Biological and Water Quality Study of the Raccoon Creek Basin (1995)

Athens, Gallia, Hocking, Jackson, Meigs, and Vinton Counties
Ohio

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NOTICE TO USERS

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

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

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

Ohio Environmental Protection Agency. 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989c. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. Water Quality Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Since the publication of the preceding guidance documents, the following new publications by the Ohio EPA have become available. These publications should also be consulted as they represent the latest information and analyses used by the Ohio EPA to implement the biological criteria.

DeShon, J.D. 1995. Development and application of the invertebrate community index (ICI), pp. 217-243. in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio, pp. 109-144. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological response signatures and the area of degradation value: new tools for interpreting multimetric data, pp. 263-286. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. 1995. Policy issues and management applications for biological criteria, pp. 327-344. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. The role of biological criteria in water quality monitoring, assessment, and regulation. Environmental Regulation in Ohio: How to Cope With the Regulatory Jungle. Inst. of Business Law, Santa Monica, CA. 54 pp.

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

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

or by accessing the Ohio EPA web site (www.epa.state.oh.us).

Acknowledgments

Jim Grow - Surface water descriptions for selected tributaries.
Marty Kuklis - Raccoon Creek mainstem and Elk Fork basin surface water, pollutant loadings, facility descriptions, and chemical trends.
Joann Montgomery - Little Raccoon and Meadow Run basin surface water and sediment chemistry, pollutant loadings, facility descriptions, and chemical trends.
Martin Knapp - Raccoon Creek basin macroinvertebrate community assessments, dioxin sediment and fish tissue analyses, study area maps, and TSD editor.
Charles Boucher - Raccoon Creek basin fish community assessments.
John Kessler, Chris Selbe - Modeling nonpoint runoff survey on Mulga Run.
Dan Imhoff - Study area description.
Jeff DeShon, Marc Smith and Chris Yoder - Reviewers.

Water chemistry and organic/metal sediment analyses were provided by the Ohio EPA Division of Environmental Services. Dioxin sediment and fish tissue analyses were conducted by Triangle Laboratories through Ross Analytical Services, Inc. Numerous college interns and District Office staff assisted in the collection of field samples. Landowners who granted permission for site access are duly appreciated.

FOREWORD

What is a Biological and Water Quality Survey?

A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year Ohio EPA conducts biosurveys in 10-15 different study areas with an aggregate total of 250-300 sampling sites.

Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions which may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns, are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (*e.g.*, NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1]), and are eventually incorporated into Water Quality Permit Support Documents (WQPSDs), State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the Ohio Water Resource Inventory (305[b] report).

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators comprised of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach is outlined in Figure 1 and includes a hierarchical continuum from administrative to true environmental indicators. The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes in health, ecology, or other effects (ecological condition, pathogens). In this process the results of

administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental "results" (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition. Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. *Stressor* indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. *Exposure* indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues, and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. *Response* indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of community and population response that are represented here by the biological indices which comprise Ohio's biological criteria. Other response indicators could include target assemblages, *i.e.*, rare, threatened, endangered, special status, and declining species or bacterial levels which serve as surrogates for the recreational uses. These indicators represent the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators *within* the roles which are most appropriate for each. Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Ohio Water Resource Inventory (305[b] report), the Ohio Nonpoint Source Assessment, and other technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Use

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

1) *Warmwater Habitat (WWH)* - this use designation defines the "typical" warmwater assemblage of aquatic organisms for Ohio rivers and streams; *this use represents the principal restoration*

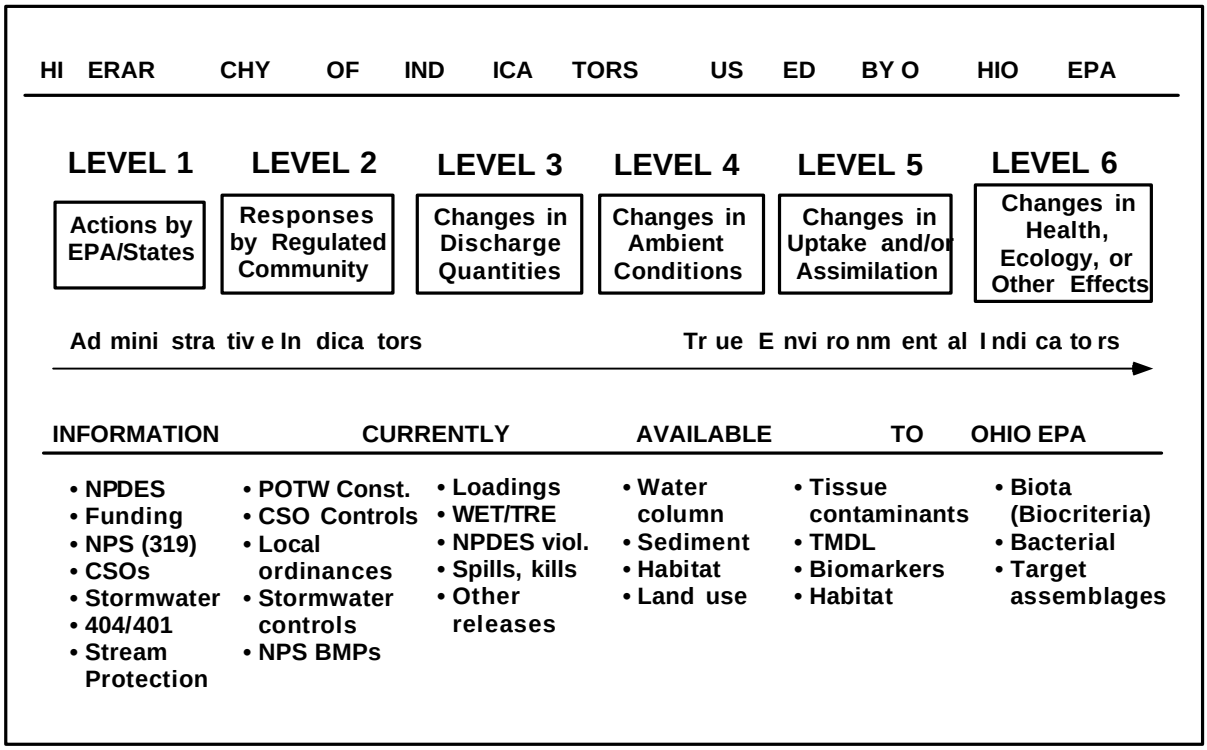


Figure 1. Hierarchy of administrative and environmental indicators used by Ohio EPA for monitoring, assessment, reporting and evaluating program effectiveness. This is patterned after a model developed by the U.S. EPA, Office of Water.

target for the majority of water resource management efforts in Ohio.

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

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

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been

subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned by state or federal law;* the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

5) *Limited Resource Water (LRW)* - this use applies to small streams (usually <3 mi.^{2} drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (*i.e.,* true ephemeral streams), or other irretrievably altered waterways.

6) *Limited Resource Water - Acid Mine Drainage (LRW-AMD)* -this use applies to streams and rivers which have been subjected to severe acid mine drainage pollution from abandoned mine lands or gob piles, and where there is no near term prospect for reclamation; the representative aquatic assemblages are generally composed of species which are tolerant to low pH, silt, metals, and poor quality habitat.

Chemical, physical, and/or biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such the system of use designations employed in the Ohio WQS constitutes a "tiered" approach in that varying and graduated levels of protection are provided by each. This hierarchy is especially apparent for parameters such as dissolved oxygen, ammonia-nitrogen, temperature, and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same water quality criteria may apply to two or three different use designations.

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use is simply having a water depth of at least one meter over an area of at least 100 square feet or where canoeing is a feasible activity. If a water body is too small and shallow to meet either criterion the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.,* fecal coliform, *E. coli)* and the criteria for each are specified in the Ohio WQS.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) use designations generally apply to all waters unless it

can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health and detailed in other documents.

Biological and Water Quality Study of the Raccoon Creek Basin (1995)

(Athens, Gallia, Hocking, Jackson, Meigs, and Vinton Counties Ohio)

INTRODUCTION

The 1995 Raccoon Creek study area consisted of the Raccoon Creek mainstem from downstream from of the confluence of the East and West Branches of Raccoon Creek (RM 109.1) to Thivener (RM 5.4). Subbasins sampled within the study area included Elk Fork, Little Raccoon Creek, and Meadow Run. Approximately 30 other tributaries within the Raccoon Creek study area were sampled, most of these for use designation issues. See Table 4 and Figures 2-4 for a complete list of sampling locations.

Specific objectives of this study were to:

1) evaluate the physical habitat, surface water and sediment quality, and the biological integrity of the Raccoon Creek study area,

2) assess impacts from municipal wastewater treatment plants, nonpoint sources of pollution, and habitat alterations,

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

4) compare results of this survey with previous surveys to assesses changes in water quality and biological integrity.

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

Previous water quality studies in the Raccoon Creek study area by the Ohio EPA Division of Surface Water include: *Biological and Water Quality Study of the Southeast Ohio River Tributaries*, June, 1991; *Comprehensive Water Quality Report for Little Raccoon Creek*, May, 1985; and *Comprehensive Water Quality Report for Elk Fork*, March, 1983.

SUMMARY

A total of 269 miles of rivers and streams in the Raccoon Creek basin was assessed as part of the 1995 survey. Biological index scores indicated that 85 miles (31.5 %) were in full attainment of the Warmwater Habitat (WWH) biocriteria or the Limited Resource Water-Acid Mine Drainage (LRW-AMD) benchmarks. Approximately 140 miles (52.0 %) were in partial attainment and 44 miles (16.5 %) were in non-attainment.

Leading causes of partial and non attainment were acid mine drainage (146 miles, 79.5 %), oil and gas operations (14 miles, 7.7 %), habitat (7.4 miles, 4.0 %), and point source dischargers (6.8 miles, 3.7 %). Approximately 56 miles (20.8 %) of the total 269 miles assessed in the 1995 survey were recommended for the LRW-AMD aquatic life use; based on biological, chemical, and physical data collected which indicated severe acid mine drainage pollution from abandoned mine lands or gob piles, and where there is no near term prospect for reclamation. Causes and sources of partial and non-attainment are presented in Table 2.

Raccoon Creek Mainstem
In the upper section of Raccoon Creek from the confluence of the East and West Branch Raccoon Creek (RM 111.96) to Sandy Run (RM 92.52), the first site (RM 109.1/108.9) downstream from the branches was in partial attainment of the LRW-AMD benchmarks (Table 1). The two remaining sites in this section were in full attainment of LRW-AMD benchmarks. Biological communities were in full or partial attainment of WWH biocriteria at all sites sampled downstream from Lake Hope (Sandy Run, RM 92.52) to Thivener (RM 5.4).

The headwaters of Raccoon Creek were substantially affected by mine impacts from the East Branch Raccoon Creek with elevated levels of aluminum, manganese, sulfate, and zinc, and low levels of alkalinity and pH. The stream segment between Radcliff (RM 63.8) and Humpback Bridge (RM 50.1) had an impact from acid mine tributaries in the area, although less severe than that observed in the upper section of Raccoon Creek. Impacts on the Raccoon Creek mainstem from the Meigs #31 Mine discharges in 1993 into Sugar Run and Strongs Run were minimal in 1995.

Elk Fork and Puncheon Fork
Biotic communities in Elk Fork were either in full or partial attainment of WWH criteria (Table 1) at all locations sampled. Puncheon Fork communities sampled upstream and downstream from the McArthur WWTP were in full attainment of WWH biocriteria.

The McArthur WWTP substantially increased levels of ammonia and BOD in Puncheon Fork. Although there were localized areas of mine drainage problems in the Elk Fork basin, they were not severe.

Little Raccoon Creek and Meadow Run
Biological communities were in partial attainment of WWH biocriteria at the three stations sampled in Little Raccoon Creek. All five sites on Meadow Run were in non-attainment of WWH biocriteria. Meadow Run stations located downstream from the Pillsbury and Wellston WWTP

discharges had very poor macroinvertebrate communities indicative of severely degraded water quality.

There were large increases in average concentrations of ammonia (from 0.09 to 5.5 mg/l) and BOD (from 2.1 to 12 mg/l), and a large decrease in dissolved oxygen (from 6.1 to 2.9 mg/l) in Meadow Run attributed to the Pillsbury and Wellston WWTP discharges. Mining impacts in the Little Raccoon Creek mainstem and the headwaters of Meadow Run appeared to be lessened from previous surveys; however, severe acid mine impacts were observed both chemically and biologically in several tributaries.

Other Tributaries

LRW Use Designation (existing and recommended)

Little Raccoon Creek tributaries Rich Run, Flint Run, Buffer Run, and Goose Run were in non-attainment of the LRW-AMD benchmarks. The Raccoon Creek tributaries East Branch Raccoon Creek , Pierce Run, and Rockcamp Run, and the Little Raccoon Creek tributary Greasy Run, were in partial attainment of the LRW-AMD benchmarks. The Raccoon Creek tributaries Indiancamp Run and Karr Run fully attained the LRW-AMD benchmarks.

These tributaries generally had the highest metal and sulfate concentrations, and the lowest alkalinity and pH readings in the Raccoon Creek basin (see the Chemical Water Quality section).

WWH Use Designation (recommended)

The Little Raccoon Creek tributary Coal Run; Raccoon Creek tributaries West Branch Raccoon Creek, Unnamed Tributary to Raccoon Creek (Austin Powder tributary), Pine Run, Coal Run, Tedroe Run, Merrit Run, and Long Run; and the Elk Fork tributary Austin Powder Tributary (trib to Elk Fork) were in non-attainment of WWH biocriteria. Raccoon Creek tributaries Twomile Run, Grass Run, Rockcamp Creek, Onion Creek, Russel Run, Flat Run, and Opossum Run were in partial attainment of WWH biocriteria. The only tributaries in full attainment of WWH biocriteria were Puncheon Fork in the Elk Fork basin, and Laurel Run and Zinns Run.

Table 1. Aquatic life use attainment status for stations sampled in the Raccoon Creek basin based on data collected July-September, 1995. The Index of Biotic Integrity (IBI), Modified Index of well-being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community.

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Comment
Raccoon Creek (1995)						
Western Allegheny Plateau: LRW - AMD Use Designation (Recommended)						
109.1/108.9	18	1.7*	14	60	PARTIAL[d]	Dst E. & W. Branches
99.7/101.2	22	5.4	18	61	FULL[d]	Ust. Austin Powder Trib.
98.4/98.3	22	4.9	18	49	FULL[d]	Ust. Lake Hope
Western Allegheny Plateau - WWH use designation (Existing)						
92.3/92.3	35*	7.0*	36	69	PARTIAL	Dst. Lake Hope
84.1/84.3	36[ns]	6.8*	38	48	PARTIAL	Ust. Onion Creek
72.2/72.3	40	8.1[ns]	46	62	FULL	Vales Mills
63.8/63.8	44	8.7	48	61	FULL	Ust. Pierce Run, Radcliff
50.1/50.1	44	7.6*	32[ns]	63	PARTIAL	Humpback Bridge
40.2/39.9	41	7.9*	38	47	PARTIAL	Vinton
35.6/35.6	41	8.5[ns]	G	63	FULL	Woods Mill
29.9/29.1	48	9.3	46	68	FULL	SR 588
10.0/10.2	40	9.5	48	70	FULL	Northup
5.4/-	40	8.4[ns]	-	55	(FULL)	Near Thivener
East Branch Raccoon Creek						
Western Allegheny Plateau: LRW - AMD Use Designation (Existing)						
6.6/6.6	12*	-	8	63	PARTIAL[d]	Dst. Sanner Rd.-AMD
2.1/0.1	12*	-	10	74	PARTIAL[d]	Near mouth
West Branch Raccoon Creek						
Western Allegheny Plateau - WWH Use Designation (Recommended)						
5.7/5.7	22*	-	F*	54	**NON**	Illesboro Cedar Falls
0.2/0.1	27*	5.0*	38	62	**NON**	Near mouth
Unnamed Tributary to Raccoon Creek (Austin Powder Trib.)						
Western Allegheny Plateau - WWH Use Designation (Recommended)						
0.1/0.1	37*	-	F*	37	**NON**	Near mouth

Table 1. Continued.

River Mile Fish/Invertebrate	IBI	MIwb	ICI	QHEI	Attainment Status	Comment
Elk Fork						
Western Allegheny Plateau - WWH use designation (Existing)						
16.2/16.2	39*	-	36	70	PARTIAL	Ust. SR 93
14.1/14.0	38*	-	54	68	PARTIAL	Ust. Puncheon Fk
Western Allegheny Plateau - WWH Use Designation (Recommended)						
13.3/13.3	44	7.6*	F*	75	PARTIAL	Dst. Puncheon Fk
11.0/10.9	43	8.0^{ns}	44	52	FULL	Dst. Austin Powder Trib
8.6/-	37*	8.0^{ns}	-	54	(PARTIAL)	Adj. T-8
2.2/-	42^{ns}	8.3^{ns}	-	66	(FULL)	Adj. T-8
0.2/0.1	36*	8.3^{ns}	42	58	PARTIAL	Near mouth
Puncheon Fork						
Western Allegheny Plateau - WWH Use Designation (Recommended)						
1.5/1.6	44	N/A	G	66	FULL	Ust. McArthur WWTP
0.3/0.3	40^{ns}	N/A	MG^{ns}	65	FULL	Dst. McArthur WWTP
Austin Powder Trib (Trib. to Elk Fork)						
Western Allegheny Plateau - WWH Use Designation (Recommended)						
-/0.4	-	-	F*	-	(**NON**)	Dst. Austin Powder
Little Raccoon Creek						
Western Allegheny Plateau - WWH use designation (Existing)						
28.3/28.3	38^{ns}	7.6*	36	60	PARTIAL	Dst Hamden, ust Meadow Run
24.6/24.6	36^{ns}	7.7*	28*	48	PARTIAL	Dst. Meadow Run, ust. AMD
Western Allegheny Plateau - WWH Use Designation (Recommended)						
11.0/11.8	37^{ns}	6.8*	18*	57	PARTIAL	Dst. AMD streams
Meadow Run						
Western Allegheny Plateau - WWH Use Designation (Recommended)						
3.1/3.1	27*	N/A	20*	56	**NON**	Ust. Jenos facility
2.1/2.1	33*	N/A	26*	43	**NON**	Dst. Jenos facility
Western Allegheny Plateau - WWH use designation (Existing)						
1.5/1.5	32*	N/A	28*	51	**NON**	Ust Pillsb.&Wellston discharge
-/1.18	-	-	*VP/VP*	-	*NA*	*Pillsbury mixing zone*
-/1.16	-	-	*VP/VP*	-	*NA*	*Wellston WWTP mixing zone*
0.8/0.8	26*	N/A	0*	52	**NON**	Chaetwood Rd.

Table 1. Continued.

River Mile Fish/Invertebrate	IBI	MIwb	ICI	QHEI	Attainment Status	Comment
Little Raccoon Creek Tributaries						
Western Allegheny Plateau: LRW - AMD Use Designation (Recommended)						
Rich Run						
1.5/0.1	12*	N/A	P*	72	**NON**[d]	Lower reach
Flint Run						
0.5/1.2	12*	N/A	VP*	60	**NON**[d]	Lower reach
Buffer Run						
0.2/0.2	12*	N/A	VP*	54	**NON**[d]	Near mouth
Greasy Run						
0.1/0.2	30	N/A	VP*	59	PARTIAL[d]	Near mouth
Goose Run						
0.4/0.4	12*	N/A	VP*	44	**NON**[d]	Lower reach
Little Raccoon Creek Tributaries						
Western Allegheny Plateau: WWH Use Designation (Recommended)						
Coal Run						
0.1/0.2	34*	N/A	P*	55	**NON**	Near mouth
Raccoon Creek Tributaries						
Western Allegheny Plateau: LRW - AMD Use Designation (Recommended)						
Pierce Run						
1.7/1.7	34	N/A	P*	52	PARTIAL[d]	Lower reach
Rockcamp Run						
0.2/0.3	12*	N/A	P*	55	**NON**[d]	Lower reach
Indiancamp Run						
0.3/0.3	28	N/A	F	82	FULL [d]	Lower reach
Karr Run						
0.2/0.2	32	N/A	P	57	PARTIAL[d]	Near mouth

Table 1. Continued.

River Mile Fish/Invertebrate	IBI	MIwb	ICI	QHEI	Attainment Status	Comment
Western Allegheny Plateau - WWH Use Designation (Recommended)						
Twomile Run						
0.1/0.1	28*	N/A	G	63	PARTIAL	Near mouth
Grass Run						
0.1/0.1	30*	N/A	G	55	PARTIAL	Near mouth
Pine Run						
-/0.1	-	-	P*	-	**(NON)**	Near mouth
Rockcamp Creek						
1.5/1.6	44	N/A	F*	55	PARTIAL	
Coal Run						
0.1/0.1	30*	N/A	F*	58	**NON**	Near mouth
Laurel Run						
-/0.1	-	-	G	-	(FULL)	Near mouth
Onion Creek						
1.4/1.4	30*	N/A	VG	77	PARTIAL	Lower reach
Tedroe Run						
0.1/0.1	28*	N/A	F*	54	**NON**	Near mouth
Merrit Run						
0.1/0.1	34*	N/A	P*	63	**NON**	Near mouth
Russell Run						
0.6/0.7	36*	N/A	G	48	PARTIAL	Lower reach
Flat Run						
1.6/1.3	36*	N/A	G	51	PARTIAL	Lower reach
Long Run						
1.4/1.4	38*	N/A	F*	69	**NON**	Lower reach

Table 1. Continued.

