whereas ratios greater than 1.0 - 2.0 indicate a significant loss of attributes that makes attainment of the WWH use questionable, provided that the modification cannot be reversed.

The disturbed streams in Figure 4 included those most impacted by interceptor sewer construction (*e.g.* Rapid Run, Wulff Run, unnamed tributary to Sycamore Creek, Clough Creek, Dry Run, E. Br. Fivemile Creek, Sycamore Creek). QHEI values ranged from a low of 30.5 in Wulff Run to a high of 53.5 in Sycamore Creek (RM 0.7). The QHEI matrix for these streams were predominated by modified habitat attributes, particularly high influence modified attributes, a paucity of warmwater attributes, and with MWH:WWH ratios commonly exceeding 2.5-3.0 and ranging up to 6.0 (Appendix Tables 3A and 5A). In Figure 4 these streams appear at the bottom of the graph thus indicating their position relative to other streams in the study area.

The Mill Creek basin streams exhibited fair to good habitat quality (Figure 3). Most of the sites were predominated by warmwater habitat attributes with MWH:WWH ratios generally less than 1.50. These streams tended to be intermediate between the good habitat quality of the Taylor Creek subbasin and the disturbed streams. A few sites reflected more extensive habitat disturbance in the loss of warmwater attributes and higher MWH:WWH ratios, some of which approached and equaled those exhibited by the disturbed streams (Appendix Table 4A). The upper sites in the W.

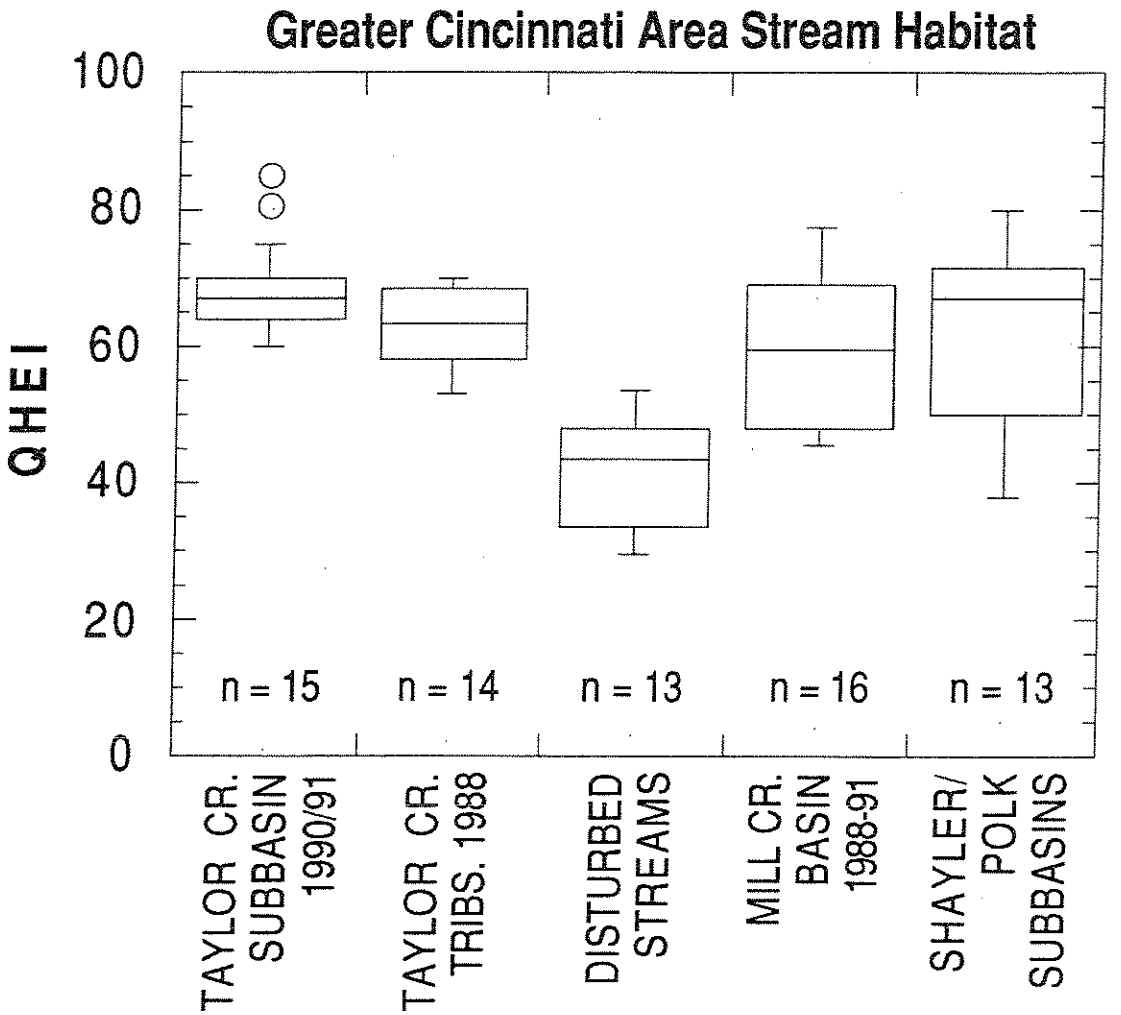

Figure 3. Comparison of Qualitative Habitat Evaluation Index (QHEI) values for five groups of streams in the greater Cincinnati study area based on data collected during July - September 1988, 1990, and 1991.

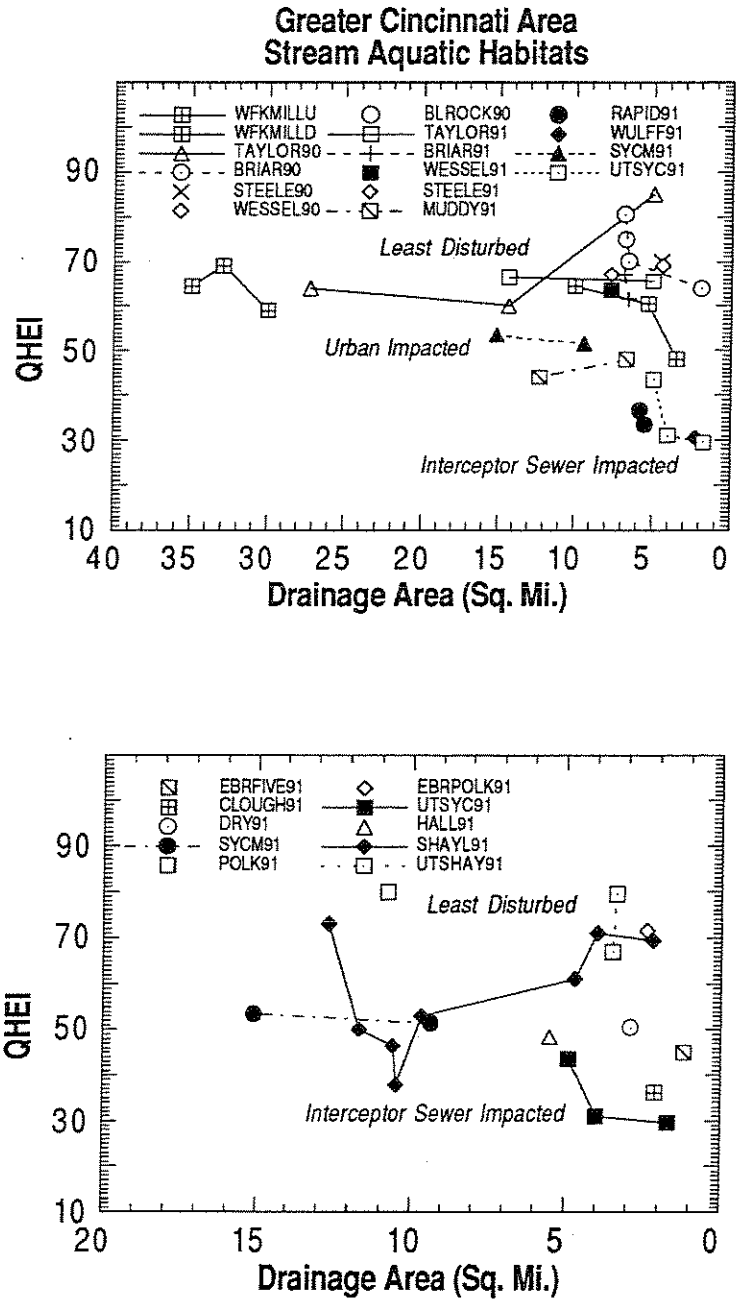

Figure 4. Qualitative Habitat Evaluation Index (QHEI) values plotted by watershed area (sq. mi.) in the Taylor Creek subbasin, W. Fork Mill Creek, Muddy Creek, Rapid Run, Wulff Run, Sycamore Creek, and the unnamed tributary to Sycamore Creek (UPPER), and the Shayler Run subbasin, Hall Run, Sycamore Creek, the unnamed tributary to Sycamore Creek, Dry Run, Clough Creek, E. Br. Fivemile Creek, and the Polk Run subbasin (LOWER), based on data collected during July - September 1988, 1990 and 1991.

Fk. Mill Creek had the poorest habitat which is largely a result of urban encroachment and to an extent, interceptor sewer line construction. Urban impacts undoubtedly were responsible for some of the modified attributes of several of the Mill Creek basin streams.

The Shayler Run, Hall Run, and Polk Run subbasins included a wide range of habitat quality from poor to excellent (Figure 3). Polk Run, E. Br. Polk Run, the upper and lower Shayler Run sites, and the unnamed tributary to Shayler Run exhibited the best habitat with a predominance of warmwater attributes and MWH:WWH ratios of less than 0.75. Shayler Run between RM 5.2 and 2.3 reflected disturbed habitat with high influence habitat attributes and MWH:WWH ratios of greater than 2.0. Hall Run also reflected some disturbance that was due primarily to the construction of I-275 (Appendix Tables 5A and 6A). The principal difference between these streams and the disturbed streams, particularly the interceptor sewer construction impacted segments, was the continuous presence of water and flow, and the semblance of a pool-run-riffle sequence, although of a much lower quality than that observed in the Taylor Creek subbasin.

The most severe habitat alterations caused by interceptor sewer construction was a virtual elimination of useable habitat, especially pools, and the destruction of the limestone bedrock substrate and the underwater ledges and crevices. The bedrock ledges and crevices provide critical habitat for many species of fish and taxa of macroinvertebrates. Pools are also a critical component of the habitat of Interior Plateau streams which naturally have low or intermittent flows during the summer-fall period. Thus the function of the pools as temporary refuges is obvious. Substrate embeddedness was particularly severe and debris torrents literally buried some of the streams to the point where there is no visible flow during normal summer flow periods. The consequences of the construction of interceptor sewers in and immediately adjacent to the beds of the area streams has also resulted in severe lateral erosion and vertical downcutting. In every stream that contained an interceptor sewer either the existing or recently replaced lines were exposed. Not only does this indicate the existence of inflow/infiltration problems, but it also verifies that replacement is a virtual certainty. Exposed lines were observed in Shayler Run, Wulff Run, and the unnamed tributary to Sycamore Creek. There is also the very real risk of raw sewage entering the streams via manhole surcharges or direct leakage from the interceptor sewers themselves.

Biological Assessment

Figures 5, 6, 7 and 8 and Tables 8 and 9 show the biological sampling results from the Taylor Creek watershed (8 sites) and the adjacent Bluerock Creek (1 site), compared to results from the other study area streams that have been impacted by past sewer line construction and replacement, combined sewers, urban development, or combinations of each. Macroinvertebrate results as portrayed by the ICI indicate that most of the sites sampled with artificial substrates achieved the ICI criterion of 30 (Figure 5; OAC 3745-1-07, Table 7-17). Only Sycamore Creek and sites in the upper Mill Creek basin (W. Fork, E. Fork, Sharon Cr.) failed to perform to the WWH criteria. All of the sites sampled in the Taylor Creek subbasin achieved the ICI criterion. More information was collected as qualitative data. The response of the macroinvetebrate community was evaluated using the Qualitative Community Tolerance Value (QCTV). The $QCTV_{50}$ (Figure 6) showed a mild tendency for the streams impacted by raw sewage to perform below the minimum $QCTV_{50}$ observed at any of the reference sites in the Interior Plateau. Along with Muddy Creek, the streams most impacted by interceptor sewer construction had the lowest $QCTV_{50}$ (Figure 6). The $QCTV_{25}$ tended to sort these impacted sites even further. All of the severely impacted sites (*e.g.* Wulff Run, Rapid Run, Muddy Creek) had the lowest $QCTV_{25}$ (Figure 7). Besides the impacted streams, the 1990 sample from Bluerock Creek also had a $QCTV_{25}$ in the same range as the heavily impacted sites, but had an ICI that easily achieved the WWH criterion. This site is approximately

Table 8. Summary of macroinvertebrate data collected from artificial substrates (quantitative evaluation) and natural substrates (qualitative evaluation) in the greater Cincinnati study area, July - September, 1990 and 1991. Qualitative samples labeled "A" were collected when the artificial substrates were set; samples labeled "B" were collected when the artificial substrates were retrieved.