River Mile Fish/Invertebrate	IBI	MIwb	ICI	QHEI	Attainment Status	Comment
Western Allegheny Plateau - WWH Use Designation (Recommended)						
Zinns Run						
0.5/0.5	44	N/A	G	69	FULL	Lower reach
Opossum Run						
0.1/0.1	42[ns]	N/A	F*	64	PARTIAL	Near mouth

Ecoregion Biocriteria: Western Allegheny Plateau (WAP)

INDEX - Site Type	WWH	EWH	MWH[e]	LRW-AMD[d]
IBI - Wading&headwater	44	50	24/24	18
IBI - Boat	40	48	24/24	18
Mod. Iwb - Wading	8.4	9.4	6.2/5.5	4.0
Mod. Iwb - Boat	8.6	9.6	5.8/5.5	4.0
ICI	36	46	22/30	8

a - MIwb is not applicable to headwater streams with drainage areas $\leq$ 20 mi^2.
b - A qualitative narrative evaluation based on best professional judgement and sampling attributes such as community composition, EPT taxa richness, and QCTV scores were used when quantitative data were not available (E-exceptional, G-good, MG-marginally good, F-fair, P-poor, VP-very poor).
c - Attainment status is given for existing use designations, except where a use designation change is recommended, in which case, the attainment status for the recommended use is given.
d - Limited Resource Water - acid mine drainage (LRW-AMD) benchmarks based on best professional judgment driven by the need to protect against acutely toxic stream conditions. Macroinvertebrate qualitative only data were evaluated based on densities of EPT taxa on the natural substrates (see Methods Section), a narrative VP* or P* indicates departure from the benchmark.
e - Modified Warmwater Habitat for channelized/mine affected habitats.
N/A - Miwb not applicable at headwater sites (< 20 mi^2).
ns - Nonsignificant departure from biocriteria ($\leq$4 IBI or ICI units, or $\leq$0.5 MIwb units).
* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb uits). Underlined scores are in the Poor or Very Poor range.

Table 2. Waterbody segment (305b) summaries for streams sampled in the Raccoon Creek basin during 1995.

Waterbody (RM) Upper/Lower	Stream Reach Length	Attainment Miles Status				Causes, Sources, and Comments	
		FULL	Partial	**NON**	Threatened		
Raccoon Creek mainstem							
111.96/103.06	8.90		8.9			*Causes*:	Aluminum, manganese, pH, zinc
						Sources:	Acid mine drainage (AMD)
						Comments:	The upper Raccoon Creek mainstem is biologically and chemically impaired due to AMD primarily from the East Branch Raccoon Creek.
103.06/89.54	13.52	10.54	2.98			*Causes*:	Manganese, zinc
						Sources:	Acid mine drainage (AMD)
						Comments:	The upper Raccoon Creek mainstem is biologically and chemically impaired due to AMD primarily from the East Branch Raccoon Creek.
89.54/66.64	22.90	11.66	11.24			*Causes*:	Manganese, zinc
						Sources:	Acid mine drainage (AMD)
						Comments:	The upper Raccoon Creek mainstem is biologically and chemically impaired due to AMD primarily from the East Branch Raccoon Creek.
66.64/47.67	18.97	5.94	12.79			*Causes*:	Metals
						Sources:	Acid mine drainage (AMD)
						Comments:	The Raccoon Creek mainstem from Radcliff to Vinton appears to be pulsed with AMD impacts during periods of high rainfall from AMD tribs between RM 60.46 (Pierce Run) and RM 53.84 (Karr Run).
47.67/37.55	10.12		10.12			*Causes*:	Metals
						Sources:	Acid mine drainage (AMD)
						Comments:	The Raccoon Creek mainstem from Radcliff to Vinton appears to be pulsed with AMD impacts during periods of high rainfall from AMD tribs between RM 60.46 (Pierce Run) and RM 53.84 (Karr Run).
37.55/27.83	9.72	9.72			9.72	*Comments*:	The lower reaches of the Raccoon Creek mainstem appear to be unaffected by AMD impacts, however, these reaches may possibly be affected during high rainfall and high flow years, or other pulse events.

Table 2. (cont.) Waterbody segment (305b) summaries for streams sampled in the Raccoon Creek basin during 1995.

Waterbody (RM) Upper/Lower	Stream Reach Length	Attainment Miles Status				Causes, Sources, and Comments
		FULL	Partial	**NON**	Threatened	
Raccoon Creek mainstem - WWH						
27.83/12.65	15.18	15.18			15.18	*Causes*: *Sources*: *Comments*: The lower reaches of the Raccoon Creek mainstem appear to be unaffected by AMD impacts, however, these reaches may possibly be affected during high rainfall and high flow years, or other pulse events.
12.65/0.00	12.65	12.65			12.65	*Causes*: *Sources*: *Comments*: The lower reaches of the Raccoon Creek mainstem appear to be unaffected by AMD impacts, however, these reaches may possibly be affected during high rainfall and high flow years, or other pulse events.
East Branch Raccoon Creek(confl. RM 111.96) LRW-AMD						*Causes*: Aluminum, iron, manganese, pH, zinc *Sources*: Acid mine drainage (AMD) *Comments*: The East Branch of Raccoon Creek was severely degraded by AMD and this contamination continued into the mainstem of Raccoon Creek from the confluence with the East and West Branches to Sandy Run.
9.30\0.0	9.30		9.30			
West Branch Raccoon Creek (confl. RM 111.96) - WWH						*Causes*: Manganese, zinc *Sources*: Acid mine drainage (AMD) *Comments*: Although there were indications of slight AMD impacts, the degradation was not as severe as observed in the East Branch. The non attainment was mostly due to the poor performance of the fish community. Benthic communities were affected by low flow at the upper site, but good performance was observed at the near mouth site.
8.10/0.00	8.10			8.10		
Tributary to Raccoon Creek (confl. RM 98.96) - WWH						*Causes*: Habitat *Sources*: Natural *Comments*: Fair biological community performance appeared to be related to poor habitat. The benthic sample was collected in a wetland habitat.
2.32\0.00	2.32			2.32		

Table 2. (cont.) Waterbody segment (305b) summaries for streams sampled in the Raccoon Creek basin during 1995.

Waterbody (RM) Upper/Lower	Stream Reach Length	Attainment Miles Status				Causes, Sources, and Comments	
		FULL	Partial	**NON**	Threatened		
Elk Fork - WWH						*Causes*:	Iron, manganese, pH, zinc
						Sources:	Acid mine drainage (AMD), mining
18.60\0.00	18.6	4.0	14.6			*Comments*:	The reach above Puncheon Fork was in partial attainment due to fair fish performance possibly due to AMD impact (elevated metals). Dst from Puncheon Fork ammonia and BOD were elevated due to McArthur WWTP. Benthic site dst from Puncheon Fork affected by siltation.
Puncheon Fork - WWH						*Sources*:	McArthur WWTP
5.60\0.0	5.60	5.6				*Comments*:	Chemical data indicated increases in ammonia and BOD downstream from the WWTP. Some D.O. exceedances.
Austin Powder Trib. (to Elk Fork) - WWH						*Causes*:	Nitrate-nitrite.
						Sources:	Austin Powder
2.95\0.0				2.95		*Comments*:	Benthic community sampled showed fair performance. 1995 chemical data showed higher levels of nitrate-nitrite in Elk Fork downstream from this tributary compared to upstream.
Little Raccoon Creek - WWH						*Causes*:	Manganese; aluminum, iron, organic enrichment
						Sources:	Acid mine drainage (AMD); Wellston WWTP and Pillsbury effluents
28.89/12.57	16.32		16.32			*Comments*:	Ammonia and BOD levels increase downstream from Meadow Run. Between RM 24.45 (Mulga Run) and RM 12.57 (Dickason Run) there are several AMD impacted tributaries that may impact Little Raccoon Ck
12.57/0.00	12.57		12.57			*Causes*:	Aluminum, iron, manganese
						Sources:	Acid mine drainage (AMD)
						Comments:	Between RM 24.45 (Mulga Run) and RM 12.57 (Dickason Run) there are AMD tributaries which may have impacts on Little Raccoon Creek.
Meadow Run - WWH						*Causes*:	Ammonia, BOD, DO; dioxin and manganese in sediments
						Sources:	Pillsbury and Wellston WWTP; acid mine drainage (AMD)
5.10/0.00	5.10			5.10		*Comments*:	AMD impacts in upper reach appear lessened. High manganese in water/ sediment at RM 1.5. Sediment dioxin at about same levels since 1989. Lower reach heavily impacted(ICI=0) from organic enrichment 84,90,95

Table 2. (cont.) Waterbody segment (305b) summaries for streams sampled in the Raccoon Creek basin during 1995.

Waterbody (RM) Upper/Lower	Stream Reach Length	Attainment Miles Status				Causes, Sources, and Comments
		FULL	Partial	**NON**	Threatened	
LITTLE RACCOON CREEK TRIBUTARIES - Use Designation						
Rich Run - LRW-AMD						*Causes*: Aluminum, manganese, pH *Sources*: Acid mine drainage (AMD) *Comments*: Poor benthic and very poor fish performance due to AMD. pH measured at 4.65 S.U. High aluminum and manganese.
4.00\0.00	4.00			4.00		
Coal Run - WWH						*Causes*: Iron, manganese *Sources*: Acid mine drainage (AMD) *Comments*: Coal Run did not appear to be as heavily impaired biologically and chemically by AMD as other Little Raccoon Creek tribs.
1.40\0.0	1.40			1.40		
Flint Run - LRW-AMD						*Causes*: Metals, pH *Sources*: Acid mine drainage (AMD) *Comments*: Chemical samples not collected but a severe AMD impact was evident: orange stained water column/sediments, v.poor fish/benthic communities
2.20\0.0	2.20			2.20		
Buffer Run - LRW-AMD						*Causes*: Aluminum, iron, manganese, nickel, pH, zinc *Sources*: Acid mine drainage (AMD) *Comments*: Biological and chemical impacts due to AMD evident. A gob pile adjacent to the stream was observed upst. from the sampling site. Coal fines made up a substantial component of the stream substrates.
2.40/0.00	2.40			2.40		
Greasy Run - LRW-AMD						*Causes*: Metals, pH *Sources*: Acid mine drainage (AMD) *Comments*: Chemical samples not collected but a severe AMD impact was evident: orange stained water column/sediments, .v.poor benthic community
2.60/0.00	2.60		2.60			
Goose Run - LRW-AMD						*Causes*: Metals, pH *Sources*: Acid mine drainage (AMD) *Comments*: Chemical samples not collected but a severe AMD impact was evident: orange stained water column/sediments, v.poor fish/benthic communities
1.80/0.00	1.80			1.80		

Table 2. (cont.) Waterbody segment (305b) summaries for streams sampled in the Raccoon Creek basin during 1995.

Waterbody (RM) Upper/Lower	Stream Reach Length	Attainment Miles Status				Causes, Sources, and Comments
		FULL	Partial	**NON**	Threatened	
RACCOON CREEK TRIBUTARIES (River Mile confluence) - Use Designation						
Twomile Run (109.38) - WWH						*Causes*: Manganese *Sources*: Acid mine drainage (AMD) *Comments*: AMD impact was suggested: orange stained sediments and coal fines; fair fish, but good benthic community performance.
4.30\0.00	4.30		4.30			
Grass Run (89.54,8.22) - WWH						*Causes*: Iron, manganese *Sources*: Acid mine drainage (AMD) *Comments*: AMD impact was suggested: elevated levels of metals; fair fish, but good benthic community performance.
2.80\0.0	2.80		2.80			
Pine Run (89.43, 6.68) - WWH						*Causes*: Metals, pH *Sources*: Acid mine drainage (AMD) *Comments*: Chemical samples not collected but an AMD impact was evident: orange stained stream margins, poor benthic community
2.10\0.0	2.10			2.10		
Rockcamp Creek (89.54, 4.01) - WWH						*Causes*: Unknown *Sources*: Natural *Comments*: No indication of AMD impacts. Fair performance of benthic community may be due to wetland influence. Good performance of fish community.
5.10/5.10	5.10		5.10			
Coal Run (89.54, 4.01, 2.5) - WWH						*Causes*: Metals, pH *Sources*: Acid mine drainage (AMD) *Comments*: Chemical samples not collected but an AMD impact was evident: slightly red stained sediments, fair fish/benthic communities.
1.60/0.00	1.60			1.60		
Laurel Run (84.34) - WWH						*Comments*: No indication of AMD impacts, but stream did have thick deposits of silt of unknown origin. Attainment status based on benthic community only.
3.30/0.00	3.30	3.30				

Table 2. (cont.) Waterbody segment (305b) summaries for streams sampled in the Raccoon Creek basin during 1995.

Waterbody (RM) Upper/Lower	Stream Reach Length	Attainment Miles Status				Causes, Sources, and Comments
		FULL	Partial	**NON**	Threatened	
RACCOON CREEK TRIBUTARIES (River Mile confluence) - Use Designation						
Onion Creek (84.04) - WWH						*Comments*: Chemical parameters tested did not show high levels of parameters; partial attainment due to fair fish community performance, but very good benthic community performance.
6.00\0.00	6.00		6.00			
Tedroe Run (82.80) - WWH						*Causes*: Manganese *Sources*: Acid mine drainage (AMD) *Comments*: Slight AMD impact suggested: some areas of stream with orange stained substrates, fair benthic and fish community performance.
2.50\0.0	2.50			2.50		
Merrit Run (82.2) - WWH						*Causes*: Unknown *Sources*: Possible acid mine drainage (AMD), oil and gas activities *Comments*: Although no chemical samples were collected a possible AMD impact was suggested: slightly orange stained substrates, fair fish and poor benthic community performance.
2.10\0.0	2.10			2.10		
Russell Run (79.43) - WWH						*Causes*: Oil and grease *Sources*: Oil and gas operations *Comments*: Chemical parameters tested did not show high levels of parameters; partial attainment due to fair fish community performance, but good benthic community performance.
3.00/0.00	3.00		3.00			
Flat Run (77.88) - WWH						*Causes*: Oil and grease *Sources*: Oil and gas operations *Comments*: Chemical parameters tested did not show high levels of parameters; partial attainment due to fair fish community performance, but good benthic community performance
7.30/0.00	7.30		7.30			
Long Run (74.6) - WWH						*Causes*: Oil and brine *Sources*: Oil and gas operations *Comments*: Chemical parameters tested did not show high levels of parameters; fair benthic and fish community performance.
3.80/0.00	3.80			3.80		

Table 2. (cont.) Waterbody segment (305b) summaries for streams sampled in the Raccoon Creek basin during 1995.

Waterbody (RM) Upper/Lower	Stream Reach Length	Attainment Miles Status				Causes, Sources, and Comments
		FULL	Partial	**NON**	Threatened	
RACCOON CREEK TRIBUTARIES (River Mile confluence) - Use Designation						
Zinns Run (63.51) - WWH						*Comments*: Although some chemical parameters (pH, aluminum, iron, and manganese) were elevated above ecoregion expectations, the substrates were not characteristic of AMD, and benthic/fish had good performance.
2.60/.00	2.60	2.60				
Pierce Run (60.46) - LRW-AMD						*Causes*: Iron, manganese, pH, zinc *Sources*: Acid mine drainage (AMD) *Comments*: AMD impact was evident: stream with orange stained substrates, poor benthic and fair fish community performance.
8.50/0.00	8.50		8.50			
Rockcamp Run (58.90) - LRW-AMD						*Causes*: Manganese, sulfates *Sources*: Acid mine drainage (AMD) *Comments*: AMD impact was evident: stream with orange stained substrates, poor benthic and very poor fish community performance.
2.10/0.00	2.10			2.10		
Indiancamp Run (55.23) - LRW-AMD						*Causes*: pH *Sources*: Acid mine drainage (AMD) *Comments*: AMD impacts evident, but not as severe as nearby tribs: brownish-orange stained substrates, fair benthic and fish community performance
2.40/2.40	2.40	2.40				
Karr Run (53.84) - LRW-AMD						*Causes*: Metals, pH *Sources*: Acid mine drainage (AMD) *Comments*: Chemical samples not collected but an AMD impact was evident: orange stained substrate rocks, poor benthic and fair fish communities.
1.20/0.00	1.20	1.20				
Opossum Run (46.05) - WWH						*Causes*: Iron, manganese, pH; siltation; oil and grease *Sources*: Possible acid mine drainage (AMD), oil and gas activities *Comments*: Visible signs of a pollutional impact included oil on water surface and silted substrates. Fair benthic/good fish performance.
1.40/0.00	1.40		1.40			

CONCLUSIONS

Modeling Nonpoint Source Runoff Survey

The modeling results from a nonpoint source runoff survey of the acid mine affected tributary, Mulga Run, show that some metal concentrations and loadings increase during rain events, but that pH levels are not lowered. It appears from these results that low pH in acid streams is actually increased during rainfall events, most likely due to the dilution of the rain water. Concentrations of aluminum and iron increased during the run-off, while instream manganese concentrations became more diluted. This increase in some metal concentrations may be due to resuspension of stream sediments or runoff containing metals from unreclaimed mine lands and gob piles.

There is a wetland near the mouth of Mulga Run. This wetland appeared to mitigate some metal parameters concentrations. Concentrations of aluminum and iron were lower at the mouth of Mulga Run compared to a site on Mulga Run upstream from the wetland.

Raccoon Creek mainstem

Mining impacts caused the most severe degradation of any source in the Raccoon Creek mainstem. Areas of unreclaimed mine lands and gob piles are located on several tributaries in the basin (Figures 2, 3, and 4). Additionally, deliberate discharges of underground mine water have been pumped into the basin, such as the Longwall Mine Project and the 1993 Meigs #31 Mine discharge.

Macroinvertebrate communities in the Raccoon Creek mainstem in 1993 were affected by the discharge of untreated and partially treated mine waters from the Meigs #31 Mine via Strongs Run (RM 43.71) and Robinson Run (RM 42.0). The site upstream from these tributaries at Humpback Bridge (RM 50.1) attained the WWH criterion with an ICI score of 42. The benthic community shifted from a predominance by tanytarsini midges upstream at RM 50.1, to a predominance by other dipterans and non-insects and a higher percentage of tolerant organisms at downstream sites. The ICI scores at Vinton (RM 39.9) and Adamsville (RM 29.1) were only in the fair range (26 and 30, respectively). No distinct impact on the fish community was evident from mine water discharged via Strongs Run and Robinson Run to Raccoon Creek between 1993 and 1994.

Unreclaimed mine lands and gob piles appeared to have their greatest impact during years of elevated rainfall. Stream flow recorded at the U.S.G.S. gauging station in Raccoon Creek at Adamsville showed that 1994 (836 cfs, average) had higher than normal stream flow (644 cfs, average for water years 1916-1995); whereas, the years 1992, 1993, and 1995 (482 cfs, 571 cfs, and 602 cfs, averages, respectively) were lower than normal stream flow. The ICI score at Humpback Bridge (RM 50.1), was lowest in 1994 (ICI=22), compared to 1993 and 1995 (ICI scores of 42 and 32, respectively). There are mine affected tributaries between Radcliff and Humpback Bridge that may have contributed more of an acid mine load during the higher rainfall, and subsequently, higher flow year in 1994.

The 1995 study delineated two areas in Raccoon Creek affected by acid mine drainage. The headwaters of Raccoon Creek were substantially affected by mine impacts from the East Branch Raccoon Creek with elevated levels of aluminum, manganese, sulfate, and zinc, and low levels of alkalinity and pH. The stream segment between Radcliff (RM 63.8) and Humpback Bridge (RM 50.1) appeared to have an impact from acid mine tributaries in the area, although less severe than that observed in the upper section of Raccoon Creek.

Little Raccoon Creek and Meadow Run

Meadow Run was heavily impacted by the Wellston WWTP and Pillsbury discharges. There were large increases in average concentrations of ammonia (from 0.09 to 5.5 mg/l) and BOD (from 2.1 to 12 mg/l), and a large decrease in dissolved oxygen (from 6.1 to 2.9 mg/l) in Meadow Run water chemistry from upstream to downstream from these dischargers. The downstream station at Chaetwood Road had a very poor macroinvertebrate community indicative of severely degraded water quality. The very poor macroinvertebrate community score (ICI=0) was reported in 1984, 1990, and 1995, indicating no change over the period of record.

Mining impacts cause severe degradation in many of the tributaries in Little Raccoon Creek. Areas of unreclaimed mine lands and gob piles are located in the drainage basins of several tributaries. Severe acid mine impacts occurred in Mulga Run, Flint Run, Buffer Run, and Goose Run.

RECOMMENDATIONS

Use designation recommendations were based on a combination of biological, chemical, and physical data. Although two streams may have scored the same biologically, they may have had different chemical or physical attributes indicating the abscence or prevalence of acid mine drainage impacts. If biological, chemical, or physical data suggested that a stream was subjected to severe acid mine drainage pollution from abondoned mine lands or gob piles, and there is no near term prospect for reclamation, it was recommended for the Limited Resource Water - Acid Mine Drainage (LRW-AMD) aquatic life use designation.

Raccoon Creek

Status of Aquatic Life Uses

Raccoon Creek is currently designated Warmwater Habitat (WWH). The performance of the biological communities and prevalence of acid mine chemical parameters in the water column extending from the confluence of the East and West Branches of Raccoon Creek (RM 111.96) to Sandy Run (RM 92.52), with no near term prospect of reclamation, warrant the LRW-Acid Mine Drainage use designation (Table 3). This section of Raccoon Creek is influenced heavily by the water quality of the East Branch Raccoon Creek, both chemically and biologically. The remaining segment, RM 92.52 to the mouth, should retain the WWH aquatic life use.

Status of Non-Aquatic Life Uses

All non-aquatic life uses should remain as presently designated in the Ohio Water Quality Standards.

Other Recommendations

Reclamation of mine lands should be encouraged throughout the basin.

Elk Fork, Puncheon Fork, and the Austin Powder Tributary

Status of Aquatic Life Uses

Elk Fork (from Puncheon Fork, RM 13.88, to the mouth), Puncheon Fork, and the Austin Powder Tributary (tributary to Elk Fork at RM 11.17) are currently designated Nuisance Prevention - Acid Mine Drainage. Performance of the biological communities and lessening of instream chemical impacts from acid mine drainage in these basins warrant the Warmwater Habitat (WWH) aquatic life use designation for these streams.

Status of Non-aquatic Life Uses

All non-aquatic life uses should remain as presently designated in the Ohio Water Quality Standards.

Future Monitoring Concerns

Wolf Creek in the Elk Fork basin should be sampled in the next five year cycle for a possible change from its current use designation of Nuisance Prevention - Acid Mine Drainage. Other acid mine impacted stream reaches in the Elk Fork basin sampled in 1995 were deemed capable of supporting the WWH use designation.

Little Raccoon Creek and Meadow Run

Status of Aquatic Life Uses

Little Raccoon Creek from Mulga Run (RM 24.4) to the mouth, and Meadow Run from the headwaters to SR 327 are currently designated Nuisance Prevention - Acid Mine Drainage. Performance of the biological communities and a lessening of acid mine impacts in these basins warrant the Warmwater Habitat (WWH) aquatic life use designation for these streams.

Status of Non-aquatic Life Uses
All non-aquatic life uses should remain as presently designated in the Ohio Water Quality Standards.

Other Recommendations
Reclamation of mine lands should be encouraged throughout the basin. Gob piles along roads and stream banks were obvious signs of poorly managed or nonexistent remediation efforts.

Future Monitoring Concerns
Additional sampling in Little Raccoon Creek from RM 24.4 to RM 11.8 should be conducted to evaluate the performance of biological communities and instream chemistry. Little Raccoon Creek tributaries in this segment showed the most severe acid mine drainage problems in the basin. Little Raccoon Creek showed partial attainment of WWH biocriteria at the Keystone Furnace site (RM 11.8/11.0) in 1995; however there were no other sites sampled in Little Raccoon Creek between Mulga Run (RM 24.4) and Keystone Furnace.

Additional dioxin sediment and fish tissue monitoring may be warranted. Dioxin sediment concentrations in the vicinity of the Wellston WWTP discharge (RM 1.20 to RM 1.16) showed a significant decrease from 1988 to 1995 (2524 ppt TTE to 361 ppt TTE, respectively). This may be in response to a section of Meadow Run being dredged from RM 2.05 to RM 1.16 in 1989, or the difference in outfall/sediment sampling locations from RM 1.20 in 1988 to RM 1.16 in 1995. The sediment dioxin concentrations at Chaetwood Road from 1989 (246 ppt TTE) to 1995 (246 ppt TTE) showed no difference. Dioxin sampling of fish tissue in Little Raccoon Creek (1990) reported one fish tissue value in the range of the FDA reduced consumption level of 25-50 ppt. (whole body carp, 33.4 ppt 2,3,7,8,-TCDD). Dioxin concentrations in fish tissue collected in 1995 were below this FDA level (25-50 ppt) and ranged between 15.3 ppt and 21.6 ppt TTE.

Other Little Raccoon Creek Tributaries
Status of Aquatic Life Uses
Dickason Run (headwaters to Dixon/Kyger Creek) and Coal Run are currently designated Limited Warmwater Habitat (LWH) - Acid Mine Drainage . Performance of the biological communities and a lessening of instream chemical impacts from acid mine drainage in these basins warrant the Warmwater Habitat (WWH) aquatic life use designation for these streams.

Rich Run, Flint Run, Buffer Run, Greasy Run, Goose Run, Tarcamp Run, and Dickason Run (Dixon Run/Kyger Creek to the mouth) are currently designated Limited Warmwater Habitat (LWH) -Acid Mine Drainage . Poor performance of the biological communities and instream chemical impacts from unreclaimed acid mine drainage with no near term prospect for reclamation in these basins warrant the Limited Resource Water (LRW) - Acid Mine Drainage aquatic life use designation for these streams.

Status of Non-aquatic Life Uses
Recommended changes to Recreation Use Designations in the Ohio Water Quality Standards are noted in Table 3. All other non-aquatic life uses should remain as presently designated in the Ohio Water Quality Standards.

Other Recommendations
Reclamation of mine lands should be encouraged throughout the basin. Gob piles along roads and stream banks were obvious signs of poorly managed or nonexistent remediation efforts.

Other Raccoon Creek Tributaries

Status of Aquatic Life Uses

West Branch Raccoon Creek,Twomile Run, Grass Run, Pine Run, Rockcamp Creek, Coal Run, Laurel Run, Onion Creek, Tedroe Run, Merrit Run, Russell Run, Flat Run, Long Run, Zinns Run, Flatlick Run, and Opossum Run are currently designated Limited Warmwater Habitat (LWH) - Acid Mine Drainage. Performance of the biological communities and a lessening of instream chemical impacts from acid mine drainage in these basins warrant the Warmwater Habitat (WWH) aquatic life use designation for these streams.

Pierce Run, Rockcamp Run, Indiancamp Run, and Karr Run are currently designated Limited Warmwater Habitat (LWH) - Acid Mine Drainage . Poor performance of the biological communities and instream chemical impacts from unreclaimed acid mine drainage in these basins with no near term prospect of reclamation warrant the Limited Resource Water (LRW) - Acid Mine Drainage aquatic life use designation for these streams. East Branch Raccoon Creek was previously listed as Nuisance Prevention and now defaults to LRW-AMD, which, based on the 1995 biological and water quality survey conducted, is deemed appropriate.

Unnamed Tributary (Raccoon Creek RM 98.96) was not previously designated. Based on the 1995 biological and water quality survey, it is recommended for the WWH aquatic life use.

Status of Non-aquatic Life Uses

Recommended changes to Recreation Use Designations in the Ohio Water Quality Standards are noted in Table 3. All other non-aquatic life uses should remain as presently designated in the Ohio Water Quality Standards.

Other Recommendations

Reclamation of mine lands should be encouraged throughout the basin. Gob piles along roads and stream banks were obvious signs of poorly managed or nonexistent remediation efforts.

Table 3. Waterbody use designations for the Raccoon Creek basin. Changes to existing use designations appear as a delta symbol (▵); designations based on the 1978 water quality standards as an asterik(*), and those designations for which results of biological field assessments are now available appear as plus signs (+). Designated use based on justification other than the resultls of a biological field assessment performed by the Ohio EPA (o).

Stream Segment	Use Designations													Comments
		Aquatic Life						Water			Recreation			
	SRW	WWH	EWH	MWW	SSH	CWH	LRW	AWS	IWS	PWS	BW	PCR	SCR	
Raccoon Creek - confluence of the East and West Branch (RM 111.9) to Sandy Run (RM 92.52)							Δ	+	+			+		Acid Mine Drainage
- Sandy Run to the mouth		+						+	+			+		
Bear Run		*						*	*			*		
Bullskin Creek		*						*	*			*		
Little Bullskin Creek		*						*	*			*		
Burnt Run		*						*	*			*		
Rocklick Creek		*						*	*			*		
Clear Fork		*						*	*			*		
Claylick Run		*						*	*			*		
Little Claylick Run		*						*	*			*		
Fox Branch		*						*	*			*		

Stream Segment	Use Designations													Comments
		Aquatic Life						Water			Recreation			
	SRW	WWH	EWH	MWW	SSH	CWH	LRW	AWS	IWS	PWS	BW	PCR	SCR	
Rocky Fork		*						*	*			*		
Mud Creek		*						*	*			*		
Fork Creek		*						*	*			*		
Polecat Run		*						*	*			*		
Ryan Run		*						*	*			*		
Indian Creek		*						*	*			*		
Little Indian Creek		*						*	*			*		
Plum Run		*						*	*			*		
Barren Creek		*						*	*			*		
Trace Run		*						*	*			*		
Little Raccoon Creek - headwaters to Mulga Run	+	+						+	+			+		
- Lake Rupert	+		*					*	*	+		*		
- at RM 30	+	+						+	+	+		*		
- Mulga Run to mouth	+	Δ						+	+			+		
Deer Creek	*	*						*	*			*		
Keeton Run		*						*	*			*		
Spring Run		*						*	*			*		
Dickason Run - headwaters to Dixon Run		o						*	*			*		
- Dixon Run (RM 1.3) to mouth							o	*	*			*		Acid Mine Drainage
Kyger Run							o	*	*			*		Acid Mine Drainage
Tarcamp Run							o	*	*			*		Acid Mine Drainage
Goose Run							Δ	+	+				Δ	Acid Mine Drainage
Greasy Run							Δ	+	+				Δ	Acid Mine Drainage
Buffer Run							Δ	+	+				Δ	Acid Mine Drainage
Flint Run							Δ	+	+				Δ	Acid Mine Drainage
Coal Run		Δ						+	+				Δ	

Stream Segment	Use Designations													Comments
		Aquatic Life						Water			Recreation			
	SRW	WWH	EWH	MWW	SSH	CWH	LRW	AWS	IWS	PWS	BW	PCR	SCR	
Rich Run							Δ	+	+			+		Acid Mine Drainage
Mulga Run							o	*	*			*		Acid Mine Drainage
Meadow Run - headwaters to S.R. 327 (RM 2.1)		Δ						+	+			+		
- RM 2.1 to mouth		+						+	+			+		
Sand Run		+						*	*			*		
Tripp Run		*						*	*			*		
Johnson Run		*						*	*			*		
McConnel Run	*		*					*	*			*		
Robinson Run		*						*	*			*		
Sugar Run		*						*	*			*		
Strongs Run	*		*					*	*			*		
Williams Run	*		*					*	*			*		
Opossum Run		Δ						+	+			+		
Flatlick Run		Δ						+	+			+		
Karr Run							Δ	+	+				Δ	Acid Mine Drainage
Indiancamp Run							Δ	+	+			+		Acid Mine Drainage
Rockcamp Run							Δ	+	+			+		Acid Mine Drainage
Pierce Run	*						Δ	+	+			+		Acid Mine Drainage
Zinns Run		Δ						+	+			+		
Elk Fork - Puncheon Fork to mouth		Δ						+	+			+		
- headwaters to Puncheon Fork	+	+						+	+			+		
Alman Run		+						+	+			*		
Flat Run		+						+	+			*		
Wolf Run							+	+	+			*		
Puncheon Fork		Δ						+	+			+		

Stream Segment	Use Designations													Comments
		Aquatic Life						Water			Recreation			
	SRW	WWH	EWH	MWW	SSH	CWH	LRW	AWS	IWS	PWS	BW	PCR	SCR	
Austin Powder Trib.		Δ						+	+				+	
Brush Fork							o	*	*			*		Acid Mine Drainage
Long Run		Δ						+	+				Δ	
Flat Run		Δ						+	+				Δ	
Russell Run		Δ						+	+				Δ	
Merrit Run		Δ						+	+				Δ	
Tedroe Run		Δ						+	+				Δ	
Onion Creek		Δ						+	+			+		
Laurel Run		Δ						+	+			+		
Hewett Fork							o	*	*			*		Acid Mine Drainage
Rockcamp Creek		Δ						+	+			+		
Coal Run		Δ						+	+				Δ	
Pine Run		Δ						+	+			+		
Grass Run		Δ						+	+				Δ	
Sandy Run - headwaters to Lake Hope	*	*						*	*			*		
- all other segments		*						*	*			*		
Little Sandy Run	*	*						*	*			*		
Wheelabout Creek	*		*					*	*			*		
Brushy Fork	*		*					*	*			*		
Unnamed Tributary (Raccoon Cr. RM 98.96)		**Δ**						**Δ**	**Δ**			**Δ**		
Rocky Branch		*						*	*			*		
Twomile Run		Δ						+	+			+		
East Branch							+	+	+			+		Acid Mine Drainage
West Branch		Δ						+	+			+		
Honey Fork		*						*	*			*		
Claylick Run		*						*	*			*		

STUDY AREA

Description

Raccoon Creek is a tributary of the Ohio River draining 683.5 square miles of the Western Allegheny Plateau Ecoregion. Raccoon Creek is formed at the junction of the East and West Branches, which drain southern Hocking County and flows south through Vinton, Jackson and Gallia Counties where it empties into the Ohio River at Gallipolis. Total mainstem length is 109 miles. Elevation of the stream ranges from 1015 feet above sea level at the source of Brushy Fork to 518 feet above sea level at the mouth. Average fall is 3.8 feet per mile (Gazetteer of Ohio Streams ODNR 1960). The topography varies from rolling hills to steep ravines with rock outcrops and caves. There are four major state lakes in the watershed: Lake Alma, Lake Hope, Lake Rupert and Tycoon Lake.

Portions of the watershed are public land. Approximately 1800 acres are part of the Wayne National Forest, 26,380 acres are part of the Zaleski State Forest and Lake Hope State Park, 189 acres are part of Lake Alma State Park, and 1298 acres part of the Wellston Wildlife area (Lake Rupert).

The watershed is primarily rural. Most communities are unsewered except the major ones: McArthur, population 2400; Wellston, population 7200; Rio Grande, population 1200; and Gallipolis, population 9000.

Coal mining has been a major activity that has severely impacted the watershed. This activity was concentrated in the upper reaches of the watershed. Mining began in the mid 1800s using shaft and deep mines. Around the 1930s strip mining became more common. Prior to the early 1970s little effort was made to reclaim mined land. As a result, 3460 acres of surface mined land, 2826 acres of deep mined land (ODNR Mitch Farley personal communication) and 185 acres of gob (coal waste) have been abandoned. These lands contribute sediments, metals (primarily iron and aluminum), and acidic water to Raccoon Creek. Reclamation is an expensive ongoing process.

The steep topography and generally poor soils result in agricultural activity that is dominated by silviculture and grazing beef cattle. Because of the terrain, cattle are concentrated in the relatively narrow valleys where they are typically given free access to the streams. In the 1800s several iron furnaces such as Keystone and Buckeye operated in the watershed. To fuel the furnaces timber was harvested to produce charcoal. Row crops are grown in the flatter valleys were they exist.

Maps

The study area maps (Figures 2,3, and 4) contain information on identified mine sources (Ohio Department of Natural Resources, 1985b). The information was collected by field personnel from the United States Soil Conservation Service and the Ohio Department of Natural Resources. Although these maps were generated in 1985, many of the features (*i.e.* gob piles) were characteristic of conditions observed by Ohio EPA field personnel in this 1995 study.

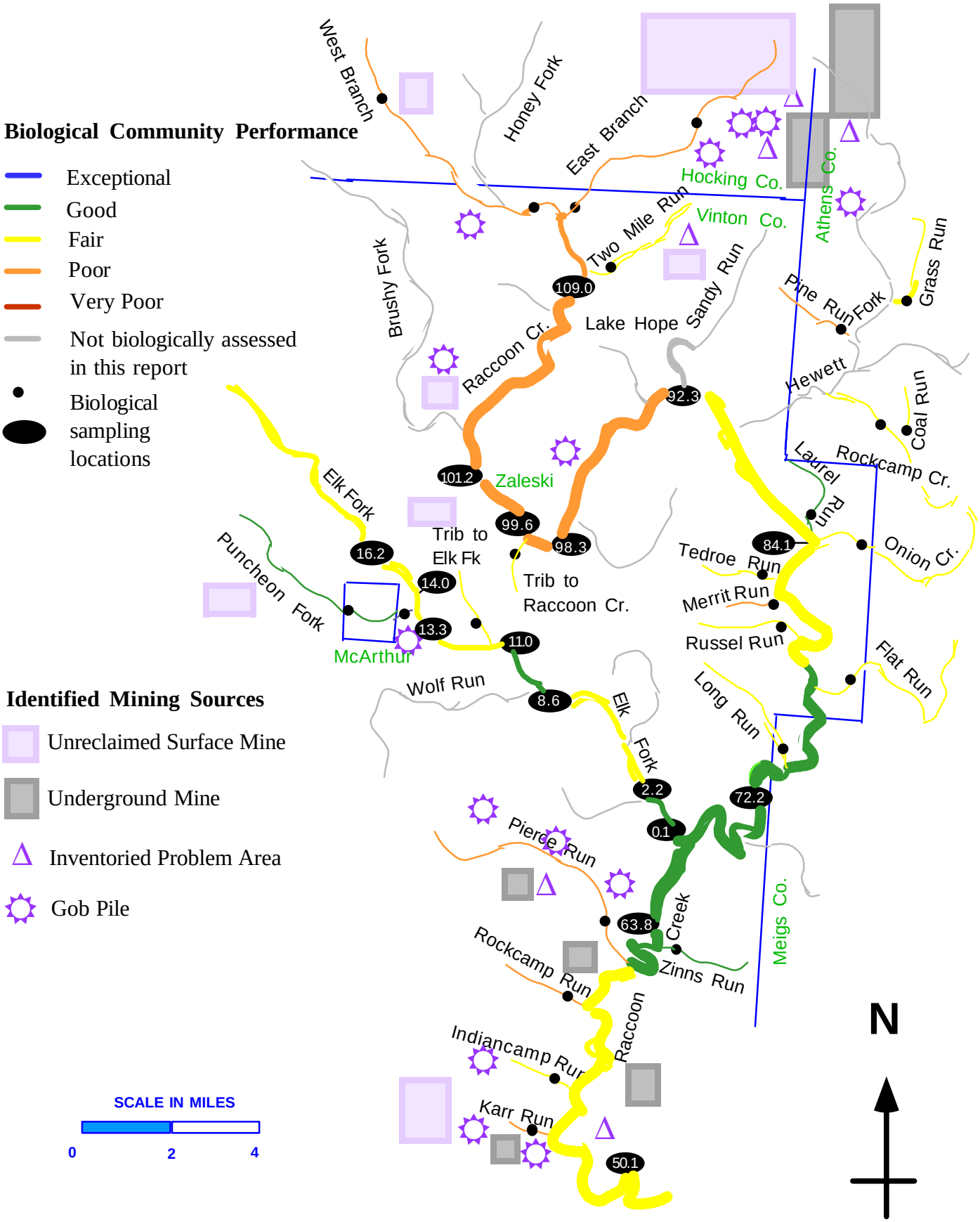


Fig 2. Upper Raccoon Creek and Elk Fork Basins

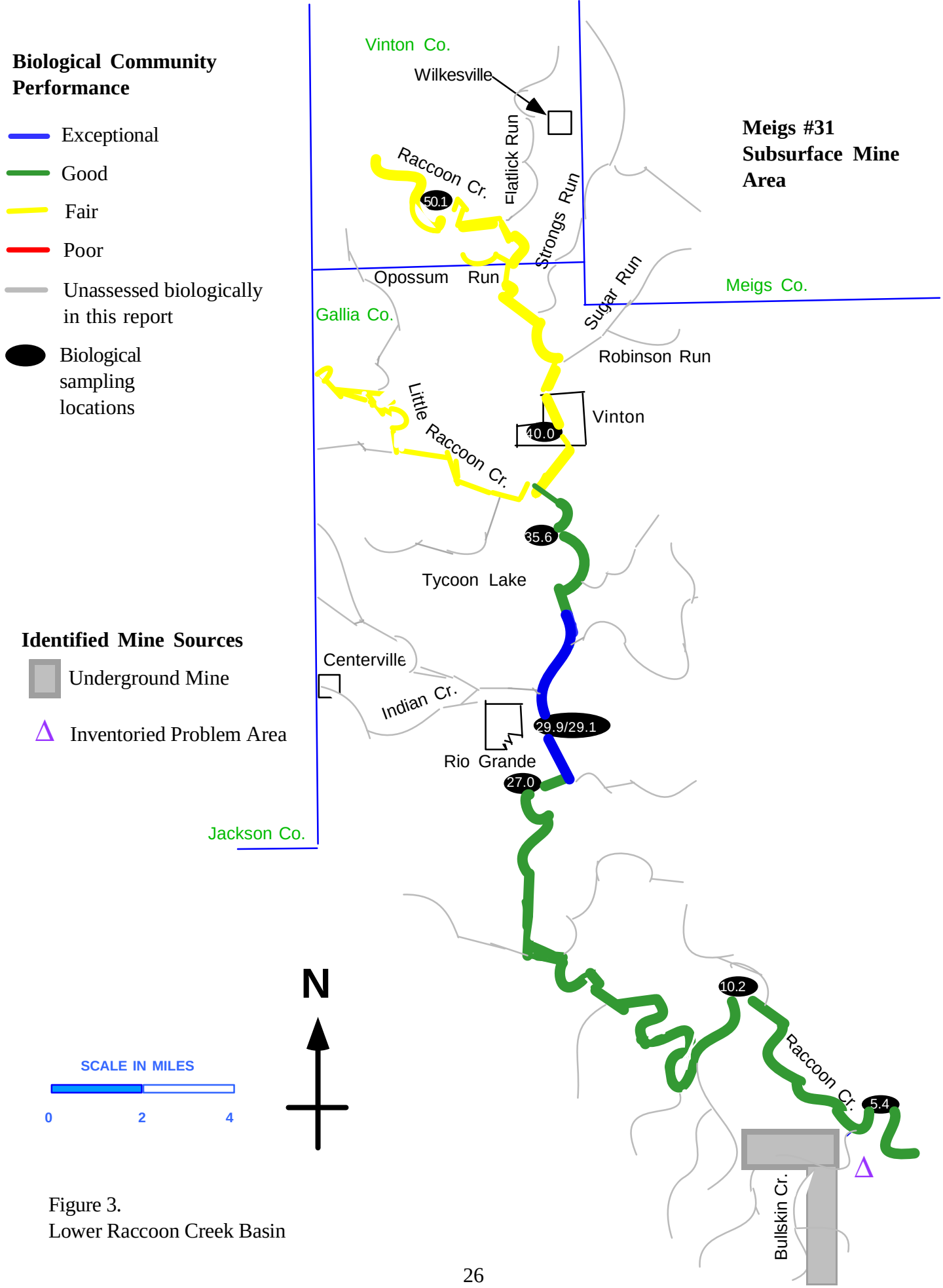


Figure 3.
Lower Raccoon Creek Basin

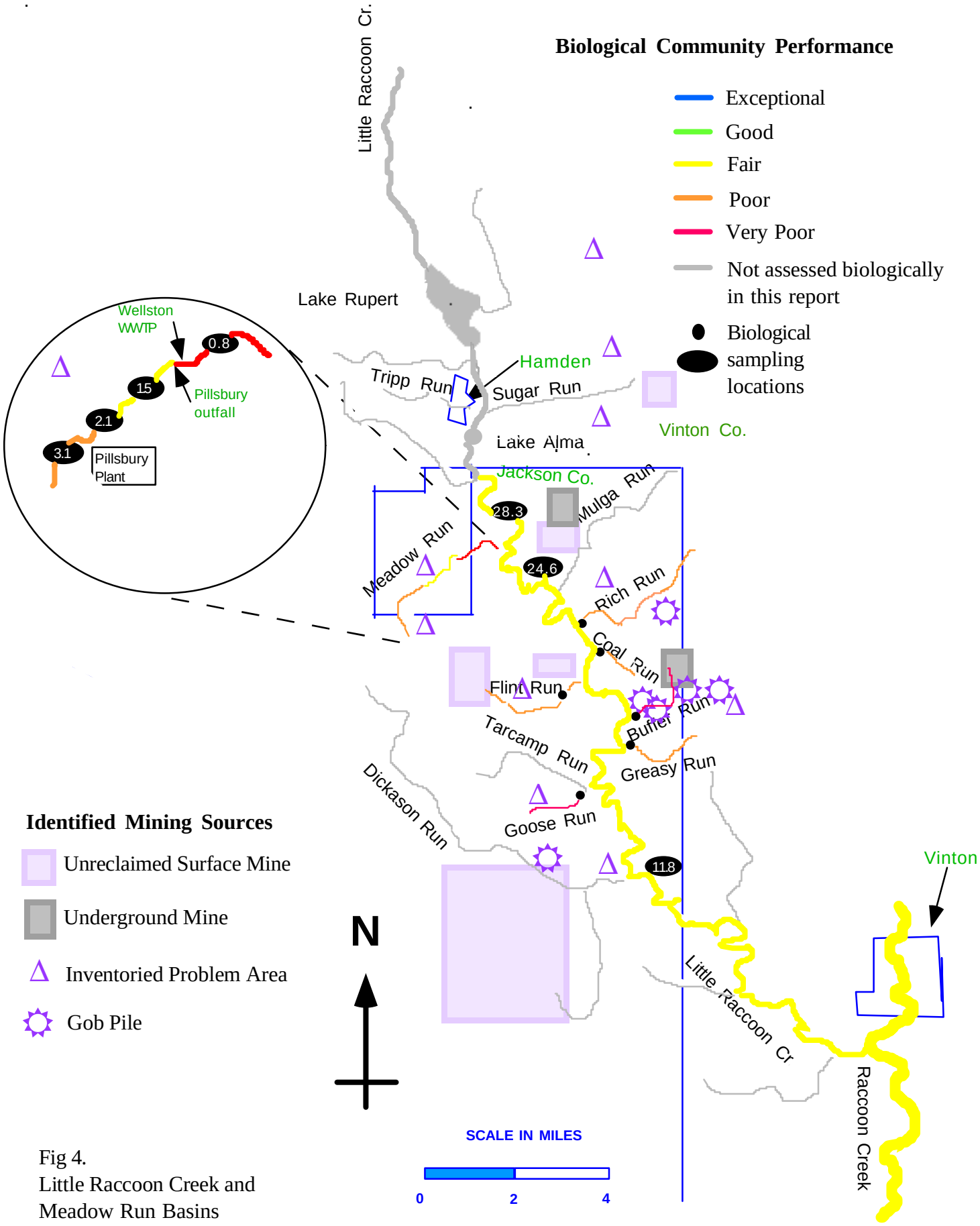


Fig 4.
Little Raccoon Creek and Meadow Run Basins

Table 4. Sampling locations in the Raccoon Creek study area, 1995 (C - conventional water chemistry, D - Datasonde continuous monitoring, F - fish, FT-fish tissue, M - benthic macroinvertebrates, S*-Sediment Organics and Sediment Metals, S²-Sediment Dioxin, S³-Sediment Organics, Metals, and Dioxin).