		Quantitative Evaluation						
Stream River Mile[d]	Relative Density	Quant. Taxa	Qual. Taxa	Qual. EPT[b]	QCTV[c] Median	25th %	ICI	Narrative Evaluation
Taylor Creek (1991)								
3.5	646	28	36	5	33.6	22.9	38	Good
1.6	559	32	40	8	34.9	29.0	38	Good
Taylor Creek (1990)								
1.8B	256	29	42	8	34.0	22.5	42	Very good
0.4B	337	31	36	8	32.6	25.8	30	Good
Briarly Creek (1991)								
1.3	220	17	22	6	38.4	30.1	30	Good
0.1	306	22	30	6	37.1	29.9	34	Good
Briarly Creek (1990)								
0.1B	495	25	32	8	34.0	24.6	46	Very good
Steele Creek (1991)								
0.2	213	21	28	7	35.3	29.9	28[ns]	Marg. good
Wesselman Creek (1991)								
0.3	184	28	30	6	35.5	28.7	38	Good
Wesselman Creek (1990)								
0.3B	198	40	36	9	35.8	30.1	46	Very good
Bluerock Creek (1990)								
0.5B	310	35	46	8	31.2	19.8	42	Very good
W. Fk. Mill Creek (1991)								
10.0	65	13	27	3	29.9	19.2	4*	Poor
Sharon Creek (1991)								
4.3	73	21	31	6	35.3	28.9	12*	Poor
E. Fk. Mill Creek (1991)								
3.3	29	23	37	8	34.0	24.8	20*	Fair
Polk Run (1991)								
0.3	325	36	42	11	37.3	28.9	46	Very good
Sycamore Creek (1991)								
1.0	399	25	32	7	34.0	22.5	22*	Fair
Shayler Run (1991)								
5.8	115	29	33	7	34.9	28.9	28[ns]	Marg. good
2.1	214	31	45	13	38.8	32.6	40	Good

Table 8. (continued).

Stream River Mile[d]	No. Qual. Taxa	*Qualitative Evaluation* QCTV[c] Median/25th %		Qual. EPT[b]	Relative Density	Predominant Organisms	Narrative Evaluation[a]
Taylor Creek (1990)							
3.5A	18	30.1	17.7	3	Low	Isopods, blackflies, mayflies, midges	Fair
3.5B	37	32.6	22.9	9	Low	Mayflies, midges riffle beetles	Good
1.8A	32	34.0	19.2	7	Mod	Mayflies, midges, blackflies, isopods	Good
0.4A	26	35.5	28.9	7	Mod	Mayflies, blackflies, midges	Marg. good
Briarly Creek (1990)							
1.7A	20	31.3	19.2	3	Mod	Isopods, blackflies, flatworms	Fair
1.7B	17	34.0	22.5	3	Low	Isopods, blackflies, mayflies, caddisflies	Fair
1.4A	21	31.3	28.7	6	Mod	Isopods, blackflies	Fair
1.4B	22	35.3	31.0	6	Mod	Isopods, mayflies, blackflies, scuds	Fair
0.1A	29	34.0	19.2	7	Mod	Mayflies, isopods, blackflies, caddisflies	Good
Steele Creek (1990)							
0.2A	22	34.9	22.5	8	Mod	Isopods, blackflies	Marg. good
0.2B	28	35.3	23.4	7	Mod	Isopods, mayflies	Marg. good
Wesselman Creek (1990)							
0.3A	26	35.8	31.2	6	Mod	Mayflies, caddisflies midges	Good
Bluerock Creek (1990)							
0.5A	41	34.0	25.8	6	Mod	Mayflies, blackflies, caddisflies, isopods	Good
Muddy Creek (1991)							
5.3	19	18.5	12.3	0	High	Midges, snails	Very poor
2.6	26	29.9	19.8	4	Low	Midges, mayflies	Poor
Rapid Run (1991)							
1.2	19	29.9	16.2	4	Mod	Midges, snails, mayflies	Poor
Wulff Run (1991)							
0.7	26	34.0	20.6	5	Low	Midges, isopods, snails	Poor
E. Br. Fivemile Creek (1991)							
3.7	18	35.3	29.9	3	Low	Isopods, mayflies, caddisflies	Fair

Table 8. (continued).

Stream River Mile[d]	No. Qual. Taxa	*Qualitative Evaluation* QCTV[c] Median/25th %		Qual. EPT[b]	Relative Density	Predominant Organisms	Narrative Evaluation[a]
Dry Run (1991)							
4.2	31	36.0	34.0	7	Low	Mayflies, midges, caddisflies, isopods	Marg. good
Clough Creek (1991)							
3.2	21	37.4	34.0	5	Low	Mayflies, midges, caddisflies, isopods	Fair
E. Br. Polk Run (1991)							
1.4	38	36.0	30.1	5	Low	Midges, caddisflies, damselflies	Marg. good
Sycamore Creek (1991)							
1.2	29	34.9	29.9	8	Low	Midges, caddisflies	Good
Tributary to Sycamore Creek (1991)							
0.1	12	29.9	18.5	0	Low	Snails	Very poor
Shayler Run (1991)							
5.2	37	37.8	29.9	8	Mod	Riffle beetles, water pennies, caddisflies	Good
3.4	29	39.9	34.9	8	Low	Mayflies, isopods, water pennies	Good
Hall Run (1991)							
0.5	41	37.3	30.1	10	Low	Caddisflies, midges, mayflies, hellgrammites	Good
Tributary to Shayler Run (1991)							
0.7	37	37.4	30.1	8	Mod	Isopods, caddisflies, mayflies, beetles	Good
0.1	38	37.8	34.0	11	Mod	Caddisflies, beetles, isopods, snails	Good

Ecoregion Biocriteria: Interior Plateau (IP)

INDEX	WWH	EWH	MWH[e]
ICI	30	46	22

[e] - Modified Warmwater Habitat for channel modified areas.

[a] The qualitative narrative evaluation is based on best professional judgement and is used when quantitative data is not available to calculate the Invertebrate Community Index (ICI) scores.
[b] EPT= total Ephemeroptera (mayflies), Plectoptera (stoneflies) and Tricoptera (caddisflies).
[c] Qualitative Community Tolerance Value (QCTV) calculated as the average of the weighted ICI for each taxa.
[d] Two sets of samples were collected from the Taylor Creek basin in 1990 and are indicated as "A" samples, collected on June 29, and "B" samples, collected on August 10.
* Significant departure from ecoregion biocriteria (>4 ICI units); poor and very poor results are underlined.
ns Nonsignificant departure from biocriterion (<4 ICI units).

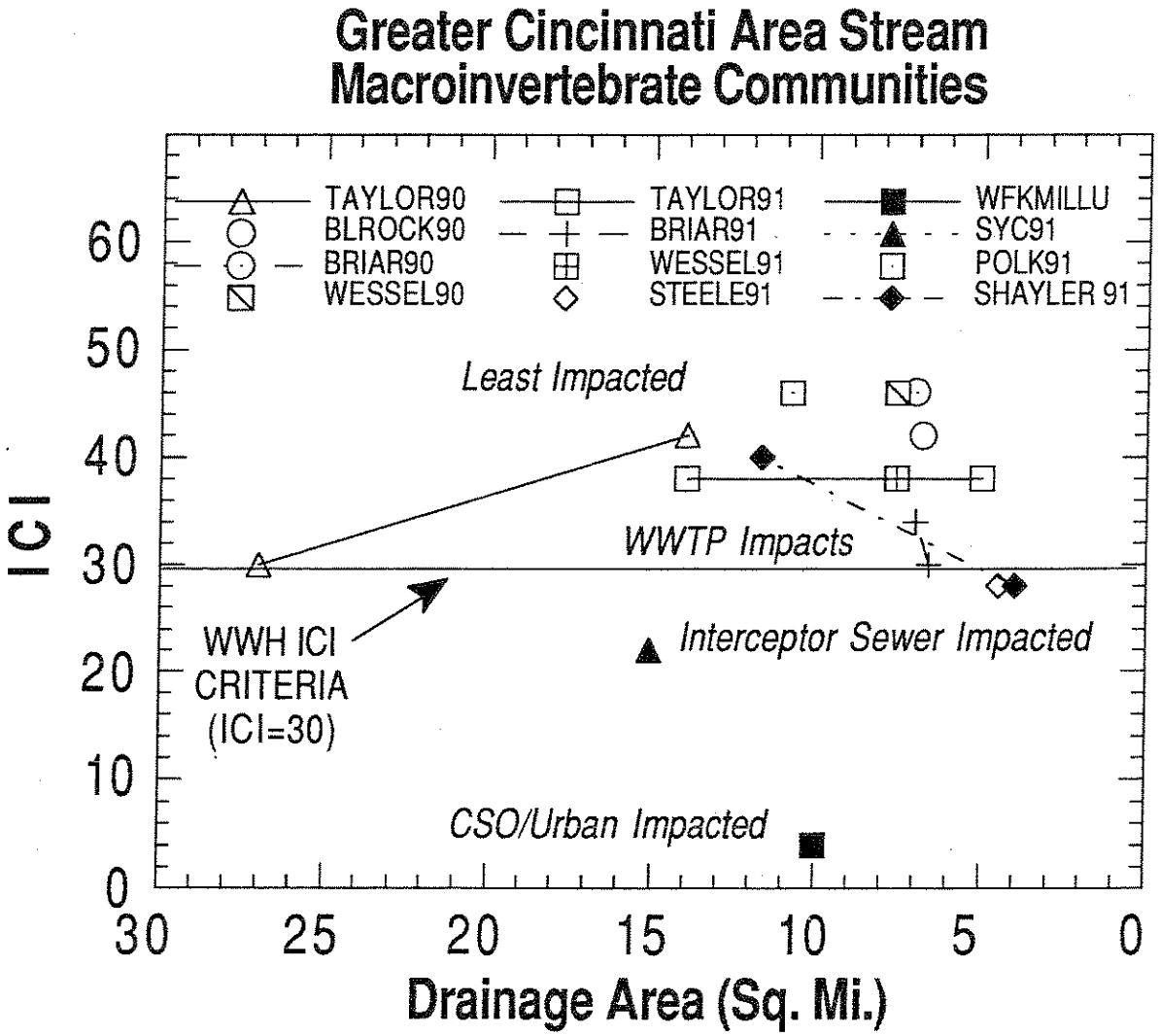

Figure 5. The Invertebrate Community Index (ICI) plotted by watershed area (sq. mi.) in the Taylor Creek subbasin, W. Fork Mill Creek, Sycamore Creek, Polk Run, and Shayler Run based on data collected during July - September 1990 and 1991.

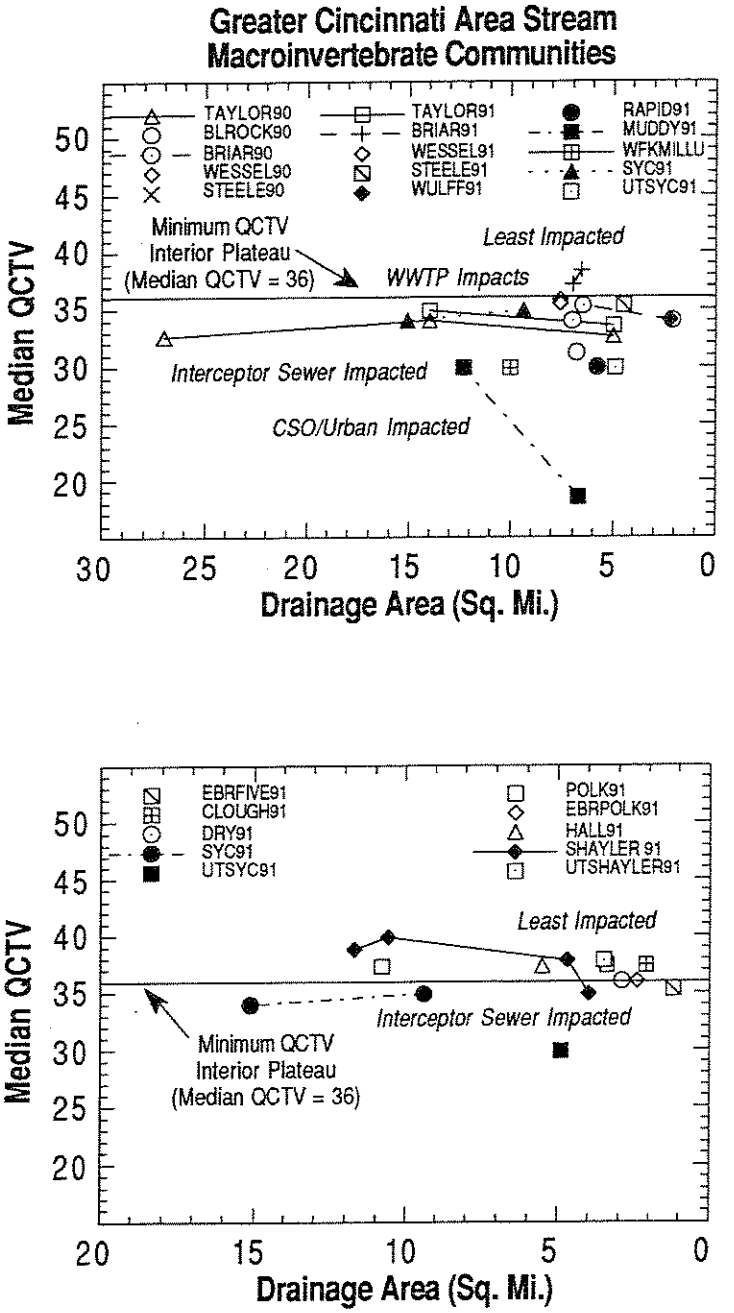

Figure 6. The median Qualitative Community Tolerance Value ($QCTV_{50}$) plotted by watershed area (sq. mi.) in the Taylor Creek subbasin, W. Fork Mill Creek, Muddy Creek, Rapid Run, Wulff Run, Sycamore Creek, and the unnamed tributary to Sycamore Creek (UPPER), and the Shayler Run subbasin, Hall Run, Sycamore Creek, the unnamed tributary to Sycamore Creek, Dry Run, Clough Creek, E. Br. Fivemile Creek, and the Polk Run subbasin (LOWER) based on data collected during July - September 1990 and 1991.