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 Minute Quadrangle Map
Raccoon Creek				
109.1	F	39°21'11"/82°23'23"	SR 328, dst.Twomile Run	Zaleski
109.00	C	39°21'09"/82°23'25"	SR 328, dst.Twomile Run	Zaleski
108.9	M	39°21'08"/82°23'30"	Dst SR 328	Zaleski
101.2	M	39°17'28"/82°25'36"	Adj T-18, ust. SR677	Zaleski
99.7	F	39°16'32"/82°24'54"	SR 677,ust. Austin 001 trib	Zaleski
99.60	C	39°16'32"/82°24'52"	SR 677,ust. Austin 001 trib	Zaleski
98.34	C	39°16'02"/82°24'09"	Rd. F-3,dst Austin 001 trib	Zaleski
98.4	F	39°16'01"/82°24'12"	Rd. F-3,dst Austin 001 trib	Zaleski
98.3	M	39°16'02"/82°24'06"	Rd. F-3,dst Austin 001 trib	Zaleski
92.30	C,M	39°19'02"/82°21'05"	Rd. C 3,dst Lake Hope	Mineral
84.3	M	39°15'57"/82°17'27"	Ust. SR 356	Mineral
84.1	F,D	39°15'54"/82°17'17"	SR 356,ust. Onion Ck	Mineral
84.08	C	39°15'52"/82°17'18"	SR 356,ust. Onion Ck.	Mineral
72.3	M	39°10'44"/82°18'52"	Ust C43	Vales Mills
72.20	C,D	39°10'42"/82°18'54"	Vales Mills	Vales Mills
63.80	C,M,D	39°07'49"/82°21'31"	C 28,ust. Pierce Run	Vales Mills
50.10	C,M,D	39°02'52"/82°22'35"	Humpback Bridge	Mulga
40.2	F	38°58'39"/82°20'21"	Ust. SR 160, Vinton	Vinton
40.01	C,D	38°58'34"/82°20'18"	SR 160, Vinton	Vinton
39.9	M	38°58'27"/82°20'19"	Dst. SR 160	Vinton
35.61	C,D	38°56'16"/82°20'21"	Eagle Rd, Woodsmill	Vinton
35.6	F,M	38°56'15"/82°20'20"	Woods Mill	Vinton
29.9	F	38°52'59"/82°21'11"	Ust. SR 588	Vinton
29.1	M	38°52'25"/82°21'22"	Dst. SR 588	Vinton
27.1	D	38°51'32"/82°21'44"	Garners Ford	Rodney
27.07	C	38°51'32"/82°21'44"	Garners Ford	Rodney
10.32	C,D	38°47'00"/82°17'02"	Northup, ups dam	Rodney
10.2	M	38°47'02"/82°16'24"	Northup, dst dam	Rodney
10.0	F	38°47'03"/82°16'45"	Northup, dst dam	Rodney
5.4	F,D	38°44'15"/82°14'29"	SR 218, near Thivener	Apple Grove
5.36	C	38°44'12"/82°14'43"	SR 218, near Thivener	Apple Grove

Table 4. Continued.

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 Minute Quadrangle Map
West Branch Raccoon Creek				
5.7	F,M	39°25'08"/82°28'09"	Illesboro Cedar Falls Rd	New Plymouth
5.68	C	39°25'11"/82°28'09"	Illesboro Cedar Falls Rd	New Plymouth
0.2	F	39°22'49"/82°23'54"	Illesboro Cedar Falls Rd	New Plymouth
0.15	C	39°22'49"/82°23'52"	SR 328	New Plymouth
0.1	M	39°22'43"/82°23'46"	Dst. SR 328	New Plymouth
East Branch Raccoon Creek				
6.64	C	39°24'59"/82°19'33"	Sanner Rd.	Union Furnace
6.6	F,M	39°25'00"/82°19'34"	Dst. Sanner Rd	Union Furnace
2.1	F	39°23'49"/82°22'30"	Adj. SR 56	New Plymouth
0.1	M	39°22'43"/82°23'43"	Near mouth	New Plymouth
Elk Fork				
16.2	F,M	39°15'57"/82°28'31"	Ust. SR 93	Zaleski
16.13	C	39°15'56"/82°28'33"	SR 93	Zaleski
14.1	M	39°14'57"/82°27'35"	Adj T-11,ust Puncheon Fk	McArthur
14.0	F	39°14'53"/82°27'35"	Adj T-11,ust Puncheon Fk	McArthur
13.90	C,D	34°14'48"/82°27'36"	C 12,ust. Puncheon Fork	McArthur
13.3	F,M	39°14'26"/82°27'12"	Ust. US 50	McArthur
13.26	C	39°14'29"/82°27'13"	SR 50	McArthur
11.0	F,D	39°14'00"/82°25'23"	Ust. Rd.T-8	McArthur
10.9	M,D	39°13'59"/82°25'20"	Ust. Rd.T-8	McArthur
10.88	C	39°13'59"/82°25'16"	Rd. T-8	McArthur
8.67	C	39°13'00"/82°24'17"	Rd. T-8	McArthur
8.6	F,D	39°13'02"/82°24'18"	Rd. T-8	McArthur
2.2	F	39°10'50"/82°21'40"	Adj. Rd.	Vales Mills
0.2	F,D	39°09'43"/82°21'08"	Rd. C-43B	Vales Mills
0.10	C,M,D	39°09'37"/82°21'07"	Rd. C-43B	Vales Mills
Unnamed Trib to Raccoon Creek				
0.55	C	39°15'37"/82°25'07"	Austin Powder 001	Zaleski
0.1	F,M	39°16'08"/82°24'39"	Near mouth	Zaleski

Table 4. Continued.

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 Minute Quadrangle Map
Puncheon Fork				
1.6	M	39°14'34"/82°29'08"	Ust. C-25	McArthur
1.51	C	39°14'36"/82°29'04"	C 25, ust. McArthur 001	McArthur
1.5	F	39°14'36"/82°29'36"	C 25, ust. McArthur 001	McArthur
1.28	C	39°1432"/82°28'50"	McArthur 001 effluent	McArthur
0.3	F,M	39°14'43"/82°28'01"	At T-11	McArthur
0.28	C	39°14'44"/82°27'55"	T 11, dst. McArthur 001	McArthur
Unnamed Trib. to Elk Fork				
0.4	M	39°14'15"/82°25'52"	At C-7	McArthur
Little Raccoon Creek				
32.95	C	39°10'20"/82°31'13"	SR 93, dst. Lake Rupert	Hamden
32.80	D	39°10'20"/82°31'13"	SR 93, dst. Lake Rupert	Hamden
30.20	D	39°08'28"/82°30'57"	SR 349, dst. Lake Alma	Hamden
30.18	C	39°08'28"/82°30'57"	SR 349, dst. Lake Alma	Hamden
28.3	M	39°07'29"/82°30'21"	Ust. Meadow Run	Mulga
27.9	C,F	39°07'21"/82°29'58"	Ust. Meadow Run	Hamden
26.7	D	39°06'33"/82°30'08"	Ust. Meadow Run	Hamden
25.4	D	39°06'08"/82°29'39"	Dst Meadow Run	Mulga
24.6	M	39°06'01"/82°29'07"	Dst Meadow Run	Mulga
24.55	C,F	39°06'01"/82°29'05"	Dst. Meadow Run-SR 32	Mulga
12.71	C,F,D	39°00'39"/82°27'09"	Keystone Furnace Road	Mulga
11.8	M	39°00'33"/82°26'40"	Adj Keystone Furnace Rd	Mulga
Little Raccoon Creek trubutaries (RM confluence)				
Meadow Run (27.1)				
3.1	C,F,M,S*	39°05'45"/82°32'48"	Ust. Pillsbury facility	Wellston
3.02	D	39°05'45"/82°32'48"	Ust. Pillsbury facility	Wellston
2.90	D	39°05'49"/82°32'48"	Dst. Pillsbury facility	Wellston
2.23	C,F	39°06'17"/82°32'14"	Ust. SR 327	Wellston
2.1	M,D	39°06'18"/82°32'09"	SR 327	Wellston
1.6	FT	39°06'34"/82°31'36"	14th Street	Wellston
1.5	M,D	39°06'34"/82°31'36"	14th Street	Wellston
1.47	C,F,S[3]	39°06'34"/82°31'35"	14th Street	Wellston
1.30	D	39°06'42"/82°31'31"	Ust Wellston WWTP	Wellston
1.26	D	39°06'43"/82°31'30"	Ust Wellston WWTP	Wellston
1.19	E	39°06'45"/82°31'29"	Pillsbury effluent 001	Wellston
1.18	M,D	39°06'45"/82°31'28"	Pillsbury mix zone	Wellston
1.17	E	39°06'46"/82°31'27"	Wellston WWTP 001	Wellston
1.16	M,S[2]	39°06'46"/82°31'26"	Wellston WWTP mix	Wellston
0.8	M,FT,D	39°06'54"/82°30'58"	Ust. Cheatwood Road	Wellston
0.72	C,F,S[3]	39°06'56"/82°30'56"	Cheatwood Road	Wellston
0.38/0.10	D	39°07'05"/82°30'41"	Sinkhole overflow	Wellston
0.05	D	39°06'54"/82°30'18"	Near mouth	Wellston
0.01	D	39°06'53"/82°30'15"	At mouth	Wellston

Table 4. Continued.

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 Minute Quadrangle Map
Little Raccoon Creek tributaries (RM confluence)				
Tripp Run (31.6)				
1.83	C	39°09'53"/82°32'27"	Cox Road	Hamden
0.30	C,D	39°09'24"/82°30'56"	SR 349 bridge	Hamden
Mulga Run (24.45)				
1.30	D	39°06'56"/82°27'79"	At permanent site	Mulga
0.60	D	39°06'23"/82°28'36"	Ust wetland	Mulga
0.12/0.03	D	39°05'59"/82°28'59"	Last wetland rivulet	Mulga
0.10	C,D	39°06'01"/82°28'56"	Near mouth	Mulga
0.05	D	39°05'58"/82°28'57"	At mouth	Mulga
Rich Run (22.22)				
1.5	C,F	39°05'34"/82°27'24"	Mulga Rd	Mulga
0.1	M	39°05'18"/82°28'27"	Near mouth	Mulga
Coal Run (21.6)				
0.1	M	39°04'55"/82°28'02"	Mohawk Rd	Mulga
0.08	C,F	39°04'53"/82°28'04"	Near mouth	Mulga
Flint Run (20.74)				
1.2	M	39°04'10"/82°28'46"	At RM 1.2	Mulga
0.5	F	39°04'21"/82°28'34"	Near mouth	Mulga
Buffer Run (19.2)				
0.2	M	39°03'41"/82°27'08"	Buckeye Pk Rd	Mulga
0.17	C,F	39°03'40"/82°27'09"	Buckeye Pk Rd	Mulga
Greasy Run (18.2)				
0.1	M	39°03'08"/82°27'23"	Near mouth	Mulga
0.02	F	39°03'08"/82°27'26"	Near mouth	Mulga
Goose Run (16.41, 0.1)				
0.4	F,M	39°02'06"/82°28'29"	Adj. Goose Run Rd	Mulga

Table 4. Continued.

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 Minute Quadrangle Map
Raccoon Creek tributaries (RM confluence)				
Twomile Run (109.38)				
0.16	C	39°21'27"/82°22'57"	Vinton Co. Rd. 1	Mineral
0.1	F,M	39°21'25"/82°23'02"	Dst. N.R. 18	Mineral
Grass Run (89.54,8.22)				
0.1	F,M	39°20'45"/82°15'18"	SR 356	Mineral
0.04	C	39°20'45"/82°15'18"	SR 356	Mineral
Pine Run (89.43, 6.68)				
0.1	M	39°20'10"/82°16'25"	near mouth	Mineral
Rockcamp Creek (89.54, 4.01)				
1.6	M	39°18'32"/82°15'51"	SR 356	Mineral
1.5	C,F	39°18'22"/82°15'38"	Adj SR 681	Mineral
Coal Run (89.54, 4.01, 2.5)				
O.1	M	39°17'59"/82°15'03"	SR 681	Mineral
Laurel Run (84.34)				
0.16	C	39°16'06"/82°17'24"	Rd. T-18	Mineral
0.1	M	39°16'03"/82°17'24"	Rd. T-18	Mineral
Onion Creek (84.04)				
1.4	C,F,M	39°15'39"/82°16'00"	Adj. CR 4/Bailey Rd	Mineral
Tedroe Run (82.80)				
0.1	C,F,M	39°15'11"/82°18'23"	Rd.T-13, near mouth	Mineral
Merrit Run (82.2)				
0.1	F,M	39°14'46"/82°18'09"	Near mouth	Vales Mills
0.12	C	39°14'48"/82°18'09"	Near mouth	Vales Mills
Russell Run (79.43)				
0.7	M	39°14'13"/82°18'04"	Adj. SR 50	Vales Mills
0.6	C,F	39°14'09"/82°18'01"	Adj. SR 50	Vales Mills

Table 4. Continued.

Stream/ River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 Minute Quadrangle Map
Raccoon Creek tributaries (RM confluence)				
Flat Run (77.88)				
1.6	C,F,	39°13'12"/82°16'16"	SR 50	Vales Mills
1.3	M	39°13'08"/82°16'26"	Dst. SR 50	Vales Mills
Long Run (74.6)				
1.4	M	39°12'20"/82°18'30"	Rd. T-11 K	Vales Mills
0.02	C,F	39°11'15"/82°18'10"	Near mouth	Vales
Zinns Run (63.51)				
0.5	M	39°07'43"/82°21'00"	At U.S.G.S. Gauge	Vales Mills
0.08	C,F	39°12'20"/82°18'30"	Near mouth	Vales Mills
Pierce Run (60.46)				
1.7	F,M	39°08'29"/82°22'49"	Radcliff bridge	Vales Mills
1.67	C	39°08'28"/82°22'49"	Radcliff	Vales Mills
Rockcamp Run (58.90)				
0.4	M	39°06'39"/82°23'27"	Rd. C-9	Mulga
0.3	C,F	39°06'34"/82°23'16"	Rd. C-9	Mulga
Indiancamp Run (55.23)				
0.3	M	39°05'06"/82°23'56"	Rd. C-26	Mulga
0.2	C,F	39°05'01"/82°23'46"	Rd. C-26	Mulga
Karr Run (53.84)				
0.2	F,M	39°04'07"/82°24'24"	Rd. T-8	Mulga
Opossum Run (46.05)				
0.15	C	39°01'53"/82°21'57"	Grey Rd	Wilkesville
0.1	F,M	39°01'53"/82°21'17"	Grey Rd	Wilkesville

METHODS

All chemical, physical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c), and The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995) for aquatic habitat assessment. Chemical, physical and biological sampling locations are listed in Table xx.

Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-14). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the Index of Biotic Integrity (IBI) and modified Index of Well-Being (MIwb), indices measuring the response of the fish community, and the Invertebrate Community Index (ICI), which indicates the response of the macroinvertebrate community. Numerical endpoints are stratified by ecoregion, use designation, and stream or river size. Three attainment status results are possible at each sampling location - Full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the Ohio WQS biocriteria or the LRW-AMD benchmarks. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria or the LRW-AMD benchmarks. Non-attainment means that none of the applicable indices meet the biocriteria or the LRW-AMD benchmarks; or, for WWH and EWH streams, one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table (see Table 1) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.*, full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), and comments and observations for each sampling location.

The attainment status of aquatic life uses (*i.e.*, Full, partial, and non-attainment) is determined by using the biological criteria codified in the Ohio Water Quality Standards (WQS; Ohio Administrative Code [OAC] 3745-1-07, Table 7-14). The biological community performance measures used include the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), based on fish community characteristics, and the Invertebrate Community Index (ICI) which is based on macroinvertebrate community characteristics. The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch *et al.* (1984). The ICI was developed by Ohio EPA (1987b) and further described by DeShon (1995). The MIwb is a measure of fish community abundance and diversity using numbers and weight information and is a modification of the original Index of Well-Being originally applied to fish community information from the Wabash River (Gammon 1976; Gammon *et al.* 1981).

Performance expectations for the principal aquatic life uses in the Ohio WQS (Warmwater Habitat [WWH], Exceptional Warmwater Habitat [EWH], and Modified Warmwater Habitat [MWH]) were developed using the regional reference site approach (Hughes *et al.* 1986; Omernik 1987). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981). Attainment of the aquatic life use is full if all three indices (or those available) meet the applicable biocriteria, partial if at least one of the indices does not attain and performance is fair, and non-attainment if all indices fail to attain or any index indicates poor or very poor performance. Partial and non-attainment indicate that the receiving water is impaired and does not meet the designated use criteria specified by the Ohio WQS.

Habitat Assessment

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional

aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the habitat characteristics used to determine the QHEI score which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently typify habitat conditions which have the ability to support exceptional warmwater faunas.

Macroinvertebrate Community Assessment

Macroinvertebrates were sampled quantitatively using multiple-plate, artificial substrate samplers (modified Hester/Dendy) in conjunction with a qualitative assessment of the available natural substrates. During the present study, analyses of macroinvertebrate data collected from the natural substrates was supplemented using an assessment tool currently in the testing and refinement phase. This method relies on tolerance values derived for each taxon, based upon the abundance data for that taxon from artificial substrate (quantitative) samples collected throughout Ohio. To determine the tolerance value of a given taxon, ICI scores at all locations where the taxon has been collected are weighted by its abundance on the artificial substrates. The mean of the weighted ICI scores for the taxon results in a value which represents its relative level of tolerance on the 0 to 60 scale of the ICI. For the qualitative collections in the Raccoon Creek study area, the median tolerance value of all organisms from a site resulted in a score termed the Qualitative Community Tolerance Value (QCTV). The QCTV shows potential as a method to supplement existing assessment methods using the natural substrate collections. Use of the QCTV in evaluating sites in the Raccoon Creek study area was restricted to relative comparisons between sites and was not unilaterally used to interpret quality of the sites or aquatic life use attainment status.

The numerical LRW-AMD benchmark for attainment status is an ICI score of 8. For qualitative only data in a LRW-AMD stream , a very poor narrative evaluation or a poor evaluation at a site where EPT taxa were not considered to be common or predominant on the natural substrates, was assessed as non-attainment status. A poor narrative evaluation at a qualitative only site was assessed as achieving the LRW-AMD benchmark if there were any EPT taxa observed to be common or predominant on the natural substrates.

Fish Community Assessment

Fish were sampled using wading or boat method pulsed DC electrofishing gear. The wading method was used at a frequency of one or two samples at each site. The boat method was used at a frequency of two samples at each site except at RM 28.1 of the Grand River where the boat method was used on the first pass, and the wading method on the second pass due to low flows.

Area of Degradation Value (ADV)

An Area Of Degradation Value (ADV; Rankin and Yoder 1991; Yoder and Rankin 1995) was calculated for the study area based on the longitudinal performance of the biological community indices. The ADV portrays the length or "extent" of degradation to aquatic communities and is simply the distance that the biological index (IBI, MIwb, or ICI) departs from the applicable biocriterion or the upstream level of performance (Figure 5). The “magnitude” of impact refers to the vertical departure of each index below the biocriterion or the upstream level of performance. The total ADV is represented by the area beneath the biocriterion (or upstream level) when the results for each index are plotted against river mile. The results are expressed as ADV/mile to normalize comparisons between segments, sampling years, and other streams and rivers.

Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of

impairment. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data, and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem "health" compared to human patient "health" (Suter 1993), in this document we are referring to the process for evaluating biological integrity and causes or sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

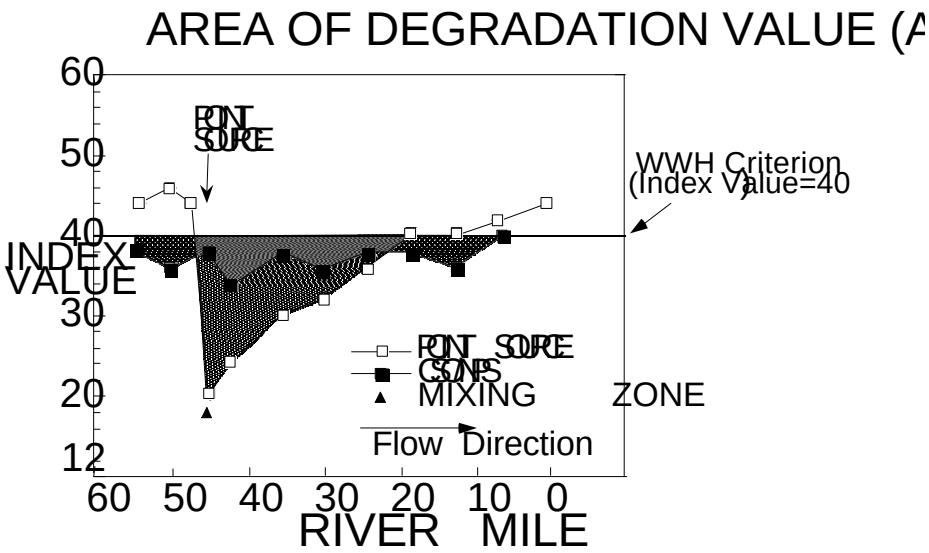


Figure 5. Graphic illustration of the Area of Degradation Value (ADV) based on the ecoregion biocriterion (WWH in this example). the index value trend line indicated by the unfilled boxes and solid shading (area of departure) represents a typical response to a point source impact (mixing zone appears as a solid triangle); the filled boxes and dashed shading (area of departure) represent a typical response to a nonpoint source or combined sewer overflow impact. The blended shading represents the overlapping impact of the point and nonpoint sources.

RESULTS AND DISCUSSION

Pollutant Loadings: 1985-1995

Wellston WWTP

The original plant was built in 1939, and upgraded in 1961. This plant, formerly known as the North Plant discharged at RM 1.20 on Meadow Run. Improvements were made during a 1992 upgrade and the discharge location is now at RM 1.17. The Pillsbury (previously known as Jenos) discharge location was located at RM 1.19 during the 1995 survey. The 1992 Wellston WWTP upgrade involved the following improvements to the wastewater treatment plant: (1) improvements in pre-screening at the headworks; (2) new pumps to handle the flow variations and the elimination of the bypass from the headworks; (3) grit removal facilities; (4) a new biological treatment unit; (5) new secondary settling tanks; (6) ultraviolet disinfection; and (7) improved sludge handling and treatment facilities, including a belt press and aerated sludge holding facilities. The City of Wellston extended sanitary sewer service to the South Wellston area, an area with a concentration of failing septic systems. This action aided in the elimination of the discharge of inadequately treated sewage to that segment of Meadow Run. The City of Wellston also started sewer rehabilitation in February 1996. The work will separate combined sewers into separate sanitary and storm sewers. The Wellston WWTP currently has a design flow of 1.44 MGD, with a peak maximum daily flow of 6.5 MGD. This extreme flow variation is attributed to increased flows from infiltration and inflow into the city's sanitary sewers and precipitation entering the combined sewers within the city.

Monthly operating report data since the plant upgrade, from 1993 to 1995, indicates NPDES permit violations (#) for ammonia (20), cadmium (9), copper (5), dissolved oxygen (6), fecal coliform bacteria (1), lead (6), mercury (10), and oil and grease (1). While many violations still continue to occur, the loadings trend data show a decline of pollutant loadings in 1993, followed by slight increases in 1994 and 1995 (Figure 6). Sampling of the Wellston 001 outfall during the 1995 survey showed high ammonia concentrations (5.50 mg/l, average).

Ambient water chemistry data from 1995 showed higher levels of ammonia, BOD_5, COD, chlorine, conductivity, nitrate-nitrite, oil and grease, phosphorus, total dissolved solids, total Kjeldahl nitrogen, and total suspended solids in Meadow Run downstream (RM 0.72) from the Pillsbury and Wellston WWTP outfalls compared to upstream (RM 1.42). Dissolved oxygen was lower at the downstream site. The increases in average ammonia (from 0.09 to 6.2 mg/l) and BOD_5 (from 2.1 to 12 mg/l) concentrations, and decrease in the average dissolved oxygen (from 6.1 to 2.9 mg/l) concentration from upstream to downstream in the 1995 survey was very similar to the chemical results from the 1984 survey. Direct comparisons of the 1990 survey data is complicated because the chemical sampling stations were not at the same locations, and the Pillsbury outfall 001 was located at RM 3.00 in 1990.

Sediment data from 1995 showed higher sediment concentrations of chromium, copper, dioxins and dibenzofurans, lead, and zinc downstream (RM 0.72) from the Pillsbury and Wellston WWTP discharges compared to upstream (RM 1.47). Sediment organic data from 1995 showed most organochlorine pesticides to be present at low levels or below detection.

The city of Wellston performed bioassay testing from January l993 through January 1994, as part of a requirement of their NPDES permit. Of the twelve tests performed, eight tests were acute tests and four were chronic tests. The test organisms were fathead minnows (*Pimephales promelas)* and microcrustacean, *Ceriodaphnia dubia.* Acute tests were conducted for 48-hour and 96-hour periods. The chronic tests were all conducted for a period of seven days. Mortality in the various dilutions during the acute testing was minimal throughout the testing period, except for the July 1993 bioassay which resulted in 100% mortality to *C. dubia*. Chronic testing resulted in a 1.2 TU_c to *P. promelas* in two tests (March and June, 1993).

Ohio EPA conducted bioassay testing of Wellston's effluent in August, September, and October 1989, July 1990, and March and August 1995. Test organisms also consisted of *P. promelas* and *C. dubia.* Acute tests were conducted for 48 hours. The effluent was acutely toxic to both species in all three of the bioassays conducted in 1989. In the July 1990 and the March 1995 bioassays, the effluent was not acutely toxic to either species. Acute toxicity was noted again in both species during the August 1995 sample, possibly attributable to the high ammonia levels in the effluent. No chronic testing was performed by the Ohio EPA lab.

Pillsbury WWTP (also referred to as Jeno's or the Wellston South Plant)
This wastewater treatment plant, built in 1968, was operated by the City of Wellston until July 1,1985, and was referred to as the South Plant. The plant has been in consistent violation of suspended solids and dissolved oxygen permit limits, believed to be due to the final treatment lagoon and the post aeration lagoon. Both lagoons have been plagued by excessive algae, depleting the oxygen levels prior to discharging to Meadow Run at RM 1.19.

Pillsbury began construction of a wastewater treatment plant upgrade during the spring of 1995. However, the new processes were not on line during the sampling period. The upgrade consisted of the following: (1) improved grit removal and housing for the pretreatment facilities; (2) improved oil and grease removal and general repair to the primary clarifiers; (3) construction of a new secondary clarifier; and (4) the addition of a new effluent line which bypasses the two final lagoons. These facilities were completed April 1996.

The design average wastewater and production water output from this facility is 0.7 MGD at Outfall 001. The current discharge is located at RM 1.19, on the opposite stream bank from the City of Wellston WWTP. Pillsbury also has a cooling water discharge (Outfall

002) with an estimated discharge of 0.25 MGD. The non-contact cooling water is discharged to Meadow Run just downstream from RM 3.1, one of the sampling sites during the 1995 survey.

On December 1,1995, flow from the two final lagoons ceased to discharge. The flow was directed from the final polishing lagoon to the outfall sewer which discharges at RM 1.19, across from the Wellston WWTP. It is planned that Pillsbury will be issued an NPDES permit at the same time that the city of Wellston's permit is issued. Discussion has been on-going between Pillsbury and Ohio EPA concerning the continuation of discharging at RM 1.19 or using an alternate newly constructed outfall at RM 2.0.

The effluent violations for Outfalls 001 and 002 are summarized in the Appendix. This list is based on the Notices of Violations sent to Pillsbury, and may not include all violations that occurred during the ten-year time period that is noted. It should also be recognized that Pillsbury was under interim effluent limits until May 10, 1990. A review of the loading data (Figure 7) shows that, while the number of effluent violations appear to have increased, the actual loadings for most of the parameters have declined. The only exception to this statement is that the total suspended solids loadings have increased steadily over the last three years.

Results from the 1995 field season reflect violations of dissolved oxygen during all seven sampling runs. Values ranged from 0.8 to 2.2 mg/l. The NPDES permit requires a minimum dissolved oxygen level of 6.0 mg/l during the summer months. pH exceeded 9.0 S.U. during six of the seven sampling events. Metals in Pillsbury's effluent were typically not a concern, except during the sampling event on September 27, when copper was 149 ug/l, nickel was 103 ug/l, and zinc was 174 ug/l. This could possibly be attributed to the lagoon "turning over" and accumulated matter from the bottom of the lagoon discharging with the effluent. All other sampling events found these parameters to be typically below detection levels or just at detection levels.

The only spill reported during the last five years in the Little Raccoon Creek basin occurred in Meadow Run on December 1, 1995. While Pillsbury was pumping their lagoons, a valve failed causing flow from the large polishing pond to enter Meadow Run. The estimated volume was approximately 196,000 gallons.

McArthur WWTP

The village of McArthur is developed both residentially and commercially. The major industries are mining and forestry. The 1990 population figures note slightly over 2000 residents. The existing average daily flow to the treatment facility is 0.134 MGD. The peak hourly flow is 2.68 MGD.

Prior to 1992 the existing wastewater treatment plant consisted of a two cell facultative

lagoon which discharged to Elk Fork.

The new system which came on line in November of 1992 consists of a four cell aerated lagoon with a combined total volume of 86,000 gallons, a 13,000 square foot rock filter, and an effluent pump station. The effluent enters the aerated lagoons, flows to the facultative lagoons, and through the rock filters, and is then pumped approximately 5875 feet south to Puncheon Fork RM 1.28. Puncheon Fork is a tributary of Elk Fork which is impacted by acid mine drainage. The system is designed to meet secondary standards for lagoons which includes 25 mg/l $CBOD_5$ and 65 mg/l TSS for the 30-day average.

Since the 1992 upgrade became operational, both BOD_5 and TSS loads have decreased substantially (Figure 8). The BOD_5 for the three year period of 1990-1992 averaged 16.99 kg/day. For the three year period 1993-1995 after the upgrade of the plant, the BOD_5 averaged 6.26 kg/day. TSS for the period of 1990-1992 had an average loading of 27.9 kg/day; the period of 1993-1995 had an average load of 9.76 kg/day.

Austin Powder

Austin Powder, with corporate headquarters in Cleveland, Ohio, is a wholly owned subsidiary of Davis Mining and Manufacturing, Incorporated. The Red Diamond plant is located 2.5 miles east of McArthur, Ohio on a 1358 acre tract of land. The company has been manufacturing commercial explosives since 1930 at the Red Diamond plant. The products produced at the plant include blasting agents, emulsions, detonating cord, detonators, dynamites, gelatins, and other explosives and blasting supplies.

Prior to 1986, the discharges originated from several ponds on the facility grounds. These were monitored at stream points at the north and south end of the property boundaries. At that time these stations were listed as 001 and 002. Currently, the stations are considered downstream sites listed as station 901 which discharges to an unnamed tributary of Elk Fork (referred to as Austin Powder Tributary in a previous study) and station 902 which discharges to an unnamed tributary of Raccoon Creek.

There are currently seven permitted outfalls on the site. They consist of small package plants with various waste sources as listed below.

OUTFALL	WASTE	TREATMENT	FLOW[1]
001	Process , Sanitary	Settling, Filtering Carbon ,Aeration	1800 GPD (2500)
002	Sanitary	Extended air, Sand Filters	125 GPD (2000)
003	Sanitary, Showers, Laundry	Extended air, Sand Filters	420 GPD (2500)
004	Sanitary, Showers	Extended air, Sand Filters	760 GPD (3500)
005	Sanitary	Extended air, Sand Filters	920 GPD (2500)
006	Sanitary, Showers, Laundry	Extended air, Sand Filters	400 GPD (2500)
007	Boiler Blowdown, Runoff	Settling, pH adjustment	65000 GPD (?)

[1] Flow data is from Monthly Operating Reports, design flow is in parentheses.

During the 1995 survey only Outfall 001 was evaluated. It contains the only process water being discharged and the other discharges (with the exception of 007) were very small flows. Outfall 007 was thought to have a limited impact on receiving waters.

Discharges 002, 003, 004, 006, and 007 discharge to an unnamed tributary (referred to as the Austin Powder Tributary) of Elk Fork. Discharges 001 and 005 flow into an unnamed tributary of Raccoon Creek.

For the period from 1987 thru 1995, the 001 Monthly Operating Report data showed little loading variance to the unnamed tributary to Raccoon Creek (Figure 9). The mean 95th percentile load for TSS was 0.335 kg/day. The maximum load was 1.7 kg/day and the minimum was 0.0076 kg/day. The ammonia mean (95th percentile) load was 0.063 kg/day. The maximum was 0.40 kg/day and the minimum was 0.0005 kg/day. Nitrite-nitrate loadings were also small. The 95th percentile mean was 0.080 kg/day. The minimum load was 0.0008 kg/day and the maximum load was 0.26 kg/day.

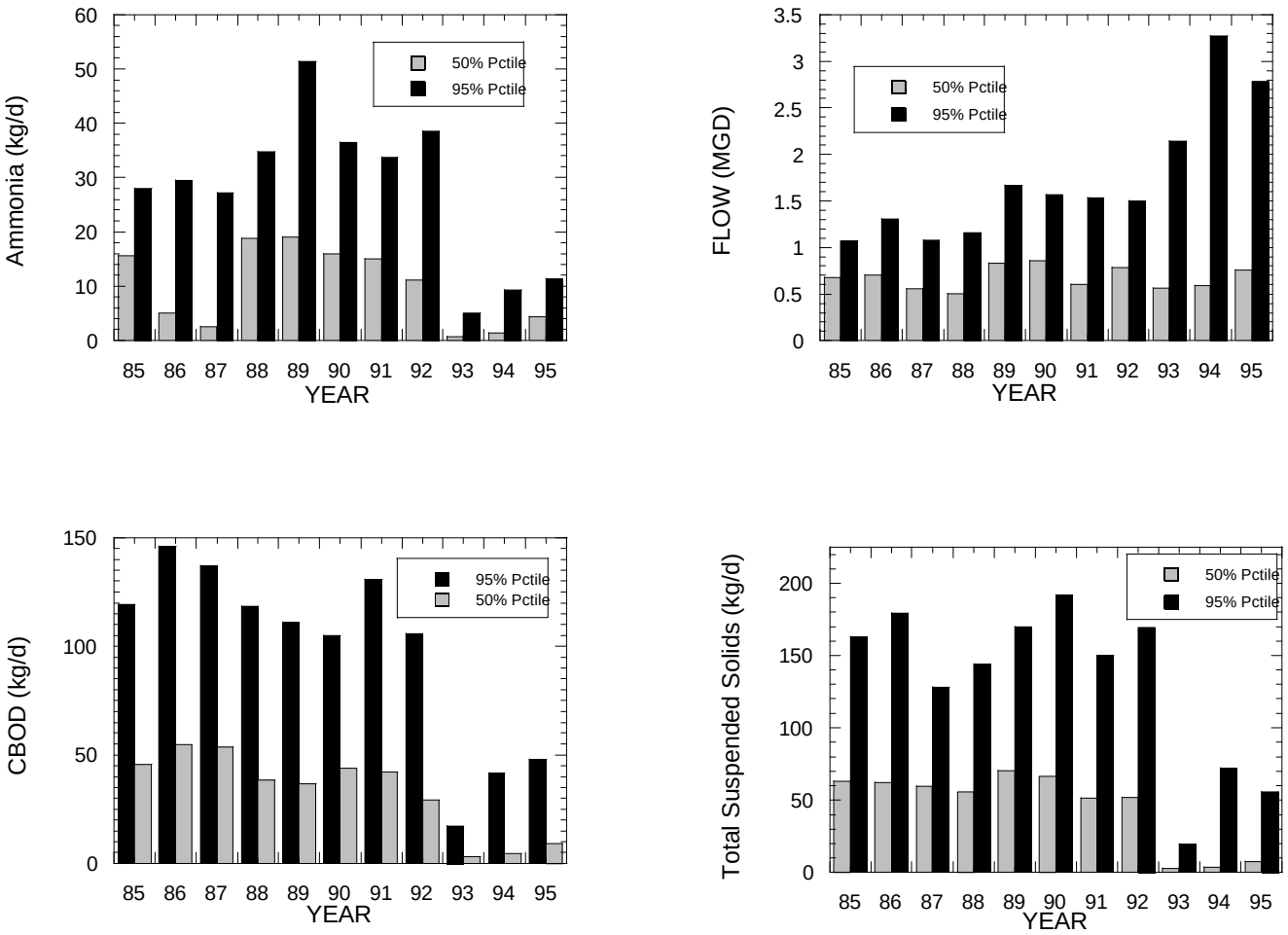


Figure 6. Median and 95th percentile flow (MGD) and median and 95th percentile annual loadings (kg/day) of ammonia, $_{CBOD5}$, and total suspended solids (TSS) for the Wellston WWTP outfall 001, 1985-95.

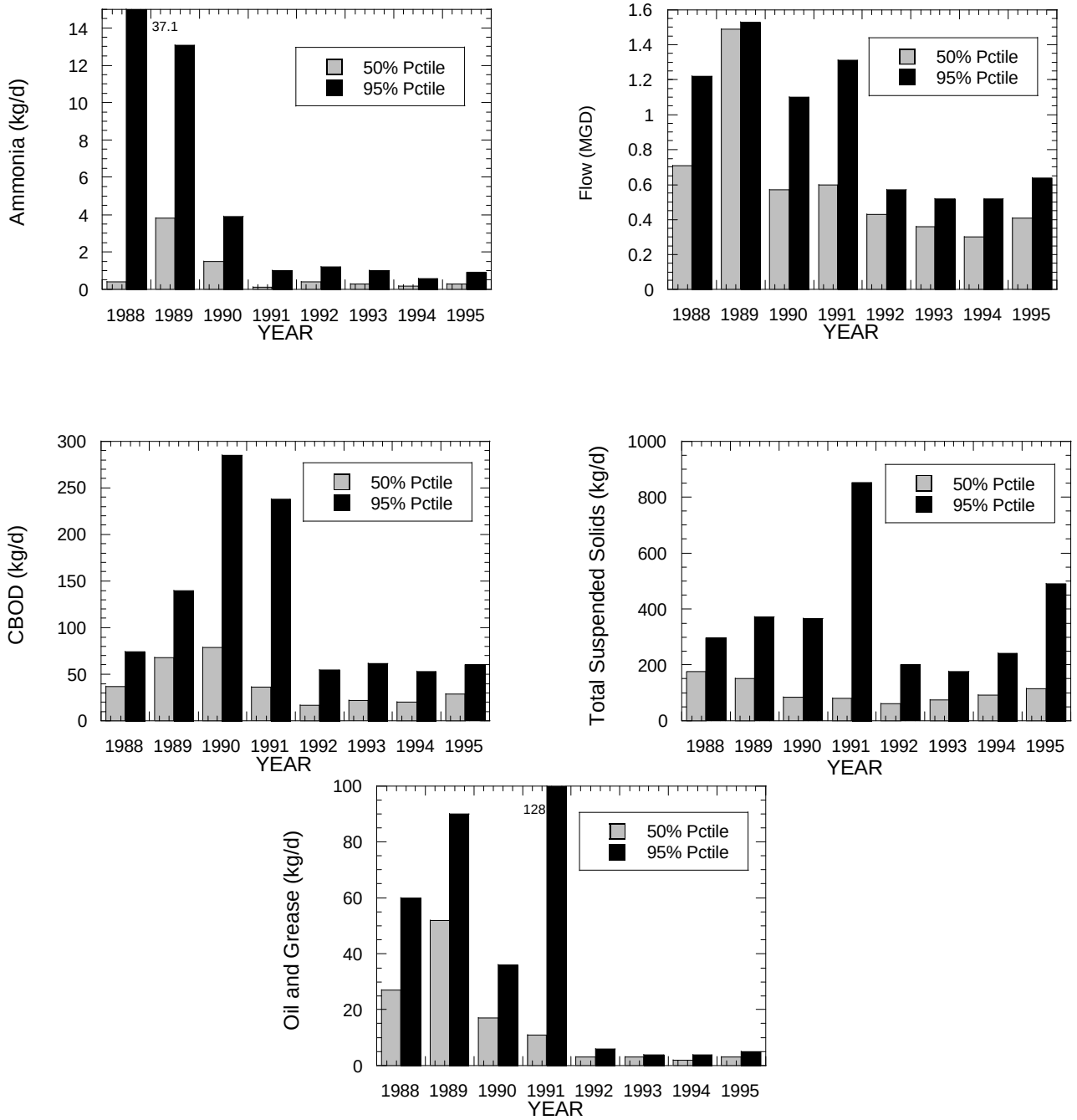


Figure 7. Median and 95th percentile flow (MGD) and median and 95th percentile annual loadings (kg/day) of ammonia, $_{CBOD5}$, total suspended solids (TSS), and oil and grease for the Pillsbury(Jenos) outfall 001, 1988-95.