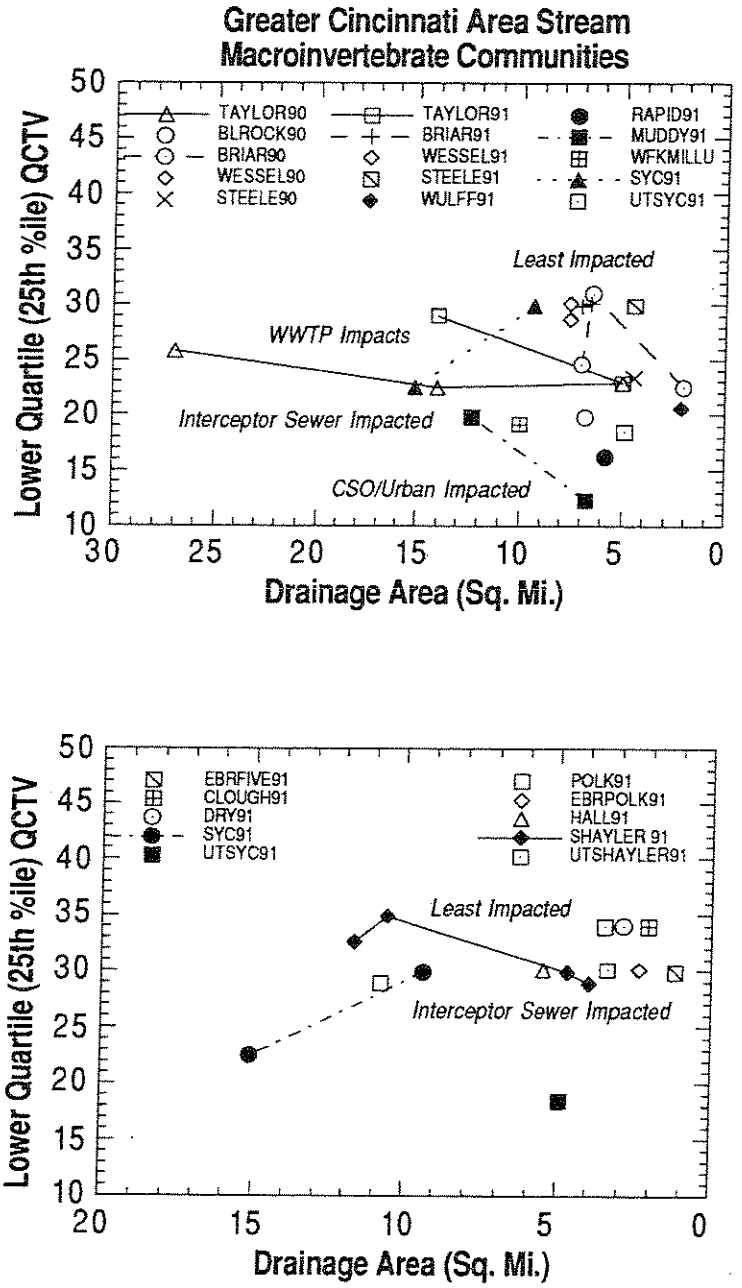

Figure 7. The lower quartile (25th percentile) Qualitative Community Tolerance Value ($QCTV_{25}$) plotted by watershed area (sq. mi.) in the Taylor Creek subbasin, W. Fork Mill Creek, Muddy Creek, Rapid Run, Wulff Run, Sycamore Creek, and the unnamed tributary to Sycamore Creek (UPPER), and the Shayler Run subbasin, Hall Run, Sycamore Creek, the unnamed tributary to Sycamore Creek, Dry Run, Clough Creek, E. Br. Fivemile Creek, and the Polk Run subbasin (LOWER) based on data collected during July - September 1990 and 1991.

Table 9. Fish community indices based on pulsed D.C. electrofishing samples at 49 locations sampled by Ohio EPA in the greater Cincinnati streams study area during July - September, 1988, 1990, and 1991. All sites were sampled with wading methods.

Stream River Mile	Mean Number of Species	Cumulative Species	Mean Rel. No. (No./Km)	Mean Rel. Wt. (Kg/Km)	QHEI	Mean Modified Index of Well-Being	Mean Index of Biotic Integrity	Narrative Evaluation
Taylor Creek (1991)								
3.4	15	15	3102	N/A	65.5	N/A	44	Good
1.6	16	16	2667	N/A	66.5	N/A	44	Good
Taylor Creek (1990)								
3.5	12	12	2184	N/A	85	N/A	44	Good
1.6	17	17	852	N/A	60	N/A	44	Good
0.5	13	13	96	N/A	64	7.4*	28*	Fair
Briarly Creek (1991)								
1.3	6	6	2438	N/A	61.5	N/A	34*	Fair
0.5	13	13	1327	N/A	67	N/A	36^{ns}	M. Good
Briarly Creek (1990)								
1.8	3	3	608	N/A	64	N/A	22*	Poor
1.3	5	5	1221	N/A	70	N/A	34*	Fair
0.5	11	11	218	N/A	80.5	N/A	36^{ns}	M. Good
Steele Creek (1991)								
0.4	4	4	1932	N/A	69	N/A	30*	Fair
Steele Creek (1990)								
0.2	5	5	909	N/A	70	N/A	20*	Poor
Steele Creek (1988)								
1.0	4	4	1038	N/A	70	N/A	18*	Poor
Wesselman Creek (1991)								
0.3	27	27	1100	N/A	63.5	N/A	52	Exceptional
Wesselman Creek (1990)								
0.3	28	28	939	N/A	67	N/A	44	Good
Bluerock Creek (1990)								
0.5	25	25	726	N/A	75	N/A	50	Exceptional
Tributary to Steele Creek (1988)								
0.3	1	1	657	N/A	70	N/A	20*	Poor
Tributary to Tributary to Taylor Creek (1988)								
0.3	4	4	3561	N/A	68.5	N/A	36^{ns}	M. Good
0.2	4	4	3465	N/A	69.5	N/A	30*	Fair
Muddy Creek (1991)								
5.3	3	3	22	N/A	48	N/A	12*	V.Poor
2.7	13	13	768	N/A	44	N/A	36^{ns}	M. Good
Rapid Run (1991)								
1.1	2	2	24	N/A	36.5	N/A	12*	V.Poor

Table 9. (continued).

Stream River Mile	Mean Number of Species	Cumulative Species	Mean Rel. No. (No./Km)	Mean Rel. Wt. (Kg/Km)	QHEI	Mean Modified Index of Well-Being	Mean Index of Biotic Integrity	Narrative Evaluation
Wulff Run (1991)								
0.6	1	1	2	N/A	30.5	N/A	12*	V.Poor
Mill Creek (1988)								
17.7	11	11	842	N/A	59.5	6.1*	20*	Poor-V.Poc
14.8	8	8	353	N/A	65	2.5*	20*	V.Poor
13.3	12	12	830	N/A	63.5	5.6*	22*	Poor-V.Poc
12.2	10	10	350	N/A	71	3.7*	20*	V.Poor
West Fork Creek (1991)								
2.7	2	2	362	N/A	61.5	N/A	12*	V.Poor
2.5	1	1	255	N/A	56.5	N/A	12*	V.Poor
Tributary to West Fork Creek (1991)								
0.1	0	0	0	N/A	46.5	N/A	12*[b]	V.Poor
W. Fk. Mill Creek (1991)								
13.9	4	4	789	N/A	48	N/A	16*	V.Poor
12.6	4	4	799	N/A	60	N/A	16*	V.Poor
10.2	3	3	475	N/A	65.5	N/A	14*	V.Poor
6.4	6	6	155	N/A	59	4.8*	24*	Poor
4.1	13	13	1029	N/A	69	5.2*	22*	Poor
2.6	13	13	1500	N/A	64.5	6.2	24*	Fair-Poor
1.1	17	17	885	N/A	69.5	5.5*	22*	Poor
Sharon Creek (1991)								
4.3	9	9	1056	N/A	77.5	N/A	34*	Fair
Sharon Creek (1988)								
4.3	10	10	1322	N/A	74	N/A	38[ns]	M.Good
0.2	6	6	87	N/A	52.5	N/A	18*	Poor
E. Fk. Mill Creek (1988)								
3.3	13	13	2997	N/A	45.5	N/A	44	Good
E. Br. Fivemile Creek (1991)								
0.4	0	0	0	N/A	45	N/A	12*[b]	V.Poor
Clough Creek (1991)								
3.2	3	3	676	N/A	36	N/A	26*	Poor
Dry Run (1991)								
4.2	3	3	876	N/A	50.5	N/A	26*	Poor
Sycamore Creek (1991)								
1.4	9	9	1416	N/A	51.5	N/A	38[ns]	M.Good
0.7	15	15	2169	N/A	53.5	N/A	38[ns]	M.Good
Tributary to Sycamore Creek (1991)								
0.1	4	4	11	N/A	43.5	N/A	14*	V.Poor

Table 9. (continued).

Stream River Mile	Mean Number of Species	Cumulative Species	Mean Rel. No. (No./Km)	Mean Rel. Wt. (Kg/Km)	QHEI	Mean Modified Index of Well-Being	Mean Index of Biotic Integrity	Narrative Evaluation
Polk Run (1991)								
0.3	29	29	4486	N/A	80	N/A	52	Exceptional
E. Br. Polk Run (1991)								
1.5	8	8	1198	N/A	71.5	N/A	34*	Fair
Shayler Run (1991)								
7.3	12	12	1244	N/A	69.5	N/A	42	Good
5.8	11	11	1668	N/A	71	N/A	32*	Fair
5.2	10	10	736	N/A	61	N/A	36ns	M.Good
4.2	11	11	1827	N/A	53	N/A	36ns	M.Good
3.0	9	9	3988	N/A	46.5	N/A	40	Good
2.3	18	18	1992	N/A	50	N/A	46	V.Good
0.6	26	26	740	N/A	73	--	50	Exceptional
Tributary to Shayler Run (1991)								
0.6	13	13	2857	N/A	79.5	N/A	40	Good
0.1	11	11	2920	N/A	67	N/A	36ns	M.Good
Hall Run (1991)								
0.5	13	13	2994	N/A	48.5	N/A	44	Good

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

ns Nonsignificant departure from biocriterion (<4 IBI units or < 0.5 MIwb units)

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

b No fish collected.

NA Headwater site; MIwb is not applicable.

Ecoregion Biocriteria: Interior Plateau (IP)

INDEX - Site Type	WWH	EWH	MWHc
IBI - Headwaters/Wading	40	50	24
Mod. Iwb - Wading	8.1	9.4	5.8

c - Modified Warmwater Habitat for channel modified areas.

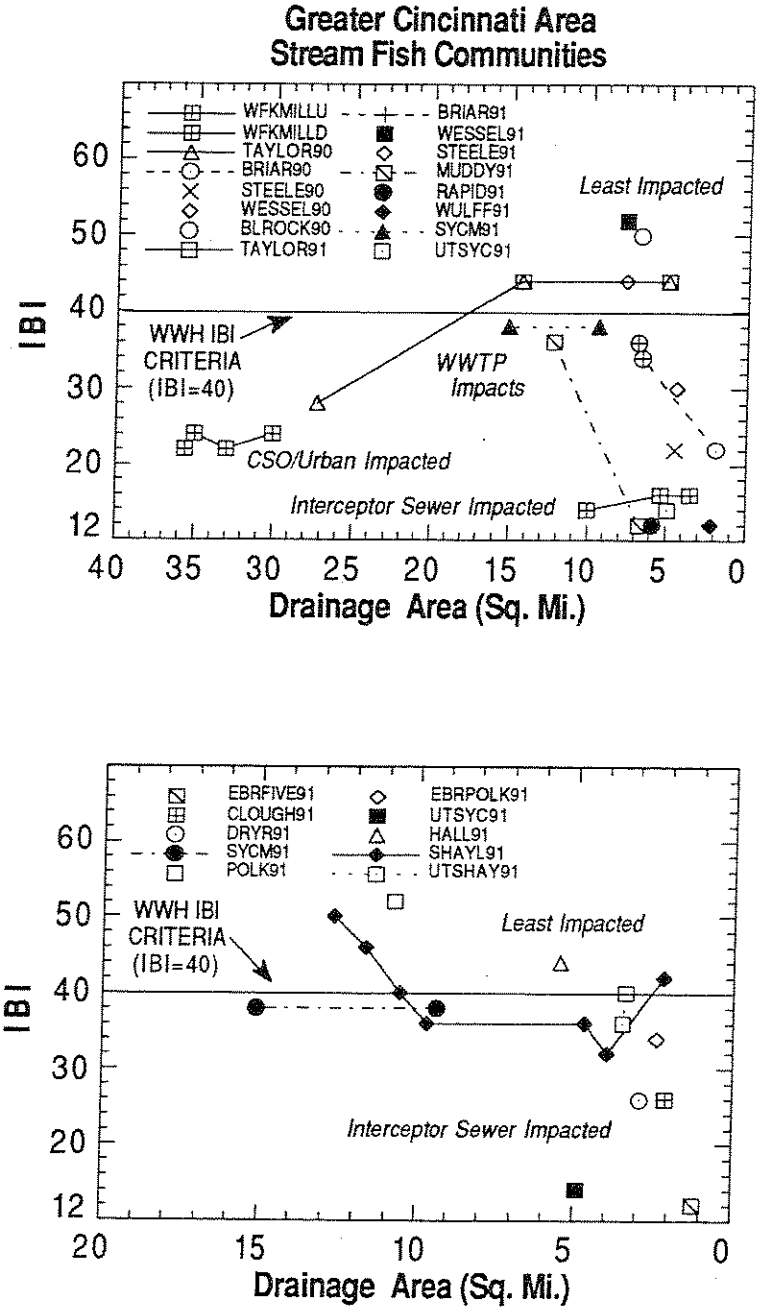

Figure 8. The Index of Biotic Integrity (IBI) plotted by watershed area (sq. mi.) in the Taylor Creek subbasin, W. Fork Mill Creek, Muddy Creek, Rapid Run, Wulff Run, Sycamore Creek, and the unnamed tributary to Sycamore Creek (UPPER), and the Shayler Run subbasin, Hall Run, Sycamore Creek, the unnamed tributary to Sycamore Creek, Dry Run, Clough Creek, E. Br. Fivemile Creek, and the Polk Run subbasin (LOWER), based on data collected during July - September 1988, 1990 and 1991.