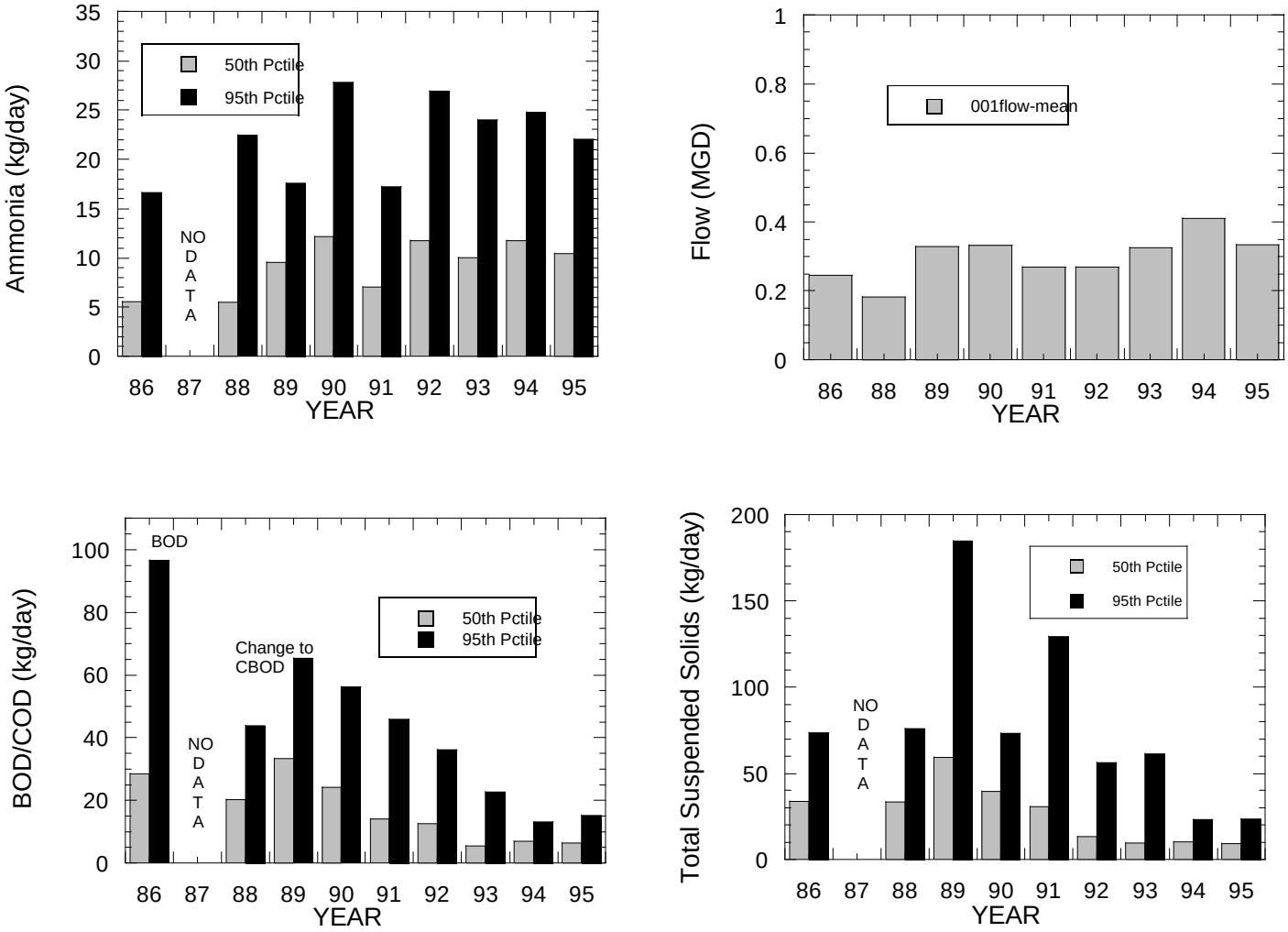


Figure 8. Median and 95th percentile annual loadings (kg/day) of ammonia, $CBOD_5$, and total suspended solids (TSS), and yearly mean flow for McArthur WWTP outfall 001, 1986-95.

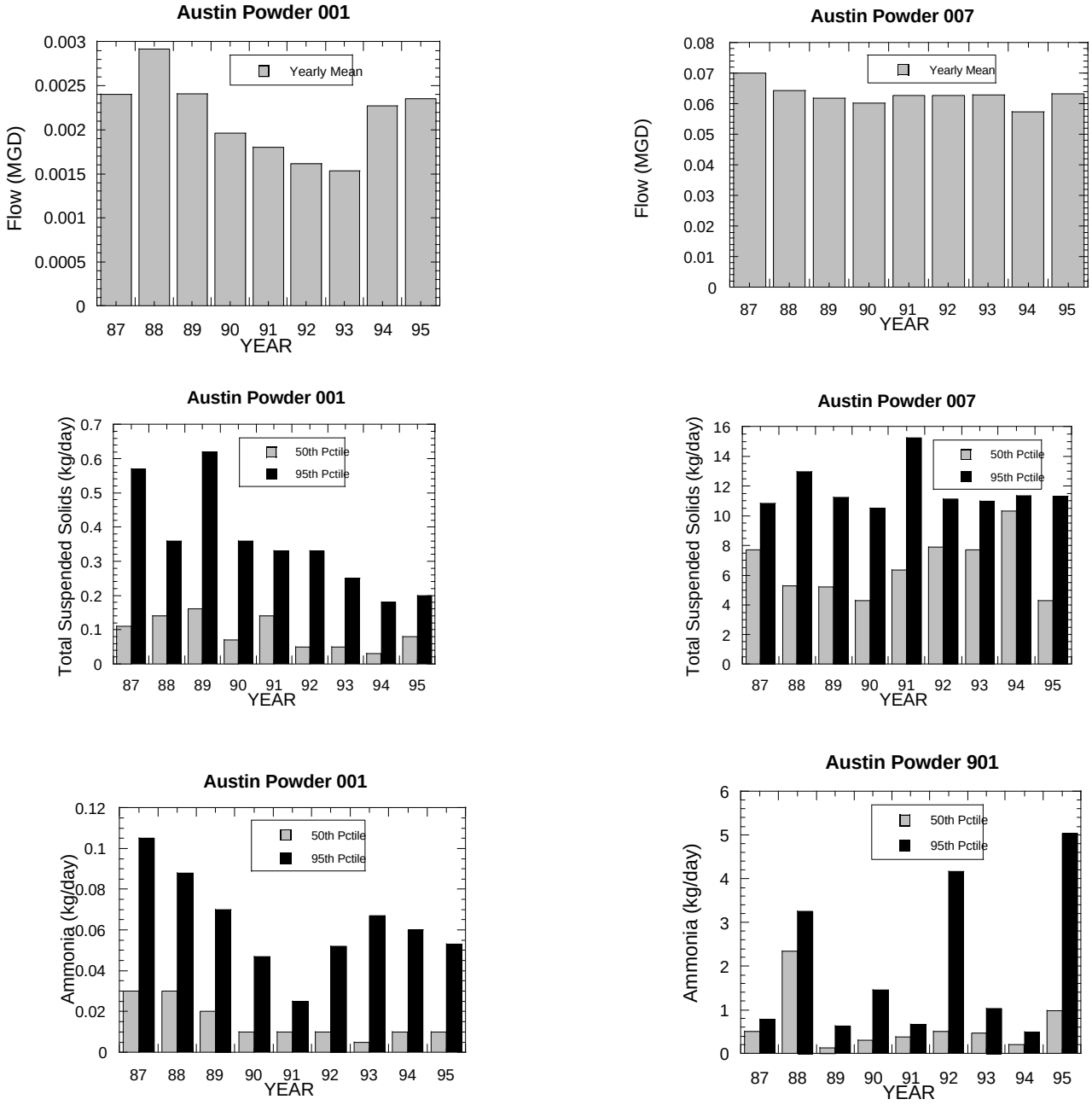


Figure 9. Median and 95th percentile annual loadings (kg/day) of ammonia and total suspended solids (TSS), and yearly mean flow for Austin Powder outfalls 001, 007, and 901, 1987-95.

Chemical Water Quality

Thirteen sites were located on the mainstem of Raccoon Creek covering approximately 109 miles of stream. In the headwaters, the West Branch had two sites and the East Branch had one site. The Elk Fork watershed had six sites on the mainstem and two sites on its tributary Puncheon Fork. The McArthur WWTP currently discharges to Puncheon Fork and it was also sampled. The Elk Fork sites were duplicates of sites sampled in 1981 when the McArthur WWTP and Austin Powder's main discharge flowed into Elk Fork. In 1986 the discharges of Austin Powder changed significantly and the 001 discharge sampled for this survey now flows into an unnamed tributary of Raccoon Creek upstream from Elk Fork. In 1992 the McArthur discharge was diverted form Elk Fork to Puncheon Fork.

Raccoon Creek (Figures 10 and 11)

The mainstem was significantly impacted primarily by the East Branch and to limited extent by the West Branch for approximately 20 miles downstream; the impact was attributed to mining activities as evidenced by the pH exceedances (Table 5).

Conductivity, manganese, nickel, total dissolved solids (TDS), sulfates and zinc mean concentrations had similar longitudinal trends, suspected due to mining. Downstream from the confluence of the two branches, these parameter concentrations were moderately to extremely elevated. These concentrations decreased substantially with increasing distance downstream from the East and West Branches. Conversely, iron values increased from upstream to downstream with the highest mean concentration at RM 40.

Mean dissolved oxygen values ranged from 6.0 to 7.4 mg/l for the sites sampled on the Raccoon Creek mainstem. Only two samples collected from the mainstem had D.O. values below 5.0 mg/l. These were at RM 99.6 (4.70 mg/l on 8/15/95) and RM 40.01 (4.4 mg/l on 8/2/95).

Alkalinity concentrations were less than 40 mg/l for the sites sampled on the Raccoon Creek mainstem. Concentrations generally showed an increasing trend from upstream to downstream, but a decrease was observed from RM 63.8 to RM 40.0 possibly due to mine affected tributaries (Figure 10).

Puncheon Fork

The McArthur WWTP had a significant chemical impact as measured at the sampling station in Puncheon Fork at RM 0.28, one mile downstream from the WWTP discharge. Upstream dissolved oxygen (D.O.) levels averaged 5.5 mg/l while those downstream averaged 4.3 mg/l. The 001 discharge of McArthur averaged 3.5 mg/l D.O. D.O. was measurements at the upstream site did violate the average D.O. criterion of 5.0 mg/l three times during the survey. This may be attributed to the very low flows and pooling of the stream at the sampling station. Despite better flow conditions at the downstream site, there were five of six sampling events where the dissolved oxygen criterion (4.0 mg/l) was not met. BOD_5

levels upstream were less than 2 mg/l while the downstream site averaged 5 mg/l. Individual samples downstream ranged from less than 2 to over 7 mg/l BOD. Ammonia levels were similar; upstream levels were below detection but the downstream site averaged 3.74 mg/l. The McArthur 001 effluent averaged 9.38 mg/l ammonia during the survey. Phosphorus levels also increased from less than detection upstream to 0.54 mg/l downstream.

Puncheon Fork is impacted by mine drainage as evidenced by the coal fines observed in the stream. Chemically, it appeared not as severe as other tributaries in the Raccoon Basin. Alkalinity upstream from the WWTP ranged from 21 mg/l to 105 mg/l. The McArthur WWTP had a positive effect with its average discharge of 211 mg/l alkalinity. At the downstream site alkalinity ranged from 63 to 185 mg/l. Iron and manganese levels were elevated indicating that the mine drainage still had some impact in Puncheon Fork. Zinc and aluminum levels were slightly above detection levels throughout the basin.

Elk Fork (Figures 12 and 13)
Dissolved oxygen concentrations in Elk Fork did not meet average or minimum criteria for five of the six samples at RM 13.9, the station upstream from Puncheon Fork. The only other exceedances of the DO criteria occurred once each at RM 10.88 and RM 16.13.

Ammonia values were generally higher downstream from Puncheon Fork at RM 13.26 due to the average discharge of 9.4 mg/l ammonia from the McArthur WWTP. The only exception was data collected on 8/30/95 at RM 13.9 in which a concentration of 6.73 mg/l ammonia was reported. Data collected on the other five sampling events showed an average concentration of 0.11 mg/l ammonia at RM 13.9 compared to 0.72 mg/l at RM 13.26 downstream from Puncheon Fork. A sample mix up between Elk Fork RM 13.9 and Puncheon Fork RM 0.28 on the 8/30/95 sampling date is suspected. There were no other exceedances of the WWH ammonia criterion in the Elk Fork basin.

BOD_5 increased downstream from the confluence of Puncheon Fork due to the average discharge of 9.8 mg/l from the McArthur WWTP. Instream values peaked at RM 13.26 (5.3 mg/l mean) and decreased to less than 2 mg/l at RM 8.67.

Although the chemical sampling locations upstream from Puncheon Fork (RM 13.9) to the mouth (RM 0.1) had some sulfate values greater than 150 mg/l, only RM 13.9 and RM 8.67 had a value greater than the Public Water Supply criterion of 250 mg/l. Only one pH value (6.2 S.U. at RM 16.13 on 9/13/95) was below the pH criterion of 6.5 S.U. Alkalinity was greater than 40 mg/l at all Elk Fork sites except once at RM 16.13 on 7/20/95 in which there was a net acidity of 5 mg/l.

The highest mean concentration of aluminum, iron, and zinc was recorded at RM 10.88. The highest concentrations of manganese were recorded upstream from Puncheon Fork at RM 16.13 and RM 13.9. Iron was the only metal exceeding numerical criteria; 16 of 35 samples

were greater than the 1.0 mg/l Public Water Supply criterion.

The highest value of nitrate-nitrite (1.66 mg/l) in the Elk Fork mainstem was reported downstream from the Austin Powder Tributary at RM 10.88.

West Branch Raccoon Creek
Exceedances of the Warmwater Habitat (WWH) water quality criterion for iron (1000 ug/l) were detected in 25 percent of the samples collected. There was one pH value (5.6 S.U. at RM 0.15) below the minimum WWH criterion (6.5 S.U.). Dissolved oxygen levels exceeded the WWH criterion in seven of the twelve samples collected at the two sites in this tributary. One sulfate value at RM 0.15 (320 mg/l) exceeded the Public Water Supply criterion. Alkalinity (mg/l as $CaCO_3$) at RM 5.68 and RM 0.15 was 37 and 31, respectively.

Nutrient levels were mostly below detection limits at the upstream station RM 5.68. The dissolved oxygen exceedances at this site were probably due to the very low flows and the effect of pooled water during the dry summer season. At the station near the mouth (RM 0.15), the nutrient levels were slightly higher (ammonia mean= 0.28 mg/l and nitrate-nitrite mean= 0.26 mg/l). This may be due to failing on- lot systems or lack of treatment at some residences.

Metal concentrations at the upstream site (RM 5.68) with the exception of manganese were very low. The mean iron concentration was 358 ug/l. The manganese mean was 1084 ug/l and zinc was 17 ug/l. Both of these metals are usually found in association with mine drainage. The downstream site (RM 0.15) had significantly higher means for iron (1234 ug/l) and manganese (4717 ug/l). There was also a slight increase in zinc (22 ug/l).

East Branch Raccoon
All samples collected exceeded the WWH minimum criterion for pH, and 83.3% exceeded the WWH criterion of 1000 ug/l for iron. One iron sample (11000 ug/l) exceeded the Agricultural Water Supply criterion. All sulfate samples exceeded the Public Water Supply criterion.

Extensive mine drainage impacts the East Branch Raccoon Creek and exerts its effects for some distance downstream from the confluence with the West Branch and into the mainstem of Raccoon Creek.

The mean pH for the East Branch Raccoon Creek at RM 6.64 was 3.6 S.U., and the mean acidity was 141 mg/l in contrast to the West Branch Raccoon Creek which had a positive total alkalinity and mean pH of 6.7 S.U. and 7.1 S.U., respectively. Sulfates in the East Branch averaged 844 mg/l compared to 173 mg/l at the station near the mouth of the West Branch. Other typical parameters associated with mine drainage such as total dissolved solids (TDS), hardness, aluminum, iron, manganese, and zinc were highly elevated. Arsenic,

cadmium, and lead levels were slightly elevated also.

Little Raccoon Creek (Figures 14 and 15)
Surface water grab samples were collected in Little Raccoon Creek from five locations on six different sampling events between July and September, l995. An additional sample was taken in October 1995 at the two sites upstream and downstream the confluence of Meadow Run in conjunction with additional sampling done on Meadow Run.

Four parameters associated with mine drainage influences (sulfate, iron, aluminum, and manganese) were plotted longitudinally for Little Raccoon Creek from data collected during 1995 (Figure 15).

Nutrient levels in Little Raccoon Creek did not reflect any significant problems. A slight increase in nutrient levels was noted at RM 24.55, downstream from Meadow Run.

Fecal coliform bacteria samples were collected three times from Little Raccoon Creek during August and September, 1995. All samples were within limits for the Primary Contact Recreation (PCR) criterion.

Meadow Run (Figure 16)
Six sites on Meadow Run were sampled seven times between July and October 1995. The Wellston WWTP and Pillsbury WWTP effluents were sampled during each event.

Surface water sampling results found elevated levels of iron occurring at RM 3.1 and RM 2.23 (100% of the samples), at RM 1.47 (86% of the samples), and at RM 0.72.

Dissolved oxygen levels did not achieve the minimum WWH dissolved oxygen criterion throughout the sampling period at RM 0.72. Algal growth was very substantial throughout the sampling period at this location. There were low dissolved oxygen levels in the Pillsbury effluent (RM 1.19).

Fecal bacteria samples were collected three times during August and September 1995. One violation of the Primary Contact Recreation Criterion occurred at RM 2.23. All three fecal bacteria samples collected at RM 0.72 violated the PCR criterion.

Tripp Run
Two sites on Tripp Run were sampled six times between June and September, 1995. These sites were selected to bracket the unsewered community of Hamden and to determine what effects, if any, this community was having on the stream.

Water chemistry indicated a minor impact at the downstream site when compared to the data at the upstream site. BOD_5 was slightly elevated.

Nutrient levels reflected consistent increases from upstream (RM 1.8) to downstream (RM 0.3) for nitrate-nitrite, ammonia, total kjeldahl nitrogen, and phosphorus.

Fecal bacteria samples were taken during five of the regular chemical sampling events and on two other occasions during August and September. With the exception of one sampling event, the fecal coliform bacteria count was always higher at RM 0.3, downstream from Hamden. The one exception occurred during the last sampling event when dry weather resulted in lack of flows in this segment of Tripp Run. The sample was collected from a pool rather than a flowing area.

Other Tributaries in the Little Raccoon Creek Basin (Figure 4)
Mulga Run was sampled at RM 0.10. The chemical sample reported the highest iron and the second highest manganese concentrations in the 1995 survey. The modeling unit sampled Mulga Run more thoroughly with continuous monitors (see Modeling Section Nonpoint Rain Survey).

Rich Run was sampled at RM 1.5. The chemical sample reported high concentrations of aluminum and manganese, along with a low pH reading (4.65 S.U.).

Buffer Run was sampled at RM 0.10 near Buckeye Furnace State Memorial. Chemical water quality at this site was indicative of severe acid mine drainage. The pH (3.32 S.U.) was low and aluminum (15,100 ug/l) and iron (39,100 ug/l) concentrations were very high. Cadmium, copper, nickel, and zinc were also detected. The acidity was 173 mg/l and all the nutrients were very low except BOD_5 (3.8 mg/l). A heavy orange precipitate covered the stream bottom.

Coal Run was sampled near the mouth. The chemical sample reported only slightly elevated concentrations of manganese and sulfates.

Other Tributaries in the Raccoon Creek Basin (Figures 2 and 3)
Twomile Run is a very small tributary that flows through Zaleski State Forest. It was sampled at RM 0.20 and has a drainage area of 4.7 square miles. Water quality in this stream was quite good. Heavy metals concentrations and nutrient levels were low, pH (6.83 S.U.) and alkalinity (46 mg/l) were moderately good, but sulfate (480 mg/l) and conductivity (878 umbos/cm) indicated the influence of some mine drainage effects.

Grass Run is a small tributary to Hewett Fork and was sampled at RM 0.10, just upstream from SR 356. Water chemistry did not indicate an acid mine drainage (AMD) problem here. The stream substrate was very sandy/silty with a limited riparian corridor along its right

bank, no deep pools, and poor sinuosity.

Rockcamp Creek is a tributary to Hewett Fork and was sampled on August 22, 1995 at RM 1.8 just upstream from SR 356 and adjacent to SR 681. The alkalinity of 42 mg/l and a pH of 6.73 S.U. possibly indicated a weak buffering capacity and slightly acidic water due to mine drainage. However, the low conductivity, and low sulfates and heavy metals concentrations tended to confirm the absence of mining impacts in this watershed. Nutrient concentrations were also low.

Laurel Run was sampled at RM 0.1 near the mouth. Concentrations of iron and manganese were elevated and the dissolved oxygen concentration was low (4.5 mg/l).

Onion Creek was one of the larger tributaries sampled in this survey with 8.3 square miles of drainage area at the sample site at RM 1.40. Water quality was excellent with low nutrient and heavy metal levels. The pH and dissolved oxygen were also very good at 7.25 S.U. and 5.4 mg/l , respectively. Low sulfate levels and high alkalinity concentrations further indicated the lack of mining impacts to this stream.

Tedroe Run, a very small stream of only 2.4 square miles drainage area, was sampled at RM 0.10 in the Zaleski State Forest. Chemical water quality at this site was sampled on August 1, 1995, and the flow at this time was interstitial, down considerably from July. Alkalinity was adequate at 68 mg/l and nutrients, bacteria, and heavy metals concentrations were low. The pH of 6.65 was only slightly low, but the dissolved oxygen (3.8 mg/l) was quite low. This was probably due to the extremely low flow of the stream at that time. Although Tedroe Run likely receives some significant acid mine drainage each year, probably during high rainfall events, it didn't appear to have those attributes during sampling visits in 1995.

Russell Run (2 mi^2 drainage area) was evaluated at RM 0.60. Water quality sampling revealed low levels of nutrients, heavy metals, and bacteria, and normal levels of dissolved oxygen, pH, conductivity and alkalinity. Sulfates were low as was iron, indicating no impacts from mining.

Flat Run was sampled at US Rt. 50 (RM 1.60) just west of the Athens County line on July 24, 1995. The chemical sample indicated good water quality with relatively low levels of metals and sulfates, and high levels of alkalinity and pH.

Long Run was sampled at the mouth. Water quality was excellent with low nutrient and metal concentrations.

Zinns Run flows into Raccoon Creek upstream from Radcliff was sampled at the mouth. The chemical sample reported a high concentration of iron and a pH lower than normal (6.43).

Pierce Run flows into Raccoon Creek near Radcliff in Vinton County and was sampled at RM 1.7 on July 17, 1995. This stream had heavy deposits of iron precipitate on the bottom and was obviously impacted by acid mine drainage. The pH was lower than normal (6.43 S.U.) and iron and sulfate concentrations were high. Nutrient levels were quite low, conductivity was high, and, although there was a net alkalinity, it was low, measuring 17 mg/l.

Rockcamp Run is a small tributary that enters Raccoon Creek about 2 miles south of Radcliff. The site was sampled at RM 0.20 and had a drainage area of 2.8 square miles. The water quality sample had a neutral pH level, moderate levels of sulfate and iron, and low levels of other metals and nutrients. An alkalinity of 28 mg/l was low and probably not sufficient to buffer slugs of acidic water flushed downstream during heavy rainfall events.