0.8 miles downstream from the Colerain Heights WWTP. Low $QCTV_{25}$ values indicate the presence of higher numbers of pollution tolerant taxa. The remaining sites scored higher and represent the varying range of WWTP impacts in the Taylor Creek sub-basin.

The Index of Biotic Integrity (IBI), based on fish community attributes, illustrates the very different aquatic life use attainment status of the different sites (Figure 8). Taylor Creek (2 of 3 sites), Wesselman Creek, and Bluerock Creek easily achieved the Warmwater Habitat (WWH) IBI criteria of 40 for headwater sites of the Interior Plateau ecoregion (OAC 3745-1-07, Table 7-17). The uppermost two Taylor Creek sites are in the area proposed for sewer construction and are downstream from the Cedar Ridge WWTP that would be eliminated by the proposed Taylor Creek Regional project. The other sites in the Taylor Creek watershed, three (3) on Briarly Creek and one (1) on Steele Creek did not achieve the WWH IBI criterion of 40. Furthermore, the IBI values in each of the Taylor Creek tributaries are lower in the upstream sections, *i.e.* at sites closest to the package WWTPs. However, even with the impact of the very poor effluent quality from the package WWTPs, these streams outperform the streams impacted the most by the construction of interceptor sewers. Wulff Run, Rapid Run, the unnamed tributary to Sycamore Creek, several sites in upper W. Fk. Mill Creek, West Fork Creek, the unnamed tributary to West Fork Creek, and E. Br. Fivemile Creek scored at or near the minimum IBI of 12, with other streams such as Shayler Run, Sycamore Creek, Clough Creek, and Dry Run exhibiting scores in the mid 20s to upper 30s (Fig. 8). The only two streams where no fish were observed was the unnamed tributary to West Fork Creek and E. Br. Fivemile Creek. The former had a physical barrier at the mouth, but the latter had some pool and riffle habitat despite being impacted by past sewer line construction. Thus the complete absence of fish was surprising. Very small juvenile crayfish, all of the same size class, were observed during the fish sampling which may suggest that some catastrophic event took place previously which completely eliminated the fish community. The macroinvertebrate community performance was fair. This site was in a suburban setting, but no obvious impacts associated with this type of land use was evident (*i.e.* excessive channel scour, splash wells, etc.).

Shayler Run represents a situation where the potential of the pre-construction natural habitat was most likely EWH. An analysis of the results of a U.S. EPA survey from 1969-1971 indicate that a fish community much different from that observed in 1991 was present (U.S. EPA 1976). Although direct translation of the EPA results into an IBI value is made difficult by differences in methods and sampling, two samples yielded an IBI of 50 which equals the EWH criterion. Two other samples yielded lower scores (38), but the previously mentioned uncertainties about methods and the influence of a now abandoned WWTP located approximately 5 miles upstream are confounding factors. Owing to the error tendency of biological field data to underestimate the true condition, especially where uncertainties exist about methods and sampling procedures, the IBIs from the EPA data should be considered as minimum scores. The two U.S. EPA IBI scores of 50, coupled with the exceptional performance of the RM 0.6 site in 1991, make the former EWH potential a likelihood. Thus evaluating the impact of the 1976 interceptor sewer construction in Shayler Run against the EWH criteria has merit.

One fish species, the southern redbelly dace (*Phoxinus erythrogaster*), was collected in abundance only from the upstream site in the unnamed tributary to Shayler Run. This is a signature headwater fish species in Ohio and occurs most commonly in areas of high relief (Trautman 1981) and where the headwater stream habitat is relatively intact. The habitat at the upstream site in the unnamed tributary to Shayler Run was relatively unimpacted and offered the bedrock ledge and rubble type habitat characterized by the headwater streams of this ecoregion. Most of the individuals captured were collected from under the ledges and overhangs provided by the bedrock

and flat rubble substrates at this site. Based on a recent mapping analysis done by Ohio EPA this species has declined in distribution throughout Ohio, presumably due to the degradation of headwater habitats.

Another finding of interest was the collection of adult and juvenile two-lined salamanders (*Eurycea bislineata*) in several of the streams in the study area. This species is broadly distributed throughout southwestern, central, southeastern, and northeastern Ohio (Guttman 1989). It was found to be common in the temporary shallow pools of Wulff Run and was very numerous in the unnamed tributary to West Fork Creek in Mt. Airy Forest. Individuals were also observed in Briarly Creek and Rapid Run. This species seemed to be more common in streams lacking large fish (>4-6 inches) which often prey on this species. This certainly correlates with the complete absence of fish in the unnamed tributary to West Fork Creek.

Each stream was assigned one or more major impact types in order to assess the relative contribution of each in the streams of the study area (Table 10) in a manner similar to that used by Ohio EPA to assess causes and sources in the biennial Water Resource Inventory (Ohio EPA 1990b) and elsewhere (Yoder 1991). These represent the major or *predominant* impacts noted in each stream, not a complete inventory of all impacts that are present. Other impacts may have been present, but were not considered to be major if judged to be either a minor influence and/or masked by the major impacts. Several streams were impacted by multiple sources thus the total stream miles and ADV units for each impact type represent cumulative totals for each category.

Using the Area of Degradation Value (ADV; Rankin and Yoder 1991) program in Ohio ECOS, a total of 57.6 stream miles were assessed (includes extrapolated miles) in the greater Cincinnati streams study area in 1988, 1990, and 1991 (Table 10). This total was calculated using the 1990 Taylor Creek subbasin survey, which covered more stream miles than the 1991 survey. A total of 37.9 miles (65.8%) were either in **NON** (36.8 mi.) or PARTIAL (1.1 mi.) attainment of the WQS (Figure 9). FULL attainment was observed in the remaining 19.7 miles (34.2%). The **NON** attaining miles increases to 41.7 miles (72%) when Shayler Run is evaluated against the Exceptional Warmwater Habitat (EWH) biocriteria. Of these totals 20.9 miles (56.8%) of the **NON** attainment were from streams that were impacted by past interceptor sewer line construction (Figure 9). Of the poor and very poor performing miles, 18.4 miles (58.4%) were from streams impacted by sewer line construction. Of the 9.4 miles of sewer construction impacted streams in FULL attainment, 7.2 miles were from Shayler Run evaluated against the WWH use designation. This total declines to 3.7 miles when Shayler Run is evaluated against the EWH use designation. Area of Degradation (ADV) units/mile for the Index of Biotic Integrity (IBI) showed that a cumulative total of 1422.8 ADV/mile (58% of a total of 2452.7 ADV/mi.) were from streams that have been impacted by the construction of interceptor sewers (Figure 9). Streams concurrently or independently impacted by intensive urbanization yielded 1174 ADV/mile (47.9%), CSO impacts yielded 997 ADV/mile (47.9%), and WWTP and other municipal sewage discharges yielded 393.9 ADV/mile (16.1%).

Although the study does not represent a completely randomized sample design, these results indicate that the severity of the impacts to the streams of the area rank in order of importance noted in the preceding estimates. The ADV results show that the construction of interceptor sewers in stream corridors has a substantial impact on streams in the study area. Streams impacted by this activity ranked third in terms of the cumulative miles of **NON** attainment (Figure 9). However, this impact type had the highest cumulative ADV/mile (Figure 9) which indicates that the severity of this impact is at least equal to, if not greater than, the CSO and urban impacts. Minimum IBI

Table 10. Area of Degradation (ADV) statistics for the greater Cincinnati streams study area, 1988, 1990, and 1991 (calculated using ecoregion criteria as the background community performance except when specified otherwise). The major impact types are indicated for each stream.

	Biological Index Scores				ADV Statistics			Attainment Status (miles[a])			
Stream Index	Upper RM	Lower RM	Mini-mum	Maxi-mum	**ADV**	ADV/ Mile	Poor/VP ADV	FULL	PARTIAL	**NON**	Poor/VP
Taylor Creek (1990) **[W]**											
IBI	3.5	0.4	28	44	67	**5.3**	0	3.0	1.1	**0.0**	0.0
ICI			30	42	0	**0.0**	0				
Taylor Creek (1991) **[W]**											
IBI	3.4	1.6	44	44	0	**0.0**	0	2.9	0.0	**0.0**	0.0
ICI			38	38	0	**0.0**	0				
Briarly Creek (1990) **[W]**											
IBI	1.8	0.5	22	36	124	**51.6**	33	0.8	0.0	**1.6**	0.8
Briarly Creek (1991) **[W]**											
IBI	1.3	0.5	34	36	18	**9.5**	0	0.0	0.8	**1.1**	0.0
Steele Creek (1990) **[W]**											
IBI	0.2	0.2	20	20	128	**160**	128	0.0	0.0	**0.8**	0.5
Steele Creek (1991) **[W]**											
IBI	0.4	0.4	30	30	60	**60**	0	0.0	0.0	**1.0**	0.0
Wesselman Creek (1990)											
IBI	0.3	0.3	44	44	0	**0**	0	0.9	0.0	**0.0**	0.0
Wesselman Creek (1991) **[O]**											
IBI	0.3	0.3	52	52	0	**0**	0	0.9	0.0	**0.0**	0.0
Bluerock Creek (1990) **[W]**											
IBI	0.5	0.5	50	50	0	**0**	0	1.1	0.0	**0.0**	0.0
Rapid Run (1991) **[S]**											
IBI	1.1	1.1	12	12	264	**240**	264	0.0	0.0	**1.1**	1.1
Wulff Run (1991) **[S]**											
IBI	0.6	0.6	12	12	264	**240**	264	0.0	0.0	**1.1**	1.1
Muddy Creek (1991) **[CSO/U/S]**											
IBI	5.3	2.7	12	36	444	**202**	204	0.6	0.0	**3.1**	2.2
Mill Creek (1988) **[CSO/U]**											
IBI	17.7	12.2	20	22	1030	**156**	436	0.0	0.0	**6.6**	6.6
MIwb			2.5	6.1	1055	**160**	93				
W. Fork Mill Creek (1988) **[CSO/U/S]**											
IBI	13.9	1.1	14	24	1766	**159**	803	0.0	0.0	**11.1**[b]	11.1[b]
MIwb	6.4	1.1	4.8	6.2	635	**99**	26				
West Fork Creek (1991) **[CSO/U]**											
IBI	2.7	2.5	12	12	312	**240**	195	0.0	0.0	**1.3**	1.3
Trib. to West Fork Creek (1991) **[CSO/U]**											
IBI	0.1	0.1	12	12	168	**240**	105	0.0	0.0	**0.7**	0.7

Table 10. (continued).

Stream / Index	Biological Index Scores: Upper RM	Lower RM	Mini-mum	Maxi-mum	ADV Statistics: ADV	ADV/ Mile	Poor/VP ADV	Attainment Status (miles[a]): FULL	PARTIAL	NON	Poor/VP
Sharon Creek (1988) **[U/W]**											
IBI	4.3	0.2	18	38	378	**77**	0	1.1	0.0	**3.8**	2.2
E. Fork Mill Creek (1988) **[O]**											
IBI	3.3	3.3	44	44	0	**0**	0	1.1	0.0	**0.0**	0.0
Clough Creek (1991) **[S]**											
IBI	3.2	3.2	26	26	110	**100**	11	0.0	0.0	**1.1**	1.1
Dry Run (1991) **[W/U]**											
IBI	4.2	4.2	26	26	110	**100**	11	0.0	0.0	**1.1**	1.1
E. Br. Fivemile Creek (1991) **[S]**											
IBI	0.4	0.4	12	12	240	**240**	150	0.0	0.0	**1.0**	1.0
Sycamore Creek (1991) **[S]**											
IBI	1.4	0.7	38	38	0	**0**	0	0.7	1.1	**0.0**	0.0
ICI			22	22	44	**24.4**	0				
Trib. to Sycamore Creek (1991) **[S]**											
IBI	0.1	0.1	14	14	154	**220**	91	0.0	0.0	**0.7**	0.7
Polk Run (1991) **[S]**											
IBI	0.3	0.3	52	52	0	**0**	0	0.9	0.0	**0.0**	0.0
E. Br. Polk Run (1991) **[S]**											
IBI	1.4	1.4	34	34	22	**20**	0	0.0	0.0	**1.1**	0.0
Hall Run (1991) **[O]**											
IBI	0.5	0.5	44	44	0	**0**	0	1.1	0.0	**0.0**	0.0
Shayler Run (1991) **[S]**											
IBI[c]	7.3	0.6	32	50	14	**1.8**	0	7.2	0.0	**0.6**	0.0
ICI[c]			40	40	0	**0**	0				
IBI[d]			32	50	446	**57.2**	0	1.5	0.8	**5.5**	0.0
ICI[d]			40	40	22	**2.8**	0				
Trib. to Shayler Run (1991) **[O]**											
IBI	0.6	0.1	36	40	0	**0**	0	1.2	0.0	**0.0**	0.0

[a] includes extrapolated miles, usually 0.5 miles added to upstream and downstream per Ohio EPA (1992).
[b] excludes 2.8 miles in Winton Lake.
[c] based on Warmwater Habitat criteria.
[d] based on Exceptional Warmwater Habitat criteria.
Impact types: W - municipal wastewater; S - sewer line construction; CSO - combined sewer overflows; U - intensive urbanization; O - other.

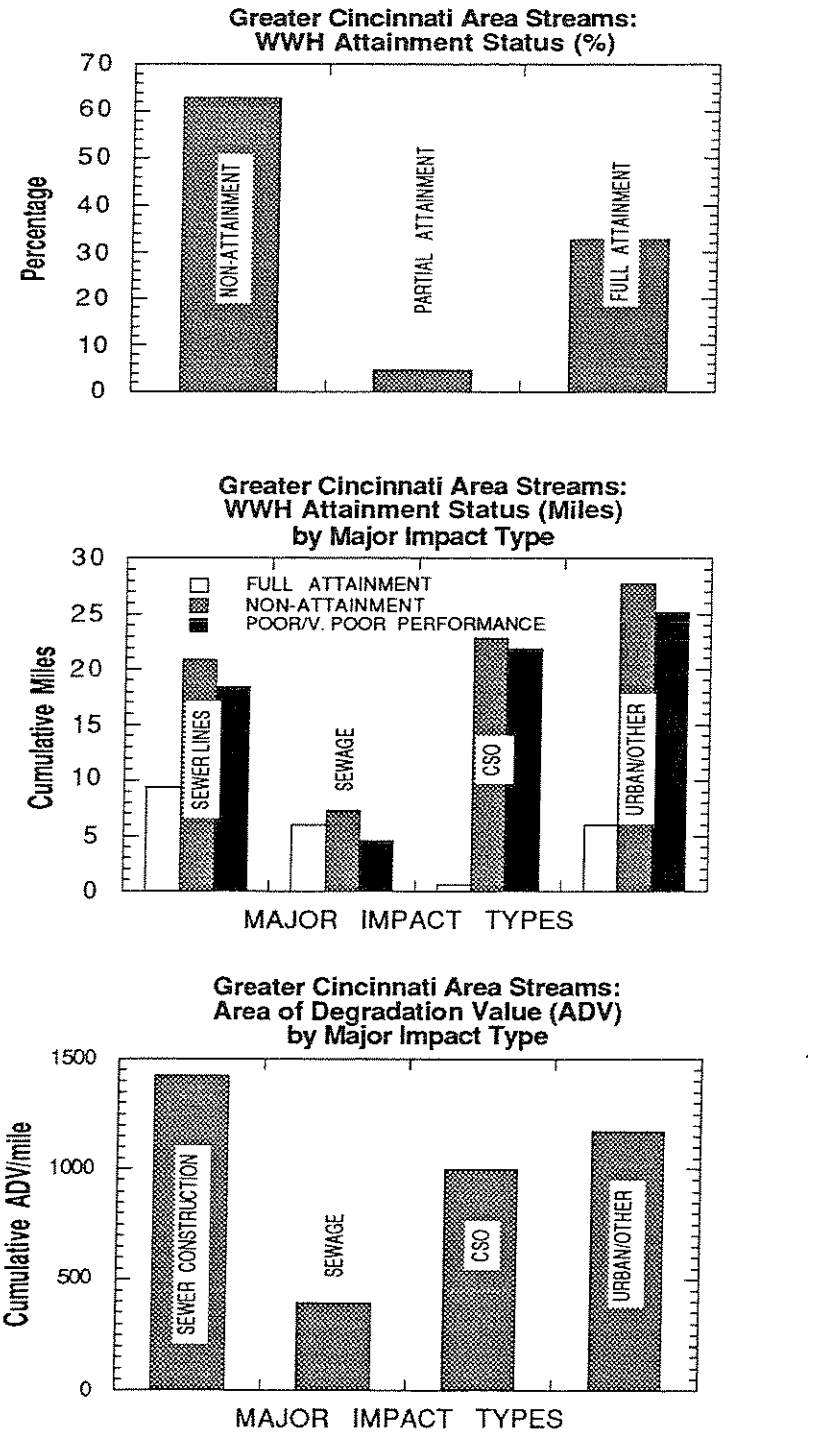

Figure 9. Percentage of stream miles monitored that are in FULL, PARTIAL, and NON attainment of the WWH use designation (UPPER), cumulative miles of FULL, PARTIAL, and NON-attainment by major impact type (MIDDLE), and cumulative ADV/mile by impact type (LOWER) in the greater Cincinnati area streams study area.

scores of 12-14 and poor and very poor macroinvertebrate community results in Rapid Run, Wulff Run, and the unnamed tributary to Sycamore Creek demonstrate the complete collapse of the aquatic community. In other streams impacted by sewer construction IBI and macroinvertebrate scores, while not attaining performance levels consistent with the WWH use designation, indicated a less severely impaired aquatic community which is reflected in the ADV scores (Table 10). The CSO and urban impact categories were also prominent in the study area. In the older, more intensively urbanized parts of Cincinnati, these impacts were often found together with past sewer construction impacts. Future development plans in the study area will need to focus on the general impact of suburban development on a watershed scale if we are to successfully protect streams that are relatively unimpacted by these activities at present. The results in the upper section of the W. Fk. Mill Creek may present a forward look to what could happen if urbanization takes place to the same degree in the Taylor Creek subbasin.

Rankin (1989) contains a figure that shows the frequency distribution of IBI scores at QHEI ranges greater than 60, 45-60, and less than 45 (Figure 10). The probability of a stream or subbasin with a predominance of QHEI values greater than 60 has a high likelihood of achieving the WWH or EWH IBI criterion. Streams with intermediate QHEI values (45-60) have an approximately equal probability of attaining or not attaining the WWH IBI criteria. QHEI values less than 45 virtually leave little realistic chance for the attainment of the IBI criteria for the WWH use designation. With regard to the greater Cincinnati area streams study area, the extensively degraded streams that have been severely impacted by interceptor sewer line construction have very low QHEI scores which means that there is no realistic prospect of attaining the WWH use. This consequence of the construction of interceptor sewers is further solidified by the permanence of the modifications and the certain need to further impact the streams by the eventual replacement of the original sewers. Even the streams that have intermediate QHEI values will likewise be prevented from attaining WWH due to the certainty of sewer replacement which will further degrade the marginal stream habitat.

The Taylor Creek subbasin streams consistently exceeded the QHEI score of 60 which indicates that the attainment of WWH is quite likely provided the presently limiting water quality impacts are abated via an alternative that does not include extensive instream construction. Furthermore, the Taylor Creek subbasin and adjacent Great Miami River tributaries represent the last remaining intact headwater stream habitats in the greater Cincinnati area. These watersheds are also somewhat unique among Interior Plateau streams having deeply dissected valleys, a topography characterized by high relief, coupled with the bedrock ledge and flat rubble substrates that are more typical of the Interior Plateau. The latter form the essential pool-run-riffle habitats needed to attain the WWH use designation in this ecoregion.

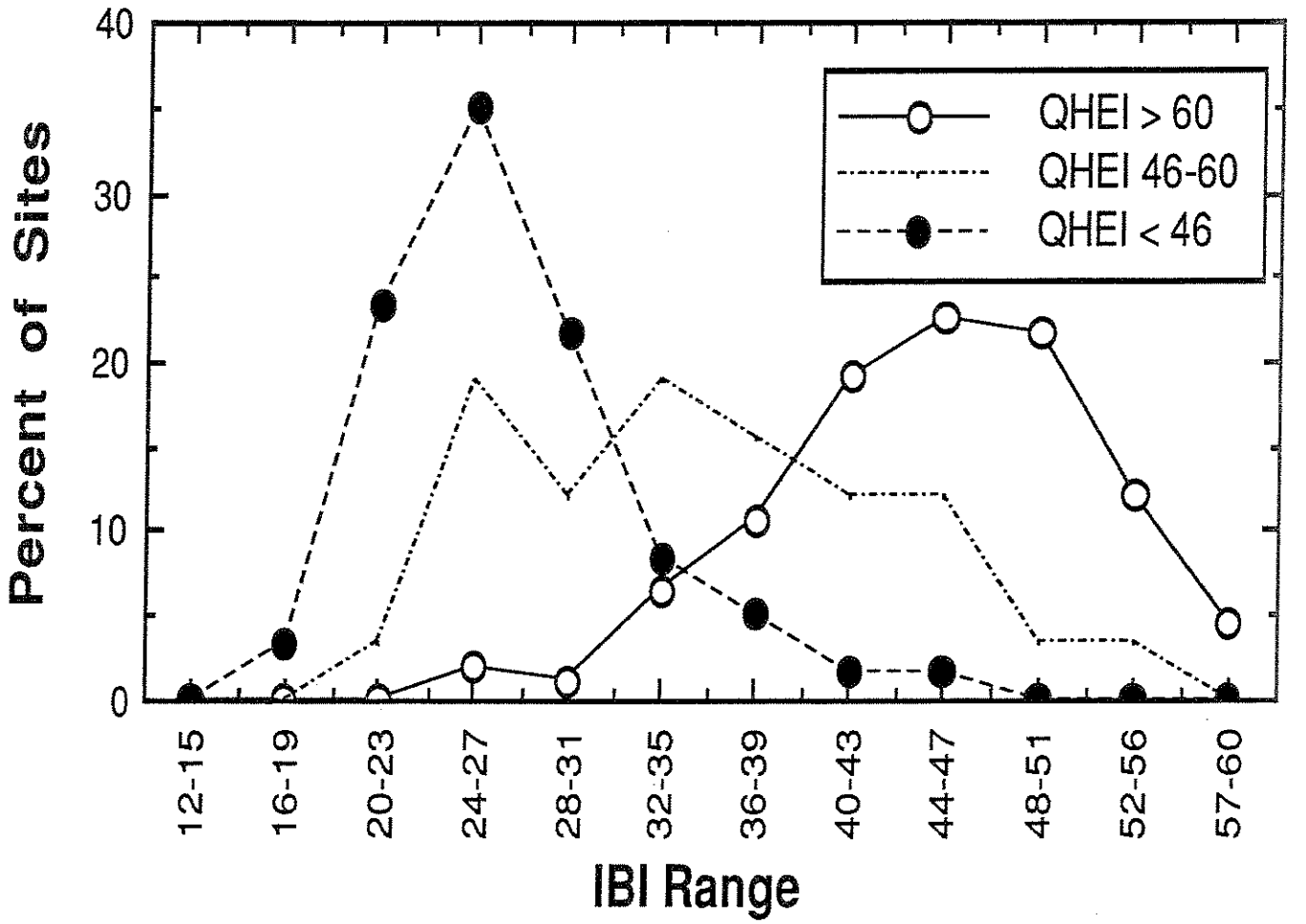

Figure 10. Frequency curves of Index of Biotic Integrity (IBI) scores at sites with QHEI scores <45, 46-60, and >60. This indicates the probability that a site has of scoring a particular IBI given the reach average QHEI (after Rankin 1989).

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Appendix Tables:

Appendix A: QHEI Matrices
Appendix B: ICI by Metric
Appendix C: IBI by Metric

Appendix Table 1A. QHEI matrix showing warmwater and modified habitat attributes for Taylor Creek and tributaries, and Bluerock Creek, 1988, 1990, and 1991.

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
(14-004) – TAYLOR CREEK																																
Year: 91																																
3.4	65.5	35.71	■		■		■		■	■	■	■	6	●	●				2	▲			▲	▲		▲					4	.43	1.00
1.6	66.5	18.87	■		■		■	■	■	■	■	■	7	●	●				2				▲								1	.38	.50
Year: 90																																
3.5	85.0	35.71	■		■	■	■	■	■	■	■	■	8						0												0	.11	.11
1.6	60.0	18.87	■				■				■		3	●					1	▲	▲		▲	▲			▲	▲	▲		7	.50	2.25
0.5	64.0	10.00	■	■			■	■			■	■	6		●				1	▲			▲	▲				▲			4	.29	.86
(14-006) – BLUEROCK CREEK																																
Year: 90																																
0.5	75.0	25.00	■	■	■	■	■	■	■	■	■	■	9	●					1	▲			▲	▲							3	.20	.50
(14-148) – BRIARLY CREEK																																
Year: 91																																
1.3	61.5	52.63	■		■		■	■			■	■	6	●					1	▲			▲	▲			▲				4	.29	.86
0.5	67.0	55.56			■	■	■	■			■	■	6						0	▲	▲						▲				3	.14	.57
Year: 90																																
1.8	64.0	58.82	■		■	■	■		■				6				●		1	▲				▲		▲	▲	▲			4	.29	.86
1.3	70.0	52.63	■		■	■	■	■	■	■	■	■	8						0												0	.11	.11
0.5	80.5	55.56	■	■	■	■	■	■	■	■	■	■	10						0												0	.09	.09
Year: 88																																
3.9	66.0	58.82	■	■		■	■			■	■	■	7			●			1	▲							▲				2	.25	.50
3.7	60.5	47.61	■	■		■	■			■		■	6			●	●		2	▲		▲					▲				3	.43	.86
3.6	65.0	47.61	■	■		■	■			■	■		6			●			1	▲							▲		▲		3	.29	.71
(14-149) – WESSELMAN CREEK																																
Year: 91																																
0.3	63.5	18.86	■	■		■		■			■	■	6		●	●			2	▲			▲	▲			▲	▲			5	.43	1.14
Year: 90																																
0.3	67.0	18.86	■				■	■	■	■	■		6		●	●			2		▲	▲	▲								3	.43	.86
(14-150) – STEELE CREEK																																
Year: 91																																
0.4	69.0	55.56	■		■		■	■			■	■	6		●				1	▲			▲					▲			3	.29	.71
Year: 90																																
0.2	70.0	55.56	■		■	■		■	■	■	■	■	8		●				1				▲	▲							2	.22	.44

Appendix Table 1A. QHEI matrix showing warmwater and modified habitat attributes for Taylor Creek and tributaries, and Bluerock Creek, 1988, 1990, and 1991.