Indiancamp Run is a small tributary (2.5 sq. mi. drainage area) that was sampled at RM 0.30 on July 25, 1995. This stream had excellent water quality with very low nutrient and heavy metals concentrations and normal dissolved oxygen, conductivity, sulfates and total dissolved and suspended solids (TDS and TSS). The pH (6.73 S.U.), hardness (123 mg/l), and alkalinity (45 mg/l) were low.

Opossum Run was sampled at RM 0.20 in Vinton County just north of Gallia County. Chemical samples reported high manganese and iron concentrations, and one pH value was low (5.51 S.U.).

Table 5. Exceedences of Ohio EPA criteria (OAC 3745-1) for chemical/physical parameters measured in the Little Raccoon Creek study area, 1995. (Units are ug/l for metals; mg/l for sulfates, ammonia, and dissolved oxygen; standard units (S.U.) for pH; and # /100 ml. for fecal coliform bacteria)

Stream Name	River Mile	Exceedance: Parameter
E. Br. Raccoon Ck	6.64	Iron (11000)[†], pH(3.5, 3.3, 4.1, 3.9, 3.6, 3.2)❹ 100% of samples. Sulfates (613, 997, 971, 796, 827, 864)❶ 100% of samples. Iron (5 of 6) samples (83.3%) exceeded 1.0 mg/l ❹ in the East Branch.
W. Br. Raccoon Ck	0.15	Sulfates (320)❶, pH (5.6)❹, DO (4.4[‡], 4.4[‡], 4.4[‡], 3.92❸) Iron (3 of 12) samples (25%) exceeded 1.0 mg/l❹ in the West Branch.
	5.68	DO (3.9, 4.6[‡], 3.5)❸.
Raccoon Creek	109.0	pH (4.5, 4.7, 5.8, 5.3)❹, Sulfates (437, 564, 278, 394, 279, 301)❶100% of samples.
	99.60	pH (5.6, 5.8, 5.6)❹, Sulfates (278, 273)❶ D.O. (4.7)❹.
	98.34	pH (5.4, 6.3)❹, Sulfates (256)❶.
	92.30	pH (6.2)❹, Sulfates (287)❶.

Table 5. (Cont.)

Stream Name	River Mile	Exceedance: Parameter
Raccoon Creek	84.08	Sulfates (276)❶.
	40.01	D.O. (4.4)❸ Iron (19 of 78) samples (24.4%) exceeded 1.0 mg/l ❹ in the Raccoon Creek mainstem.
Elk Fork	16.13	D.O.(4.2)❸; pH(6.2)❹
	13.90	D.O.(3.4, 4.1‡, 4.5‡, 3.15)❸; Sulfates(273)❶
	10.88	D.O.(4.3)❸
	8.67	Sulfates(346)❶; Lead(20)❹ Iron (16 of 35) samples (46%) exceeded 1.0 mg/l ❹ in the Elk Fork mainstem.
Puncheon Fork	1.51	D.O. (4.95, 4.60, 4.89)❸
	0.28	D.O.(3.8,3.5,3.8,3.9,3.4)❸ Iron (7 of 12) samples (58%) exceeded 1.0 mg/l❹ in Puncheon Fork
Little Raccoon Creek	32.95	Iron (1030)❹, zinc (103)❹
	30.18	Iron (1330, 1200, 1140, 1250)❹
	27.9	Sulphates (322)❶, Iron (1130)❹
	24.55	Iron (1550, 1500, 1760, 1750, 1500, 1790, 1290)❹

Table 5. (Continued)

Stream Name	River Mile	Exceedance: Parameter
Meadow Run	3.1	Iron (3340)❹
	1.47	Iron (1020, 1360, 1250, 1760, 1350, 1620)❹
	0.72	NH_3(8.71)❺, D.O.(2.8,2.2,3.0,2.5,2.9,4.0,3.3)❸, Iron (1080)❹
Tripp Run	1.8	Fecal coliform (5500)❷
	0.3	Fecal coliform (3200, 37000, 4000, 4100)❷
Buffer Run	0.17	Iron (39100❹), zinc (247)❹, Sulfate (621)❶,pH(3.32)❹
Coal Run	0.08	Iron (1070❹),Manganese(857)❶
Flat Run	1.30	Iron(2000)❹,Manganese(677)❶ Fecal coliform (1020)❷
Goose Run	0.10	Iron(41800)†,Manganese(3940)❶, Sulfate(984)❶, TDS(1620)❹,pH(3.05)❹

Table 5. (Continued)

Stream Name	River Mile	Exceedance: Parameter
Grass Run	0.04	Iron(2400)❹,Manganese(1600)❶
Laurel Run	0.10	Iron(74600)†,Manganese(7580)❶
Long Run	0.10	Manganese(206)❶
Mulga Run	0.10	Iron(3300)❹,Manganese(4800)❶, Sulfate(511)❶
Onion Creek	1.40	Manganese(310)❶
Opossum Run	0.15	Iron(2100,3340)❹,Manganese(957,3640)❶ pH(5.51)❹
Pierce Run	1.70	Manganese(1800)❶,Sulfate(313)❶
Rich Run	1.50	Manganese(4890)❶,pH(4.65)❹
Rockcamp Creek	1.50	Iron(7400)†, Manganese(535)❶
Rockcamp Run	0.20	Manganese(1490)❶
Russel Run	0.60	Manganese(198)❶
Tedroe Run	0.10	Manganese(3200)❶,Dissolved Oxygen(3.8)❹
Zinns Run	0.01	Iron(5750)†, Manganese(982)❶,pH(6.43)❹

† Exceedence of the Agricultural Water Supply criterion.
❶ Exceedance of Public Water Supply criterion.
❷ Exceedance of Primary Contact Recreational Use criterion
❸ Violation of the minimum dissolved oxygen criterion (4.0 mg/l) or the average dissolved oxygen criterion (5.0 mg/l) for WWH
❹ Exceedance of numerical criteria for prevention of chronic toxicity (CAC) 30-day average outside the mixing zone
❺ WWH outside mixing zone maximum total NH_3-N criterion

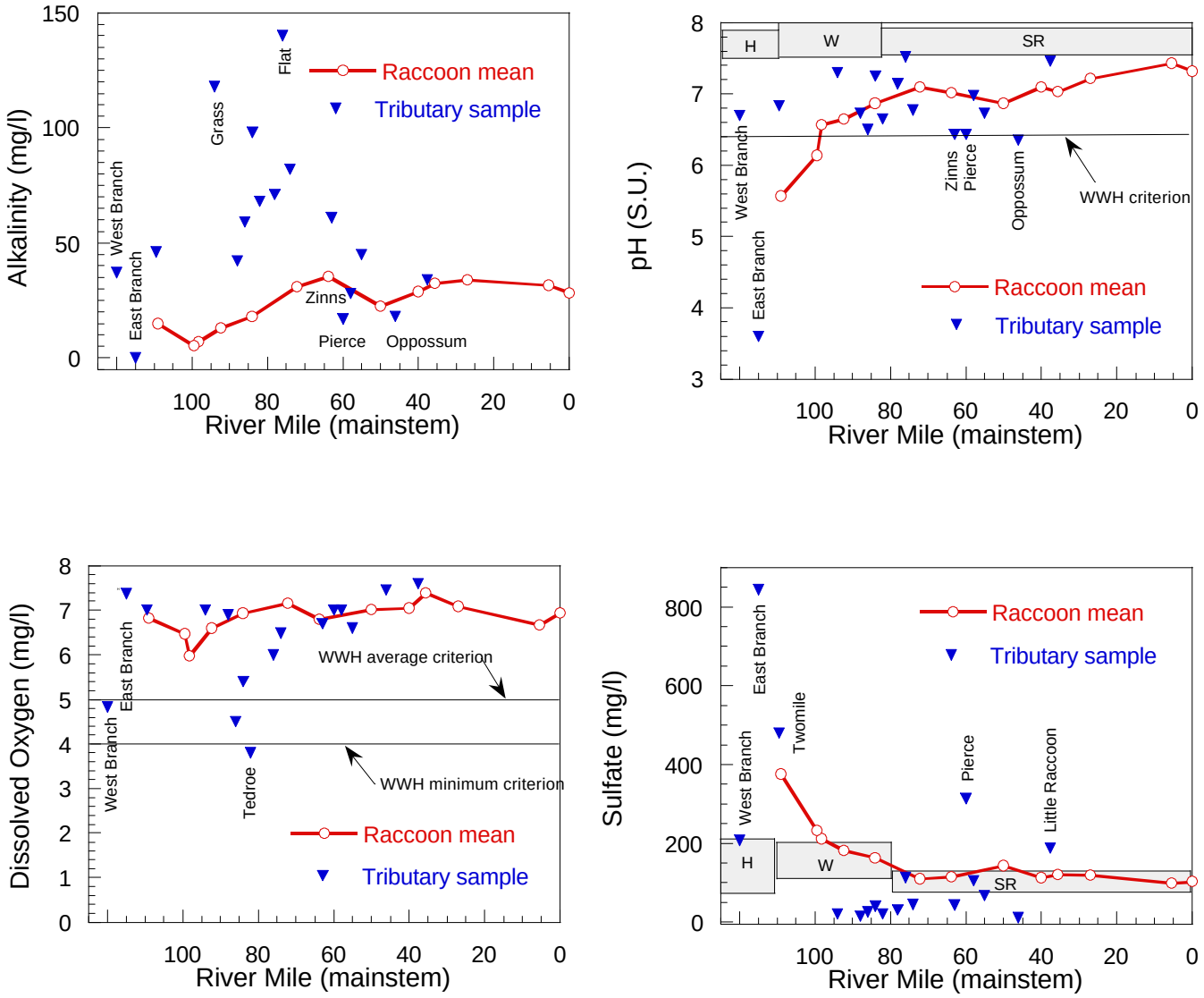


Figure 10 . Longitudinal profile of mean values (Raccoon Creek, East Branch Raccoon Creek, and West Branch Raccoon Creek) and individual samples (tributaries) for alkalinity, dissolved oxygen, pH, and sulfate in the Raccoon Creek basin, 1995. Shaded areas represent the range between the median and 75th percentile values for sulfate, and the median and 25th percentile values for pH, for sites in the Western Allegheny Plateau ecoregion with IBI values that attain WWH criteria. H= headwater stream (tributary), W= wadable stream, and SR= small river drainage sizes.

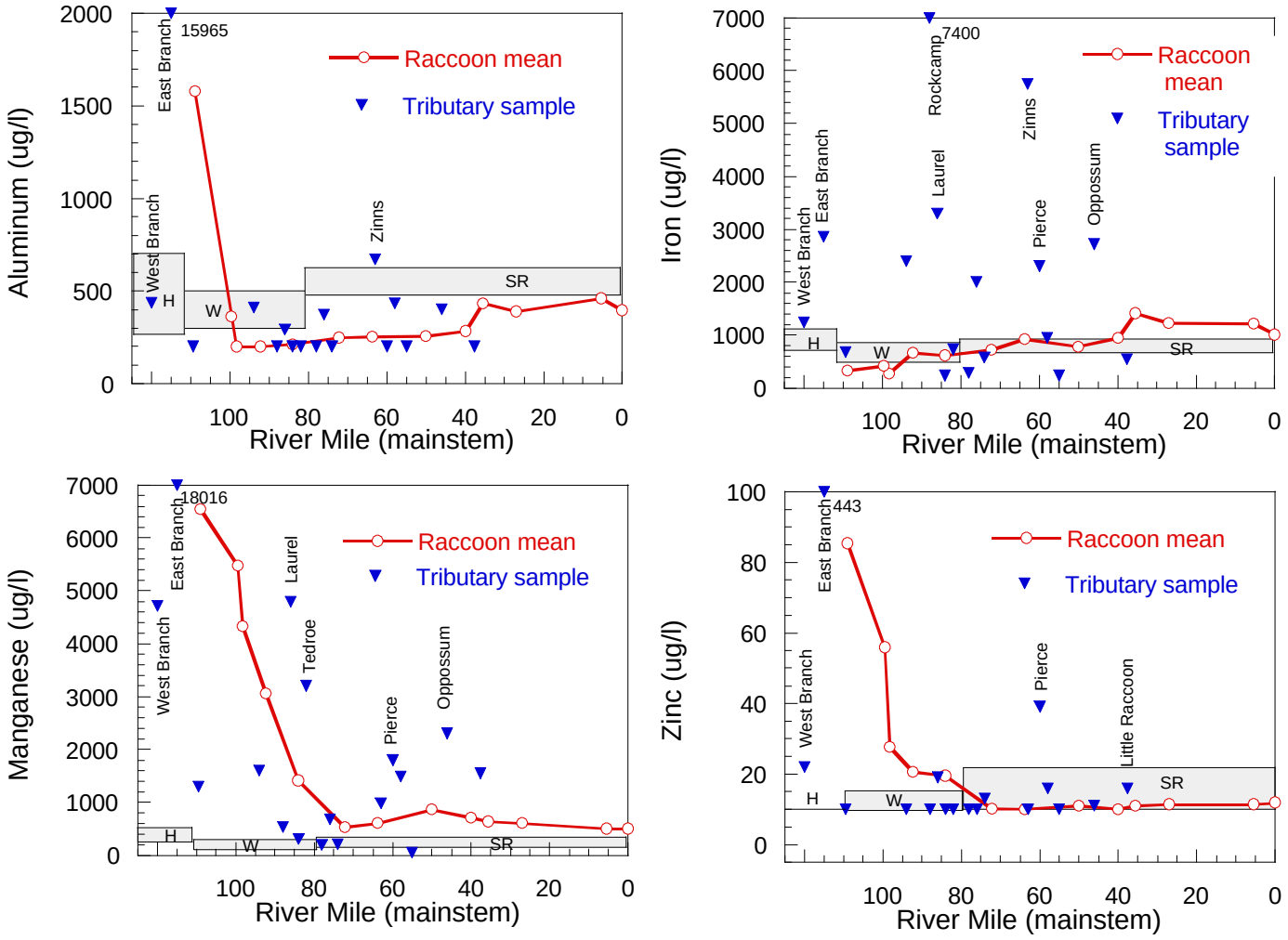


Figure 11 . Longitudinal profile of mean values (Raccoon Creek, East Branch Raccoon Creek, and West Branch Raccoon Creek) and individual samples (tributaries) for aluminum, iron, manganese, and zinc in the Raccoon Creek basin, 1995. Shaded areas represent the range between the median and 75th percentile values for sites in the Western Allegheny Plateau ecoregion with IBI values that attain WWH criteria. H= headwater stream (tributary), W= wadable stream, and SR= small river drainage sizes.

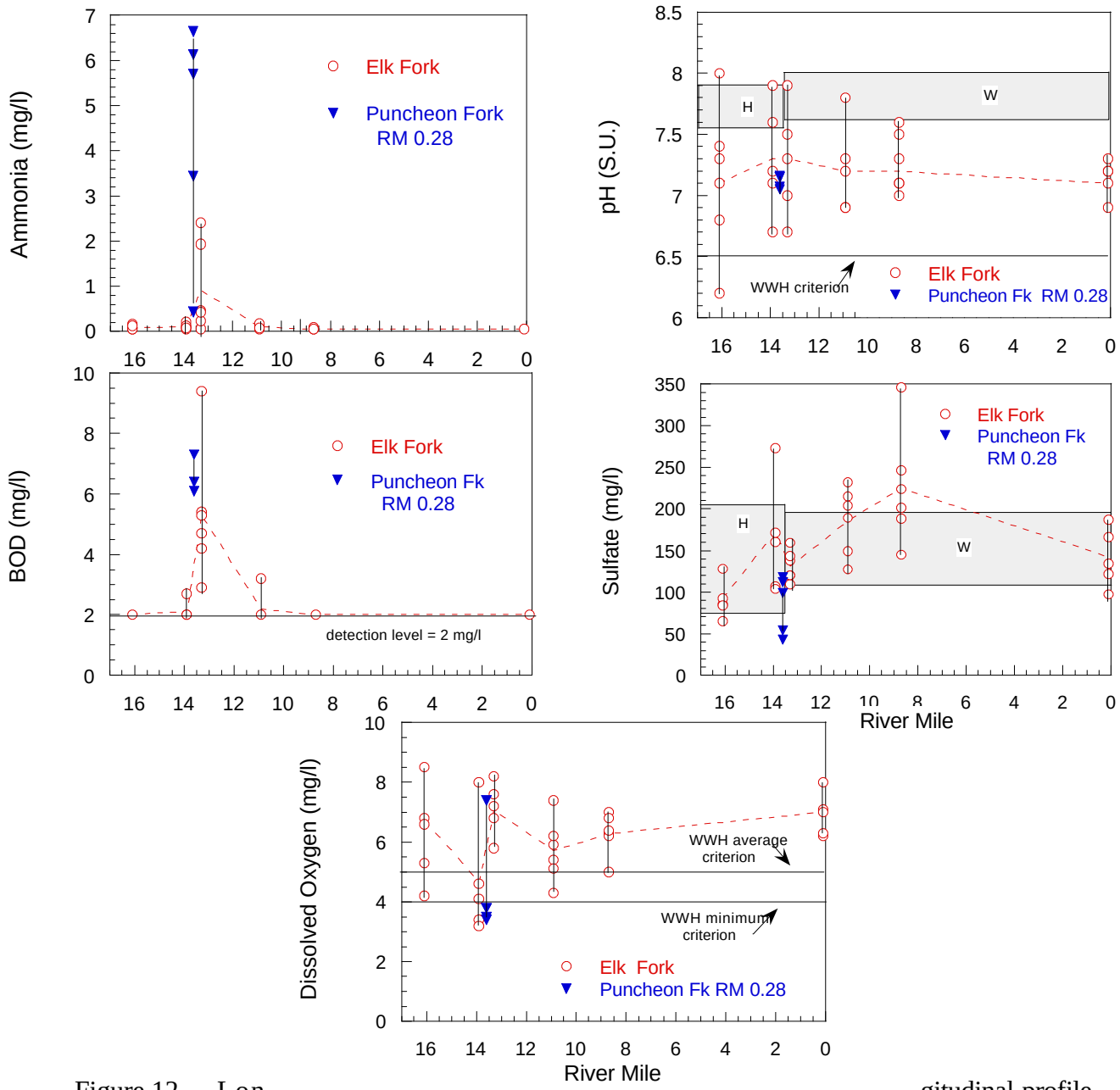


Figure 12 . Longitudinal profile of ammonia, BOD, dissolved oxygen, pH, and sulfate in the Elk Fork basin, 1995. Shaded areas represent the range between the median and 75th percentile values for sulfate, and the median and 25th percentile values for pH, for sites in the Western Allegheny Plateau ecoregion with IBI values that attain WWH criteria. H= headwater stream, and W= wadable stream.

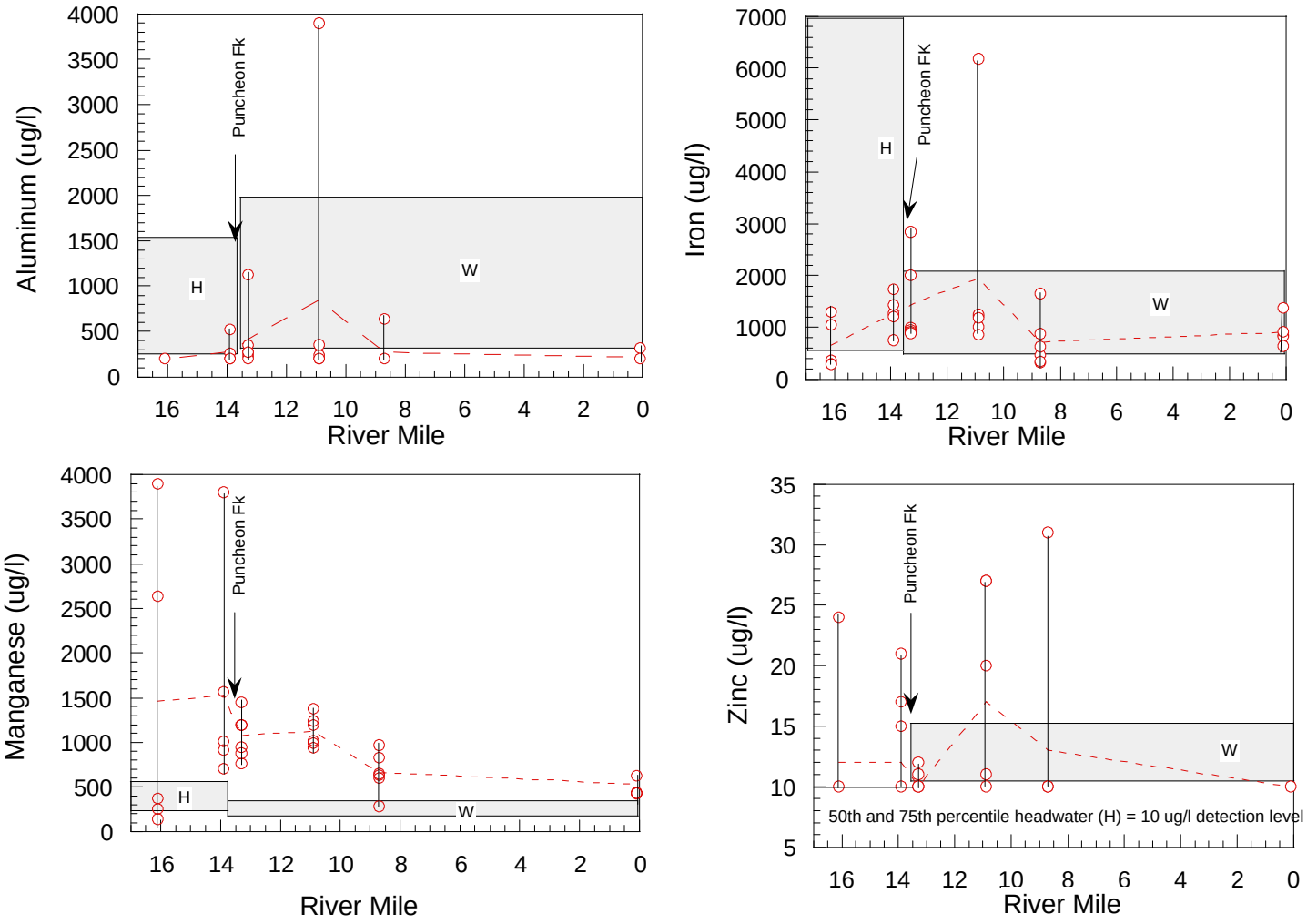


Figure 13. Longitudinal profile of aluminum, iron, manganese, nickel, and zinc in the Elk Fork basin, 1995. Shaded areas represent the range between the median and 75th percentile values for sites in the Western Allegheny Plateau ecoregion with IBI values that attain WWH criteria. H= headwater stream and W= wadable stream drainage sizes.