Key QHEI Components

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
Year: 88																																		
1.0	70.0	58.82	■	■		■	■		■	■	■	■	8				●		1		▲			▲								2	.22	.44

River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Grad
14-004 TAYLOR CREEK								
Year: 91								
3.4	65.5	16.0	7.0	16.0	8.5	6.0	4.0	8
1.6	66.5	19.0	8.0	15.0	5.5	7.0	4.0	8
Year: 90								
3.5	85.0	23.0	17.0	18.0	9.0	9.0	4.0	8
1.6	60.0	18.0	12.0	10.0	4.0	6.0	2.0	8
0.5	64.0	13.0	11.0	12.0	3.0	11.0	4.0	10
14-006 BLUEROCK CREEK								
Year: 90								
0.5	75.0	13.0	15.0	14.5	3.5	12.0	7.0	10
14-148 BRIARLY CREEK								
Year: 91								
1.3	61.5	15.0	9.0	16.0	6.5	7.0	4.0	4
0.5	67.0	15.0	11.0	14.0	8.0	11.0	4.0	4
Year: 90								
1.8	64.0	17.0	10.0	17.0	7.5	5.0	3.5	4
1.3	70.0	17.5	11.0	18.0	8.5	7.0	4.0	4
0.5	80.5	23.0	16.0	19.0	7.5	9.0	5.0	4
Year: 88								
3.9	66.0	15.0	10.0	17.5	7.5	8.0	4.0	4
3.7	60.5	15.0	7.0	17.0	8.5	5.0	4.0	4
3.6	65.0	15.0	9.0	18.0	10.0	6.0	3.0	4
14-149 WESSELMAN CREEK								
Year: 91								
0.3	63.5	13.5	12.0	11.0	4.0	10.0	3.0	10
Year: 90								
0.3	67.0	9.5	14.0	13.0	4.0	12.0	4.5	10
14-150 STEELE CREEK								
Year: 91								
0.4	69.0	16.0	12.0	16.0	8.0	9.0	4.0	4
Year: 90								
0.2	70.0	20.0	9.0	16.0	8.0	7.0	6.0	4
Year: 88								
1.0	70.0	20.0	8.0	16.0	8.0	9.0	5.0	4

Appendix Table 2A. QHEI matrix showing warmwater and modified habitat attributes for Taylor Creek and headwater tributaries, 1988.

Key QHEI Components

WWH Attributes

MWH Attributes

High Influence *Moderate Influence*

River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Subs trates	Silt Free Substrates	Good/Excellent Development	Mod/High Sinuosity	Extensive/Mod erate Cover	Fast Current/ Eddies	Low/Normal Em beddedness	Max Depth >40 cm	Low/No Riffle Embeddedness	**Total WWH Attributes**	Channelized or No Recovery	Silt/Muck Sub strates	Low Sinuosity	Sparse/No Cov er	Max Depth < 4 0 cm (WD,HW)	**Total (High Influence) MWH Attributes**	Recovering Channel	Heavy/Mod. Si lt Cover	Sand Substrat es (BT)	Hardpan Origin	Fair/Poor Dev elopment	Low/No Sinuos ity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Curre nt	High/Mod. Embeddedness	Ext./Mod. Rif fle Embeddedness	No Riffle	**Total (Moderate Influence) MWH Attributes**	MWH (High)/WWH Attributes	MWH (Mod.)/WWH Attributes
(14-004) – TAYLOR CREEK																																	
Year: 88																																	
4.7	68.5	**.**	■	■	■	■	■	■	■	■	■	■	8				●		1		▲										1	.22	.33
4.6	69.5	**.**	■	■	■	■	■	■	■	■	■	■	9				●		1		▲										1	.20	.30
(14-159) – TRIB. TO TAYLOR CREEK (AUDUBON WOODS)																																	
Year: 88																																	
0.7	57.0	**.**	■			■	■		■				4				●	●	2		▲								▲	▲	3	.60	1.20
(14-161) – TRIB TO TRIB TO TAYLOR CREEK (W F ACRES)																																	
Year: 88																																	
0.2	58.0	**.**	■	■	■		■			■		■	6				●		1			▲							▲		2	.29	.5
0.1	62.0	**.**	■	■		■	■			■	■	■	7				●	●	2		▲	▲									2	.38	.63
(14-162) – TRIB. TO STEEL CREEK (BRUNSWICK VILL.)																																	
Year: 88																																	
1.6	53.0	90.91	■	■	■		■			■			5				●		1			▲							▲	▲	3	.33	.83
(14-163) – TRIB. TO STEEL CREEK (OAK HOLLOW EST.)																																	
Year: 88																																	
0.5	61.0	**.**	■	■	■	■	■			■		■	7				●	●	2			▲							▲		2	.38	.63
0.4	64.5	90.91	■	■		■	■	■		■			6				●	●	2										▲	▲	2	.43	.71
(14-164) – TRIB. TO STEEL CREEK (OAKVIEW ESTATES)																																	
Year: 88																																	
0.3	70.0	**.**	■	■		■	■	■		■	■	■	8				●		1		▲	▲							▲		3	.22	.56
0.2	58.0	**.**	■			■				■		■	4				●	●	2			▲							▲		2	.60	1.00

River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Grad
14-004 TAYLOR CREEK								
Year: 88								
4.7	68.5	14.0	11.0	17.0	8.5	9.0	5.0	4
4.6	69.5	14.0	13.0	17.0	8.5	9.0	4.0	4
14-159 TRIB. TO TAYLOR CREEK (AUDUBON								
Year: 88								
0.7	57.0	11.0	8.0	17.0	10.0	5.0	2.0	4
14-161 TRIB TO TRIB TO TAYLOR CREEK (W F								
Year: 88								
0.2	58.0	18.0	6.0	16.0	10.0	0.0	4.0	4
0.1	62.0	16.0	7.0	16.0	10.0	4.0	5.0	4
14-162 TRIB. TO STEEL CREEK (BRUNSWICK								
Year: 88								
1.6	53.0	16.0	8.0	15.0	7.5	0.0	2.5	4
14-163 TRIB. TO STEEL CREEK (OAK HOLLOW								
Year: 88								
0.5	61.0	19.0	8.0	15.5	6.0	4.0	4.5	4
0.4	64.5	17.0	12.0	16.0	9.0	5.0	1.5	4
14-164 TRIB. TO STEEL CREEK (OAKVIEW								
Year: 88								
0.3	70.0	17.0	15.0	16.0	8.0	6.0	4.0	4
0.2	58.0	18.0	5.0	15.0	8.0	4.0	4.0	4

Appendix Table 3A. QHEI matrix showing warmwater and modified habitat attributes for Muddy Creek, Rapid Run, Wulff Run, E. Br. Fivemile Creek, Clough Creek, and Dry Run, 1991.

Key
QHEI
Components

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
(10-536) – E. BR. FIVEMILE CREEK																																		
Year: 91																																		
0.4	45.0	90.91	■										1			●	●	●	3	▲	▲			▲	▲			▲	▲	▲		7	2.00	5.50
(11-002) – CLOUGH CREEK																																		
Year: 91																																		
3.2	36.0	**.**	■	■									2	●		●	●	●	4					▲	▲	▲		▲	▲		▲	6	1.67	3.67
(11-005) – DRY RUN																																		
Year: 91																																		
4.2	50.5	50.00	■			■	■						3			●	●	●	3	▲	▲			▲	▲			▲	▲	▲		7	1.00	2.75
(23-007) – MUDDY CREEK																																		
Year: 91																																		
5.3	48.0	50.00	■	■			■				■		4	●		●			2					▲	▲			▲	▲		▲	5	.60	1.60
2.7	44.0	83.33	■	■			■						3	●		●	●	●	4					▲	▲			▲	▲		▲	5	1.25	2.50
(23-008) – RAPID RUN																																		
Year: 91																																		
1.2	33.5	**.**	■	■									2	●		●	●	●	4					▲	▲	▲		▲	▲		▲	6	1.67	3.67
1.1	36.5	**.**	■	■									2	●		●	●	●	4					▲	▲	▲		▲	▲		▲	6	1.67	3.67
(23-012) – WULFF RUN																																		
Year: 91																																		
0.6	30.5	90.91	■										1	●		●	●	●	4		▲			▲	▲	▲		▲	▲		▲	7	2.50	6.00

River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Grad
10-536 E. BR. FIVEMILE CREEK								
Year: 91								
0.4	45.0	14.5	6.0	10.0	7.5	4.0	-1.0	4
11-002 CLOUGH CREEK								
Year: 91								
3.2	36.0	17.0	2.0	4.0	6.0	3.0	0.0	4
11-005 DRY RUN								
Year: 91								
4.2	50.5	17.5	10.0	10.0	6.5	1.5	1.0	4
23-007 MUDDY CREEK								
Year: 91								
5.3	48.0	14.0	13.0	7.5	5.0	4.5	0.0	4
2.7	44.0	17.0	8.0	7.0	5.0	3.0	0.0	4
23-008 RAPID RUN								
Year: 91								
1.2	33.5	15.5	1.0	4.0	6.0	3.0	0.0	4
1.1	36.5	12.0	5.0	6.0	6.5	3.0	0.0	4
23-012 WULFF RUN								
Year: 91								
0.6	30.5	15.5	2.0	4.0	4.0	1.0	0.0	4

Appendix Table 4A. QHEI matrix showing warmwater and modified habitat attributes for Mill Creek and selected tributaries, 1988 and 1991.

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 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 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
(23-001) – MILL CREEK																																	
Year: 88																																	
17.7	59.5	6.67	■	■	■	■	■			■			6						0					▲	▲	▲	▲				4	.14	.71
14.8	65.0	11.76	■				■	■		■			4	●		●			2				▲	▲			▲	▲			4	.60	1.40
13.3	63.5	6.25	■	■				■	■	■	■		6	●		●			2				▲	▲							2	.43	.71
12.2	71.0	9.26	■	■				■	■		■	■	6						0				▲	▲			▲				3	.14	.57
(23-002) – WEST FORK																																	
Year: 91																																	
2.7	61.5	52.63	■	■		■	■	■			■		6		●				1	▲	▲		▲	▲			▲	▲		▲	7	.29	1.29
2.5	56.5	52.63	■	■		■	■	■			■		6		●	●			2		▲		▲	▲			▲	▲		▲	6	.43	1.2°
(23-004) – W. FK. MILL CREEK																																	
Year: 91																																	
13.9	46.5	18.52		■							■		2		●	●			2	▲	▲		▲	▲			▲	▲		▲	7	1.00	3.33
10.2	55.0	14.49					■				■		2		●	●			2	▲	▲		▲	▲			▲	▲	▲		7	1.00	3.33
Year: 88																																	
13.9	48.0	12.20		■									1		●	●	●		3	▲			▲	▲	▲		▲	▲	▲	▲	8	2.00	6.00
12.6	60.0	25.00					■				■		2		●				1	▲			▲	▲			▲	▲	▲		6	.67	2.67
10.2	65.5	14.49							■	■	■		3		●	●			2	▲			▲	▲			▲				4	.75	1.75
6.4	59.0	52.63	■	■	■			■		■		■	6						0				▲	▲			▲				3	.14	.57
4.1	69.0	14.29	■	■	■			■		■	■		6						0				▲	▲			▲		▲		4	.14	.71
2.6	64.5	7.25	■	■		■	■			■	■	■	7			●			1				▲	▲			▲				3	.25	.63
1.1	69.5	10.31	■	■		■	■	■			■		6			●			1				▲	▲			▲	▲	▲		5	.29	1.00
(23-005) – SHARON CREEK																																	
Year: 91																																	
4.3	77.5	31.25	■	■		■	■	■		■	■		8						0		▲						▲	▲	▲		4	.11	.56
Year: 88																																	
4.3	74.0	32.26	■	■	■	■	■	■		■		■	8				●		1					▲							1	.22	.33
0.2	52.5	13.89	■							■	■		3		●	●			2	▲			▲	▲			▲		▲	▲	6	.75	2.25
(23-006) – E. FK. MILL CREEK																																	
Year: 88																																	
3.3	45.5	38.46	■	■				■	■				4	●		●	●		3		▲						▲	▲	▲	▲	5	.80	1.8
(23-013) – TRIB. TO WEST FORK																																	
Year: 91																																	

Appendix Table 4A. QHEI matrix showing warmwater and modified habitat attributes for Mill Creek and selected tributaries, 1988 and 1991.

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
0.1	46.5	83.33	■				■		■	■			4	●		●	●		3	▲			▲	▲	▲		▲	▲		▲	7	.80	2.20

River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Grad
23-001 MILL CREEK								
Year: 88								
17.7	59.5	12.0	14.0	13.5	3.0	9.0	0.0	8
14.8	65.0	15.0	11.0	6.5	6.5	11.0	5.0	10
13.3	63.5	18.0	8.0	8.0	6.5	8.0	7.0	8
12.2	71.0	14.5	12.0	13.0	4.5	11.0	6.0	10
23-002 WEST FORK								
Year: 91								
2.7	61.5	18.5	14.0	11.5	7.5	6.0	0.0	4
2.5	56.5	16.5	9.0	12.0	8.0	7.0	0.0	4
23-004 W. FK. MILL CREEK								
Year: 91								
13.9	46.5	13.5	6.0	6.0	6.0	5.0	0.0	10
10.2	55.0	12.5	10.0	10.0	6.0	5.0	1.5	10
Year: 88								
13.9	48.0	16.0	5.0	9.5	6.5	3.0	0.0	8
12.6	60.0	12.5	12.0	10.0	6.5	8.0	1.0	10
10.2	65.5	19.0	7.0	10.5	8.0	6.0	5.0	10
6.4	59.0	16.0	12.0	13.0	9.0	0.0	5.0	4
4.1	69.0	21.5	11.0	14.0	5.0	7.0	2.0	10
2.6	64.5	16.0	8.0	14.5	4.5	8.0	3.5	10
1.1	69.5	14.0	12.0	14.5	6.0	10.0	3.0	10
23-005 SHARON CREEK								
Year: 91								
4.3	77.5	17.0	16.0	17.0	7.0	10.0	2.5	8
Year: 88								
4.3	74.0	16.0	15.0	19.0	7.0	5.0	4.0	8
0.2	52.5	16.0	8.0	9.0	3.5	6.0	0.0	10
23-006 E. FK. MILL CREEK								
Year: 88								
3.3	45.5	7.0	6.0	15.5	6.0	3.0	0.0	8
23-013 TRIB. TO WEST FORK								
Year: 91								
0.1	46.5	17.5	7.0	8.0	6.0	4.0	0.0	4

Appendix Table 5A. QHEI matrix showing warmwater and modified habitat attributes for Sycamore Creek and tributary, Polk Run, and E. Br. Polk Run, 1991.

Key QHEI Components			WWH Attributes										MWH Attributes																					
													High Influence										*Moderate Influence*												
River Mile	QHEI	Gradient (ft/mile)	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**	Channelized or No Recovery	Silt/Muck Substrates	Low Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD,HW)	**Total (High Influence) MWH Attributes**	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
(11-007) – SYCAMORE CREEK																																		
Year: 91																																		
1.4	51.5	76.92	■	■			■				■		4	●		●			2				▲	▲		▲	▲			▲	5	.60	1.60
0.7	53.5	37.04					■				■		3		●	●	●		3	▲	▲		▲	▲		▲	▲	▲			7	1.00	2.75
(11-009) – POLK RUN																																		
Year: 91																																		
0.3	80.0	43.48	■	■		■	■	■	■	■	■	■	9						0	▲											1	.10	.20
(11-048) – E. BR. POLK RUN																																		
Year: 91																																		
1.5	71.5	50.00	■	■		■	■	■		■	■	■	8						0								▲				1	.11	.22
(11-049) – TRIB. TO SYCAMORE CREEK																																		
Year: 91																																		
1.9	29.5	52.63	■										1	●		●	●	●	4	▲			▲	▲	▲		▲	▲		▲	7	2.50	6.00
1.0	31.0	80.00	■	■									2	●		●	●	●	4				▲	▲	▲		▲	▲		▲	6	1.67	3.67
0.1	43.5	66.67					■				■		2	●	●	●	●		4	▲			▲	▲	▲		▲	▲		▲	7	1.67	4.00

River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Grad
11-007 SYCAMORE CREEK								
Year: 91								
1.4	51.5	15.5	11.0	8.0	8.0	5.0	0.0	4
0.7	53.5	5.0	13.0	10.0	6.5	10.0	3.0	6
11-009 POLK RUN								
Year: 91								
0.3	80.0	19.5	17.0	17.0	7.5	11.0	4.0	4
11-048 E. BR. POLK RUN								
Year: 91								
1.5	71.5	21.0	13.0	17.0	8.0	6.0	3.5	4
11-049 TRIB. TO SYCAMORE CREEK								
Year: 91								
1.9	29.5	12.5	1.0	4.0	5.0	3.0	0.0	4
1.0	31.0	14.0	1.0	4.0	5.0	3.0	0.0	4
0.1	43.5	10.0	8.0	7.0	5.5	9.0	0.0	4

Appendix Table 6A. QHEI matrix showing warmwater and modified habitat attributes for Shayler Run and tributary, and Hall Run, 1991.

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
(11-101) – HALL RUN																																	
Year: 91																																	
0.5	48.5	58.82	■	■			■						3	●		●		●	3				▲	▲			▲	▲		▲	5	1.00	2.25
(11-105) – SHAYLER RUN																																	
Year: 91																																	
7.3	69.5	17.39	■	■		■	■	■			■		6						0		▲						▲	▲		▲	4	.14	.71
5.8	71.0	17.54	■	■		■	■	■		■	■		8			●			1		▲			▲			▲	▲	▲		5	.22	.78
5.2	61.0	17.54	■	■			■						4			●	●	●	3	▲			▲	▲			▲	▲	▲		6	.80	2.00
4.2	53.0	66.67					■			■	■		3	●		●			2	▲			▲	▲			▲	▲			5	.75	2.00
3.3	38.0	86.96	■	■									2	●		●	●	●	4				▲	▲	▲		▲	▲	▲		6	1.67	3.67
3.0	46.5	76.92		■						■			2	●		●	●		3				▲	▲			▲	▲		▲	5	1.33	3.00
2.3	50.0	52.63	■	■			■			■			4	●		●	●		3	▲			▲	▲	▲		▲	▲	▲		7	.80	2.20
0.6	73.0	12.82	■	■		■	■	■			■		6						0		▲						▲	▲	▲		4	.14	.71
(11-161) – TRIB. TO SHAYLER RUN																																	
Year: 91																																	
0.6	79.5	17.85	■			■	■	■		■	■	■	7			●			1		▲			▲			▲	▲			4	.25	.75
0.1	67.0	36.36	■	■		■	■	■		■	■	■	8			●	●		2					▲				▲			2	.33	.56

River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Grad
11-101 HALL RUN								
Year: 91								
0.5	48.5	19.0	11.0	6.5	5.0	3.0	0.0	4
11-105 SHAYLER RUN								
Year: 91								
7.3	69.5	14.0	14.0	16.0	7.5	8.0	0.0	10
5.8	71.0	18.0	13.0	15.5	7.0	5.0	2.5	10
5.2	61.0	16.5	11.0	10.0	7.0	4.5	2.0	10
4.2	53.0	16.0	10.0	8.5	7.0	4.0	3.5	4
3.3	38.0	12.0	5.0	6.0	6.0	4.0	1.0	4
3.0	46.5	17.0	6.0	7.5	8.0	4.0	0.0	4
2.3	50.0	13.5	7.0	8.0	7.0	8.0	2.5	4
0.6	73.0	14.0	17.0	16.0	6.0	9.0	1.0	10
11-161 TRIB. TO SHAYLER RUN								
Year: 91								
0.6	79.5	17.0	14.0	16.5	7.0	10.0	5.0	10
0.1	67.0	16.0	8.0	16.5	8.5	6.0	4.0	8

Appendix Table 1B. ICI table for Taylor Creek and tributaries, and Bluerock Creek, 1990 and 1991.

River Mile	Drainage Area (sq mi)	Number of: Total Taxa	Mayfly Taxa	Caddisfly Taxa	Dipteran Taxa	Percent: Mayflies	Caddis-flies	Tany-tarsini	Other Dipt/NI	Tolerant Taxa	Qual. EPT	Eco-region	ICI
TAYLOR CREEK — 14-004													
Year: 91													
3.5	5.0	28(4)	4(2)	2(4)	17(4)	10.9(2)	0.7(4)	51.9(6)	36.2(4)	7.2(6)	5(2)	2	38
1.6	14.2	32(4)	4(2)	2(4)	18(4)	21.8(4)	4.6(6)	10.7(4)	62.7(2)	8.8(4)	8(4)	2	38
Year: 90													
1.8B	14.2	29(4)	4(2)	3(6)	14(4)	56.7(6)	2.8(4)	2.4(2)	37.6(4)	2.9(6)	8(4)	2	42
.4B	27.2	31(4)	5(4)	2(4)	17(4)	14.5(4)	1.1(2)	2.8(2)	81.4(0)	19.9(2)	8(4)	2	30
BLUEROCK CREEK — 14-006													
Year: 90													
.5B	6.8	35(4)	5(4)	1(4)	21(6)	2.5(2)	2.4(6)	32.1(6)	61.9(2)	10.3(4)	8(4)	2	42
BRIARLY CREEK — 14-148													
Year: 91													
1.3	6.6	17(2)	3(2)	1(4)	7(2)	15.5(4)	1.5(6)	4.1(2)	78.8(0)	1.3(6)	6(2)	2	30
.1	7.0	22(2)	3(2)	2(4)	12(2)	42.3(6)	4.0(6)	1.4(2)	52.1(2)	0.5(6)	6(2)	2	34
Year: 90													
.1B	7.0	25(4)	5(4)	3(6)	11(2)	22.4(4)	8.4(6)	35.3(6)	33.3(4)	0.8(6)	8(4)	2	46
WESSELMAN CREEK — 14-149													
Year: 91													
.3	7.7	28(4)	5(4)	0(0)	15(4)	40.5(6)	0.0(0)	33.3(6)	24.9(6)	2.8(6)	6(2)	2	38
Year: 90													
.3B	7.7	40(6)	5(4)	2(4)	23(6)	15.6(4)	4.0(6)	29.5(6)	46.1(2)	11.3(4)	9(4)	2	46
STEELE CREEK — 14-150													
Year: 91													
.2	4.6	21(2)	3(2)	2(4)	8(2)	10.0(2)	3.9(6)	0.0(0)	84.8(0)	2.8(6)	7(4)	2	28

Appendix Table 2B. ICI table for Mill Creek basin tributaries, 1991.

River Mile	Drainage Area (sq mi)	Number of: Total Taxa	Mayfly Taxa	Caddisfly Taxa	Dipteran Taxa	Percent: Mayflies	Caddis-flies	Tany-tarsini	Other Dipt/NI	Tolerant Taxa	Qual. EPT	Eco-region	ICI
W. FK. MILL CREEK — 23-004													
Year: 91													
10.0	10.0	13(2)	0(0)	0(0)	9(2)	0.0(0)	0.0(0)	0.0(0)	99.9(0)	73.0(0)	3(0)	2	4
SHARON CREEK — 23-005													
Year: 91													
4.3	1.7	21(2)	2(0)	0(0)	14(4)	8.5(2)	0.0(0)	8.8(2)	82.4(0)	43.3(0)	6(2)	2	12
E. FK. MILL CREEK — 23-006													
Year: 91													
3.3	5.4	23(2)	4(2)	0(0)	14(4)	25.2(6)	0.0(0)	4.9(2)	69.9(0)	27.3(0)	8(4)	2	20

Appendix Table 3B. ICI table for Sycamore Creek, Polk Run, and Shayler Run, 1991.

River Mile	Drainage Area (sq mi)	Number of: Total Taxa	Mayfly Taxa	Caddisfly Taxa	Dipteran Taxa	Percent: Mayflies	Caddis-flies	Tany-tarsini	Other Dipt/NI	Tolerant Taxa	Qual. EPT	Eco-region	ICI
SYCAMORE CREEK — 11-007													
Year: 91													
1.0	14.7	25(4)	3(2)	1(2)	17(4)	0.5(2)	0.5(2)	18.6(4)	80.4(0)	34.5(0)	7(2)	2	22
POLK RUN — 11-009													
Year: 91													
.3	10.8	36(4)	6(4)	2(4)	20(6)	41.4(6)	0.3(2)	23.8(6)	33.8(4)	10.3(4)	11(6)	2	46
SHAYLER RUN — 11-105													
Year: 91													
5.8	4.0	29(4)	6(4)	0(0)	15(4)	43.7(6)	0.0(0)	0.0(0)	56.0(2)	15.1(4)	7(4)	2	28
2.1	11.7	31(4)	5(4)	0(0)	20(6)	72.4(6)	0.0(0)	1.0(2)	26.3(6)	0.5(6)	13(6)	2	40

Appendix Table 1C. IBI table for Taylor Cr. and tributaries 1988, 1990, and 1991.

River Mile	Type	Date	Drainage area (sq mi)	Number of: Total species	Minnow species	Headwater species	Sensitive species	Darter & Sculpin species	Simple Lithophils	Percent of Individuals: Tolerant fishes	Omni-vores	Pioneering fishes	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)	IBI
Taylor Creek - (14-004)																
Year: 91																
3.4	E	07-25-91	5.0	14(5)	8(5)	1(1)	3(3)	1(1)	4(3)	18(5)	10(5)	16(5)	10(1)	0.0(5)	2548(5)	**44**
1.6	E	07-02-91	14.3	17(5)	6(3)	1(1)	6(5)	2(1)	6(3)	6(5)	6(5)	5(5)	23(1)	0.0(5)	2500(5)	**44**
Year: 90																
3.5	D	06-26-90	5.0	12(5)	6(5)	0(1)	3(3)	0(1)	4(3)	11(5)	2(5)	11(5)	7(1)	0.0(5)	1941(5)	**44**
1.6	D	06-26-90	14.3	17(5)	8(5)	1(1)	5(3)	2(1)	6(3)	30(5)	29(3)	29(5)	64(5)	0.0(5)	597(3)	**44**
Briarly Creek (Trib. - (14-148)																
Year: 91																
1.3	E	07-02-91	6.6	6(1)	3(3)	0(1)	0(1)	0(1)	1(1)	23(5)	8(5)	19(5)	1(1)	0.0(5)	1868(5)	**34**
0.5	E	07-03-91	6.9	12(3)	4(3)	1(1)	2(1)	1(1)	2(1)	20(5)	8(5)	15(5)	7(1)	0.0(5)	1067(5)	**36**
Year: 90																
1.8	E	06-29-90	2.1	3(1)	2(1)	0(1)	0(1)	0(1)	0(1)	79(1)	0(5)	79(1)	1(1)	0.0(5)	128(3)	**22**
1.3	E	06-29-90	6.6	5(1)	3(3)	0(1)	0(1)	0(1)	1(1)	19(5)	5(5)	17(5)	0(1)	0.0(5)	989(5)	**34**
0.5	E	06-26-90	6.9	11(3)	4(3)	0(1)	2(1)	0(1)	3(3)	15(5)	3(5)	12(5)	19(1)	0.0(5)	187(3)	**36**
Wesselman Creek - (14-149)																
Year: 91																
0.3	D	07-25-91	4.4	26(5)	9(5)	1(1)	6(5)	3(5)	6(5)	32(5)	29(1)	30(5)	58(5)	0.0(5)	744(5)	**52**
Wesselman Creek - (14-149)																
Year: 90																
0.3	D	06-27-90	7.7	27(5)	9(5)	1(1)	6(5)	4(5)	6(5)	46(3)	42(1)	44(3)	47(5)	0.7(3)	504(3)	**44**
Year: 91																
0.4	E	07-03-91	7.6	4(1)	3(3)	0(1)	0(1)	0(1)	1(1)	49(3)	7(5)	45(3)	0(1)	0.0(5)	980(5)	**30**

Appendix Table 1C. IBI table for Taylor Creek and headwater tributaries, 1988.

River Mile	Type	Date	Drainage area (sq mi)	Number of: Total species	Minnow species	Headwater species	Sensitive species	Darter & Sculpin species	Simple Lithophils	Percent of Individuals: Tolerant fishes	Omni-vores	Pioneering fishes	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)	IBI
Taylor Creek - (14-004)																
Year: 88																
4.7	E	09/21/88	3.9	4(1)	3(3)	0(1)	0(1)	0(1)	2(1)	55(3)	5(5)	50(3)	0(1)	0.0(5)	1614(5)	**30**
4.6	E	09/21/88	3.9	4(1)	3(3)	0(1)	0(1)	0(1)	1(1)	44(3)	9(5)	35(3)	0(1)	0.2(3)	1944(5)	**28**
Steel Creek - (14-150)																
Year: 88																
1.0	E	09-20-88	4.2	4(1)	3(3)	0(1)	0(1)	0(1)	1(1)	67(1)	28(1)	55(1)	0(1)	0.3(3)	342(3)	**18**
Trib. to Steel Creek - (14-164)																
Year: 88																
0.3	E	09-20-88	1.0	1(1)	1(1)	0(1)	0(1)	0(1)	0(1)	100(1)	0(5)	100(1)	0(1)	0.0(5)	0(1)	**20**

Appendix Table 1C. IBI table for Taylor Cr. and tributaries 1988, 1990, and 1991.

River Mile	TypeDate	Drainage area (sq mi)	Number of: Total species	Sunfish species	Sucker species	Intolerant species	Darter species	Percent of Individuals: Simple Lithophils	Tolerant fishes	Omni-vores	Top carnivores	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)		Modifie IBI Iwb
TAYLOR CREEK - (14004)																
Year: 90																
0.5	D 07-06-90	27	12(3)	3(3)	0(1)	0(1)	0(1)	0(1)	9(5)	25(3)	14(5)	47(3)	1.6(1)	87(1)	*	28 7.4

na - Qualitative data, Modified Iwb not applicable.

Appendix Table 2C. IBI table for Bluerock Creek, 1990.

River Mile	Type	Date	Drainage area (sq mi)	Number of: Total species	Minnow species	Headwater species	Sensitive species	Darter & Sculpin species	Simple Lithophils	Percent of Individuals: Tolerant fishes	Omni-vores	Pioneering fishes	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)	IBI
BLUEROCK CREEK - (14-006)																
Year: 90																
0.5	D	06-27-90	6.8	24(5)	9(5)	2(3)	5(5)	2(3)	8(5)	25(5)	22(3)	13(5)	54(5)	1.2(3)	544(3)	50

Appendix Table 3C. IBI table for Muddy Creek, Rapid Run, and Wulff Run, 1991.

River Mile	Type	Date	Drainage area (sq mi)	Number of: Total species	Minnow species	Headwater species	Sensitive species	Darter & Sculpin species	Simple Lithophils	Percent of Individuals: Tolerant fishes	Omni-vores	Pioneering fishes	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)	IBI
Muddy Creek - (23-007)																
Year: 91																
5.3	E	08-13-91	6.7	2(1)	1(1)	0(1)	0(1)	0(1)	0(1)	73(1)	73(1)	27(1)	0(1)	0.0(1)	6(1)**	12
2.7	E	08-13-91	12.3	12(3)	7(5)	1(1)	0(1)	0(1)	4(3)	50(3)	16(5)	20(5)	5(1)	0.0(5)	384(3)	36
Rapid Run - (23-008)																
Year: 91																
1.1	E	09-10-91	5.8	2(1)	1(1)	0(1)	0(1)	0(1)	0(1)	42(1)	0(1)	42(1)	0(1)	0.0(1)	14(1)**	12
Wulff Run - (23-012)																
Year: 91																
0.6	E	08-13-91	2.2	1(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0.0(1)	2(1)**	12

Appendix Table 4C. IBI table for Mill Creek and selected tributaries, 1988 and 1991.

River Mile	Type	Date	Drainage area (sq mi)	Number of: Total species	Minnow species	Headwater species	Sensitive species	Darter & Sculpin species	Simple Lithophils	Percent of Individuals: Tolerant fishes	Omni-vores	Pioneering fishes	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)	IBI
West Fork Mill Creek - (23-002)																
Year: 91																
2.7	F	09-06-91	3.1	2(1)	1(1)	0(1)	0(1)	0(1)	0(1)	99(1)	0(1)	100(1)	0(1)	0.0(1)	2(1)	12
2.5	F	09-06-91	4.8	1(1)	1(1)	0(1)	0(1)	0(1)	0(1)	100(1)	0(1)	100(1)	0(1)	0.0(1)	0(1)	12
W. FK. MILL CREEK - (23-004)																
Year: 88																
13.9	D	08-08-88	3.5	4(1)	2(1)	0(1)	0(1)	0(1)	0(1)	92(1)	16(3)	92(1)	15(1)	0.3(3)	67(1)	16
12.6	D	08-08-88	5.3	4(1)	2(1)	0(1)	0(1)	0(1)	0(1)	95(1)	27(1)	95(1)	36(3)	0.9(3)	36(1)	16
10.2	D	08-08-88	10.0	3(1)	2(1)	0(1)	0(1)	0(1)	0(1)	99(1)	63(1)	99(1)	19(1)	0.5(3)	5(1)	14
Sharon Creek - (23-005)																
Year: 91																
4.3	E	10-23-91	1.7	9(5)	4(3)	2(3)	0(1)	1(3)	2(3)	84(1)	25(1)	70(1)	22(3)	0.0(5)	340(5)	34
Year: 88																
4.3	E	08-11-88	1.7.	10(5)	4(3)	2(3)	0(1)	2(5)	3(5)	62(1)	11(3)	52(3)	12(1)	0.5(3)	505(5)	38
0.2	E	08-10-88	10.5	6(1)	3(1)	1(1)	0(1)	0(1)	2(1)	98(1)	21(3)	52(3)	22(3)	1.7(1)	2(1)*	18
E. FK. MILL CREEK - (23-006)																
Year: 88																
3.3	D	08-11-88	5.4	13(5)	7(5)	1(1)	0(1)	2(3)	4(3)	28(5)	5(5)	15(5)	11(1)	0.0(5)	2160(5)	44
Trib to West Fk - (23-013)																
Year: 91																
0.1	F	09-06-91	1.7	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0.0(1)	0(1)**	12

Appendix Table 4C. IBI table for Mill Creek and selected tributaries, 1988 and 1991.

River Mile	Type	Date	Drainage area (sq mi)	Number of: Total species	Sunfish species	Sucker species	Intolerant species	Darter species	Percent of Individuals: Simple Lithophils	Tolerant fishes	Omni-vores	Top carnivores	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)		Modified IBI	Iwb
MILL CREEK - (23001)																		
Year: 88																		
17.7	D	08-11-88	43	10(3)	1(1)	1(1)	0(1)	1(1)	13(1)	61(1)	14(5)	0(1)	10(1)	1.7(1)	330(3)		20	6.1
14.8	D	08-10-88	64	7(1)	1(1)	1(1)	0(1)	0(1)	0(1)	99(1)	2(5)	0(1)	77(5)	4.9(1)	3(1)		20	2.5
13.3	D	08-10-88	72	10(1)	1(1)	1(1)	0(1)	1(1)	5(1)	74(1)	7(5)	0(1)	65(5)	1.8(1)	219(3)		22	5.6
12.2	D	08-10-88	73	9(1)	1(1)	1(1)	0(1)	0(1)	3(1)	95(1)	7(5)	0(1)	88(5)	14.6(1)	18(1)		20	3.7
W. FK. MILL CREEK - (23004)																		
Year: 88																		
6.4	D	08-09-88	30	5(1)	2(3)	1(1)	0(1)	0(1)	4(1)	43(3)	13(5)	0(1)	6(1)	0.0(5)	88(1)	*	24	4.8
4.1	D	08-09-88	33	11(3)	4(5)	1(1)	0(1)	0(1)	1(1)	94(1)	53(1)	0(1)	44(3)	0.7(3)	60(1)		22	5.2
2.6	D	08-09-88	35	12(3)	2(3)	1(1)	0(1)	0(1)	13(1)	76(1)	34(3)	0(1)	5(1)	0.0(5)	360(3)		24	6.2
1.1	D	08-10-88	35	10(3)	2(3)	1(1)	0(1)	0(1)	7(1)	68(1)	40(1)	0(1)	19(1)	0.0(5)	470(3)		22	5.5

na - Qualitative data, Modified Iwb not applicable.

Appendix Table 5C. IBI table for E. Br. Fivemile Cr., Clough Cr., and Dry Run, 1991.

River Mile	Type	Date	Drainage area (sq mi)	Number of: Total species	Minnow species	Headwater species	Sensitive species	Darter & Sculpin species	Simple Lithophils	Percent of Individuals: Tolerant fishes	Omni-vores	Pioneering fishes	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)	IBI
East Br Five Mile Cr - (10-536)																
Year: 91																
0.4	F	09-10-91	1.2	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0(1)	0.0(1)	0(1)**	12
Clough Creek - (11-002)																
Year: 91																
3.2	F	09-11-91	2.1	3(1)	3(3)	1(1)	0(1)	0(1)	1(1)	94(1)	0(5)	17(5)	0(1)	0.0(5)	42(1)	26
Dry Run - (11-005)																
Year: 91																
4.2	F	09-11-91	2.9	3(1)	3(3)	1(1)	0(1)	0(1)	1(1)	77(1)	0(5)	43(3)	0(1)	0.0(5)	200(3)	26

Appendix Table 6C. IBI table for Sycamore Creek and tributary, Polk Run, and E. Br. Polk Run, 1991.

River Mile	Type	Date	Drainage area (sq mi)	Number of: Total species	Minnow species	Headwater species	Sensitive species	Darter & Sculpin species	Simple Lithophils	Percent of Individuals: Tolerant fishes	Omni-vores	Pioneering fishes	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)	IBI
Sycamore Creek - (11-007)																
Year: 91																
1.4	F	09-06-91	9.4	9(3)	7(5)	1(1)	1(1)	0(1)	4(3)	35(3)	2(5)	23(5)	1(1)	0.0(5)	920(5)	38
0.7	E	09-06-91	15.1	16(5)	6(3)	1(1)	2(1)	3(3)	6(3)	48(3)	6(5)	33(3)	4(1)	0.0(5)	1131(5)	38
Polk Run - (11-009)																
Year: 91																
0.3	E	09-05-91	10.8	29(5)	13(5)	3(3)	9(5)	3(3)	9(5)	14(5)	10(5)	12(5)	14(1)	0.0(5)	3848(5)	52
E. Br. Polk Run - (11-048)																
Year: 91																
1.4	E	09-26-91	2.4	8(3)	5(5)	2(3)	0(1)	2(3)	2(3)	95(1)	9(5)	51(3)	4(1)	0.0(5)	58(1)	34
Trib To Sycamore Cr. - (11-049)																
Year: 91																
0.1	E	09-05-91	4.9	4(1)	3(3)	0(1)	0(1)	0(1)	0(1)	50(1)	17(1)	50(1)	0(1)	0.0(1)	6(1)**	14

Appendix Table 7C. IBI table for Shayler Run and tributary, and Hall Run, 1991.

River Mile	Type	Date	Drainage area (sq mi)	Number of: Total species	Minnow species	Headwater species	Sensitive species	Darter & Sculpin species	Simple Lithophils	Percent of Individuals: Tolerant fishes	Omni-vores	Pioneering fishes	Insect-ivores	DELT anomalies	Rel.No. minus tolerants /(0.3km)	IBI
Hall Run - (11-101)																
Year: 91																
0.5	F	09-05-91	5.5	13(5)	6(5)	1(1)	1(1)	2(3)	6(5)	42(3)	2(5)	23(5)	17(1)	0.0(5)	1750(5)	**44**
Shayler Run - (11-105)																
Year: 91																
7.3	E	08-14-91	2.2	12(5)	5(5)	3(3)	0(1)	3(5)	4(5)	77(1)	19(3)	74(1)	20(3)	0.0(5)	288(5)	**42**
5.8	E	09-06-91	4.0	11(3)	4(3)	2(3)	0(1)	3(5)	3(3)	78(1)	32(1)	81(1)	26(3)	0.0(5)	365(3)	**32**
5.2	E	08-14-91	4.7	10(3)	4(3)	2(3)	0(1)	3(3)	3(3)	61(1)	14(3)	43(3)	36(5)	0.0(5)	284(3)	**36**
4.2	E	09-26-91	9.7	11(3)	4(3)	2(3)	0(1)	3(3)	3(3)	45(3)	22(3)	39(3)	13(1)	0.0(5)	1010(5)	**36**
3.0	E	09-27-91	10.6	9(3)	4(3)	2(3)	0(1)	3(3)	3(1)	28(5)	8(5)	15(5)	4(1)	0.0(5)	2859(5)	**40**
2.3	E	08-14-91	11.7	18(5)	5(3)	2(3)	4(3)	4(3)	5(3)	14(5)	6(5)	14(5)	18(1)	0.0(5)	1718(5)	**46**
0.6	E	09-06-91	12.7	26(5)	8(5)	1(1)	6(5)	4(3)	8(5)	24(5)	17(3)	26(5)	71(5)	0.0(5)	566(3)	**50**
Trib. to Shayler Run - (11-161)																
Year: 91																
0.6	E	08-14-91	3.4	13(5)	5(3)	3(3)	0(1)	3(5)	4(3)	65(1)	10(5)	48(3)	6(1)	0.0(5)	990(5)	**40**
0.1	E	10-23-91	3.5	11(5)	4(3)	2(3)	0(1)	3(5)	3(3)	61(1)	37(1)	54(3)	8(1)	0.0(5)	1144(5)	**36**