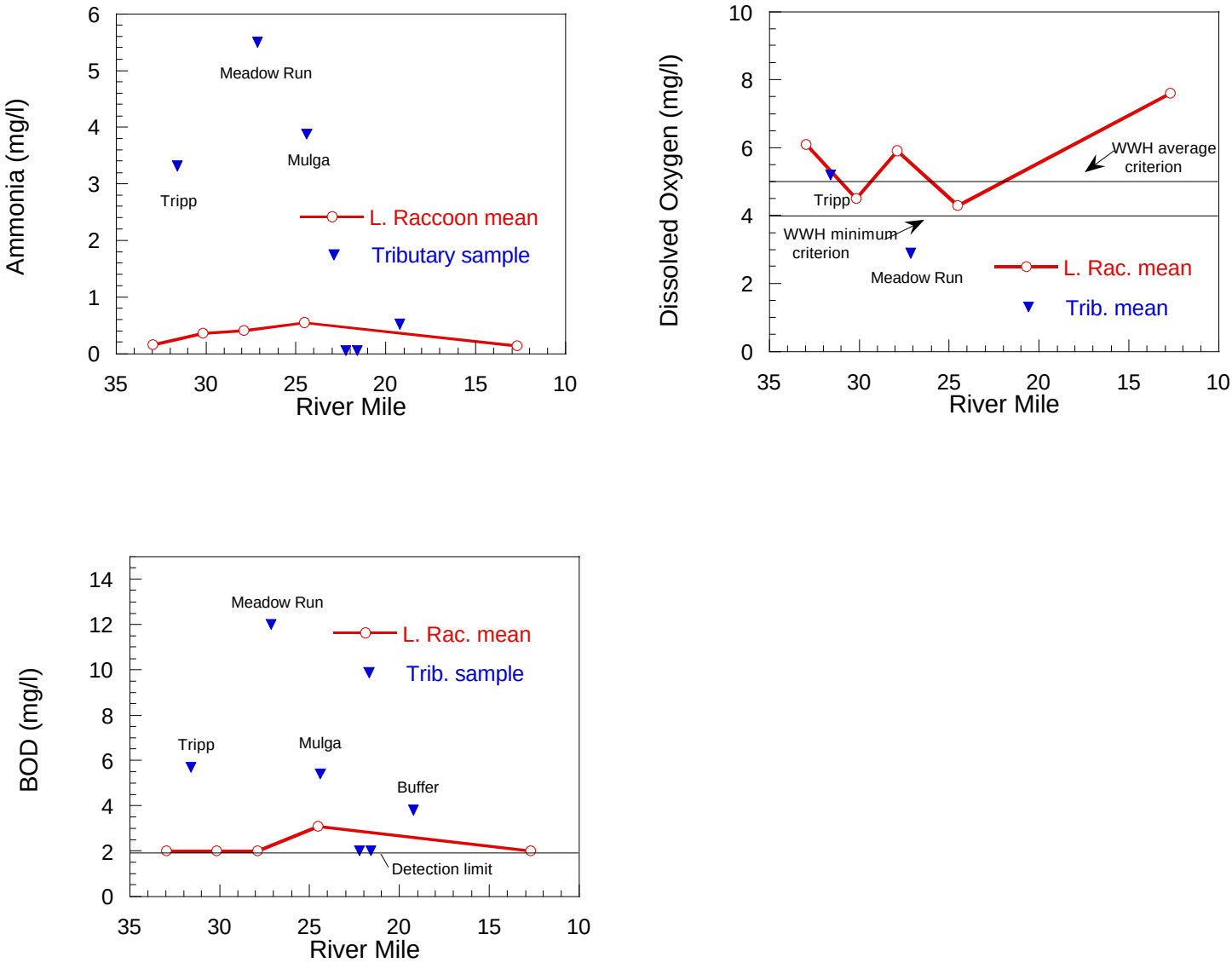


Figure 14 . Longitudinal profile of ammonia, BOD, and dissolved oxygen in the Little Raccoon Creek basin, 1995.

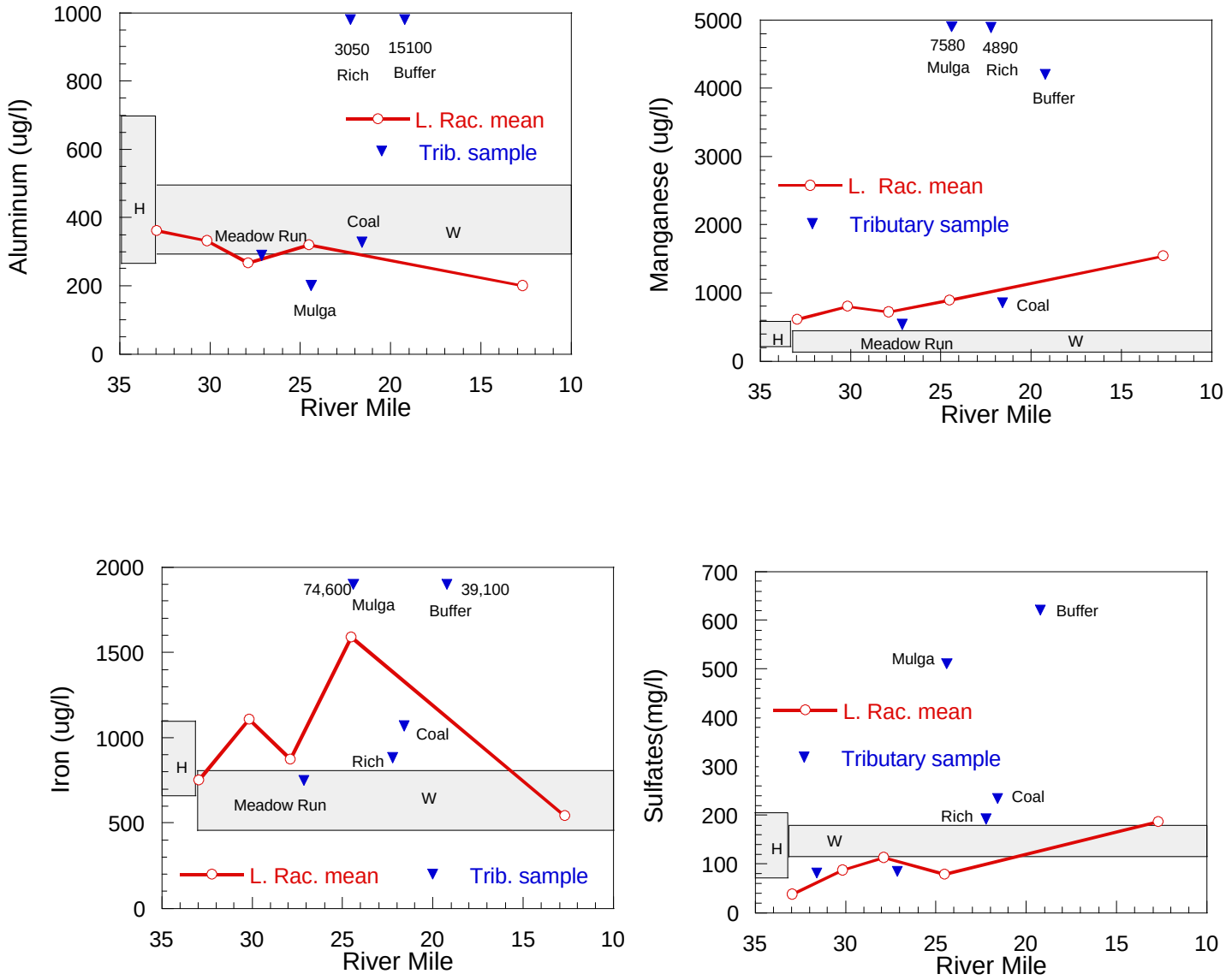


Figure 15 . Longitudinal profile of aluminum, iron, manganese, and sulfate in the Little Raccoon Creek basin, 1995. Shaded areas represent the range between the median and 75th percentile values for sites in the Western Allegheny Plateau ecoregion with IBI values that attain WWH criteria. H= headwater stream and W= wadable stream drainage sizes.

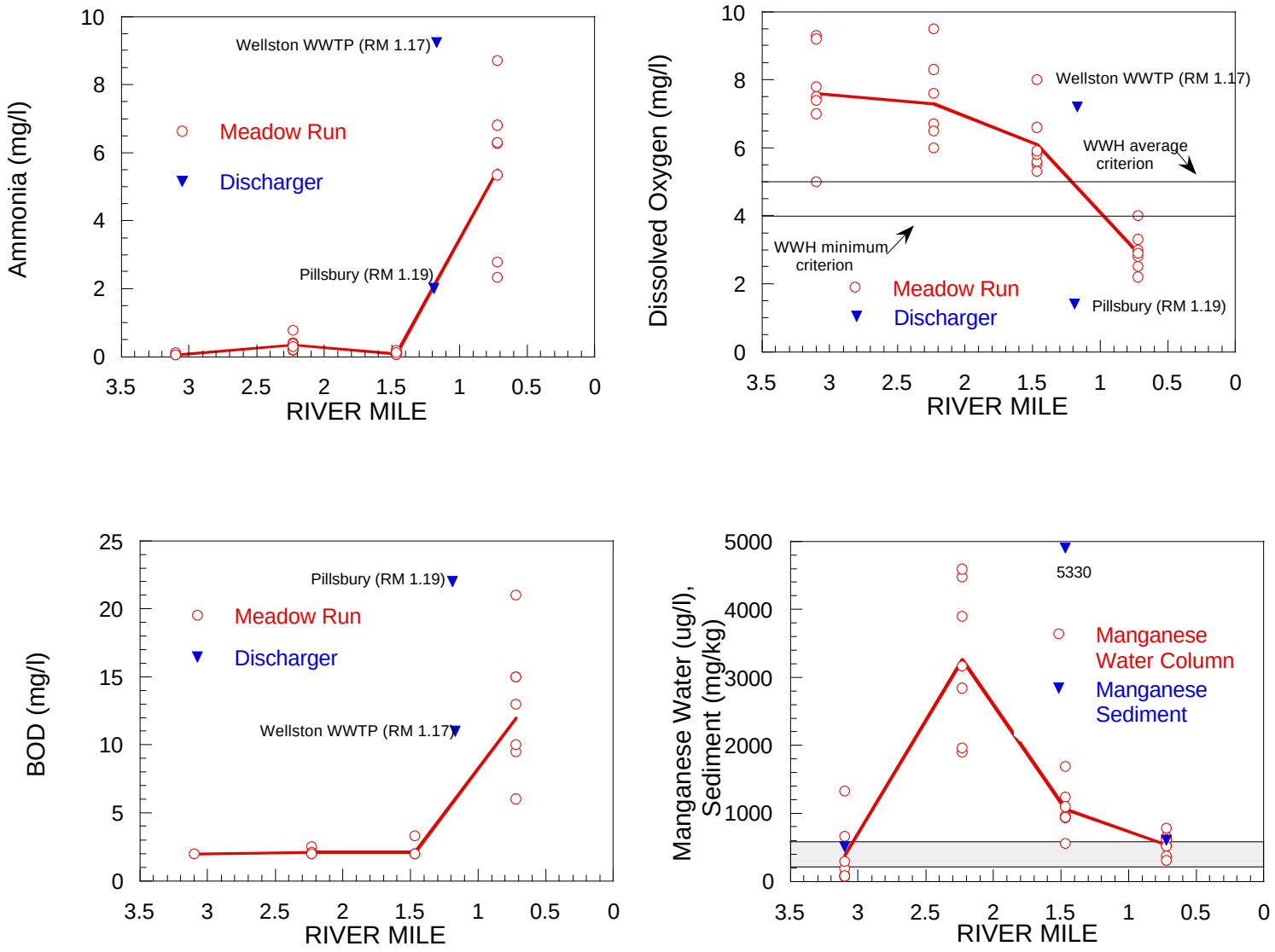


Figure 16. Longitudinal profile of ammonia, BOD, dissolved oxygen, and manganese in the Meadow Run basin, 1995. Shaded areas represent the range between the median and 75th percentile values for manganese water column data for sites in the Western Allegheny Plateau ecoregion with IBI values that attain WWH criteria in headwater site drainage basins (<20 square miles).

Modeling Section Nonpoint Runoff Survey

Introduction

Between June 1995 and November 1995, the Water Quality Modeling Unit conducted a water quality and hydraulic survey on Mulga Run near Wellston, Ohio. Mulga Run is a small tributary to Little Raccoon Creek in Vinton County and drains an area of approximately 7.9 square miles which was heavily mined in the past and contained operating mines during the survey. The primary objective of this study was to characterize and quantify some of the water chemistry impacts on Mulga Run due to severe acid mine drainage in the region during typical dry and wet periods. The principal parameters for the study included aluminum, iron, manganese and stream pH. Another stream, Scott Creek, a small tributary to the Hocking River draining about 40 square miles near Logan, Ohio was also sampled and used as a control site for the study. That is, Scott Creek was considered to be a stream with similar hydraulic characteristics as Mulga Run, but much less impacted by mining and possessing good chemical, physical and biological indices. Presented below are the summarized results from baseline (dry weather) sampling and results from a storm event along with projected average loading from the principal metals.

Study Areas and Survey Approach

Between June and November of 1995, six sites were sampled for the Mulga Run survey. These sites are shown below in Figure 17. Site 1 was at the mouth of Mulga Run where some influence from Little Raccoon Creek was observed, depending on the flow state of the streams. Site 2 was located just inside a wetland adjacent to Mulga Run. Just upstream from the wetland, flow from Mulga Run splits with part clearly entering the wetland and the remainder continuing to flow through the natural stream channel to Little Raccoon Creek. Near the mouth of Mulga Run, the wetland had two to four defined mouths where the flow from the wetland emptied back into Mulga Run or Little Raccoon Creek. Site 2 was located just upstream from one of the wetland mouths to Mulga Run and it was sampled to determine if the wetland had any mitigating effects on the acid mine drainage (AMD) impacts. Site 3 was on an unnamed tributary to Mulga Run which drained a small area to the south of Mulga Run. Site 3 was frequently dry. Site 4 was located directly on Mulga Run upstream of the wetland. Site 4 included a permanent hydraulic measurement station where stream flow and depth were monitored. Site 5 was located on an unnamed tributary to Mulga Run which drained an area where a mine was currently in operation. Site 6 was located Scott Creek and used as a control site for comparison with Mulga Run sites. The drainage area above site 6 was approximately 2 square miles. This region was relatively free from AMD impacts.

Grab samples were collected at most sites 4 times between June and November. Samples were analyzed for 3 primary metals: aluminum, iron and manganese. The stream pH was monitored hourly for approximately three one week periods during relatively dry periods. Samples and measurements taken during this period provided data for the baseline (dry weather) results. Five

storm event (wet weather) grab samples were collected during an approximately 1 inch rainfall (12 hour storm) on October 4th an 5th and analyzed for the three primary metals. The pH was also measured during the storm event grab samples at sites 4 and 6.

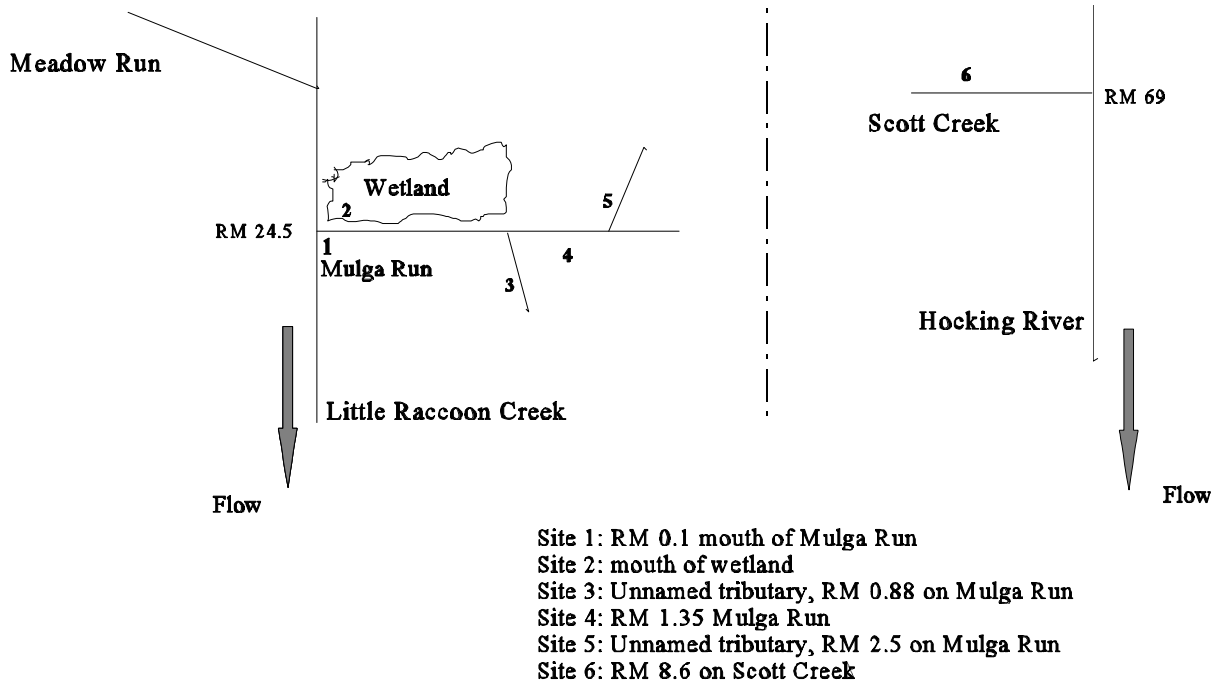


Figure 17. Acid Mine Drainage Study Areas

Baseline sampling results were also measured during the storm event grab samples at sites 4 and 6. The average values for aluminum, iron, manganese and stream pH are presented in Figure 18 and Table 4 for the baseline (dry weather) sampling. Concentrations for all three metals were elevated at all sites on Mulga Run when compared to those of Scott Creek with the exception of aluminum at site 2 (wetland mouth). Interestingly, the average aluminum values at the mouth of the wetland were about one fifth the average value at Scott Creek and considerably lower than the other sites on Mulga Run, particularly, sites 4 and 5. Sites 4 and 5 typically had the highest average metals concentrations. Average pH was very acidic and ranged between 4.3 and 5.5 at the measured sites on Mulga Run while pH averaged 7.2 on Scott creek.

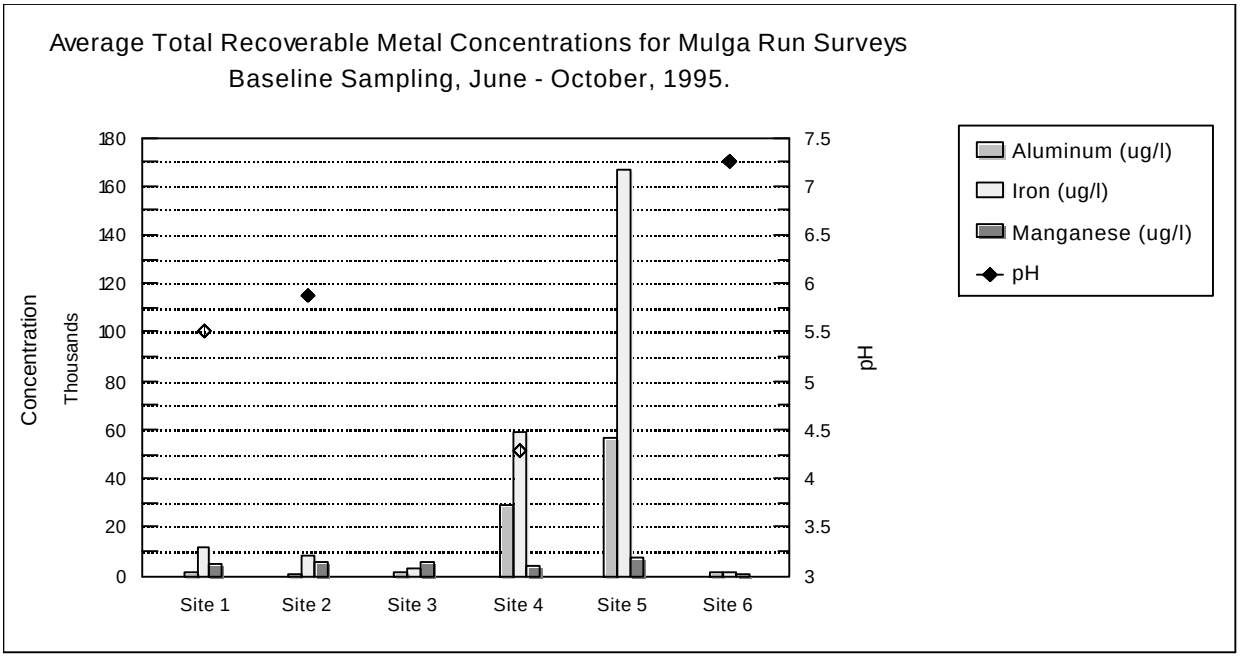


Figure 18. Baseline (Dry Weather) Sampling Results

Table 4. Baseline (Dry Weather) Average Sampling Data

Site	Aluminum (ug/l)	Iron (ug/l)	Manganese (ug/l)	pH
1, mouth of Mulga	1032	12063	5085	5.5
2, wetland mouth	270	8112	5302	5.9
3, unnamed trib	1580	3140	5220	--
4, Mulga Run above wetland	28852	58750	4111	4.3
5, unnamed trib from active mining area	56784	166243	7057	--
6, Scott Cr control	1027	1310	298	7.2

Hydraulic Survey Results

A permanent hydraulic measuring station was installed at site 4 on Mulga Run for the period of

study. Stream depth was measured continuously with a fixed ultrasonic level recorder and stream flow was measured near the level recorder on nine separate occasions between June and November. Readings from the level recorder representative of the time during which the stream flow was measured were matched with the flow measurements and used to develop the relationship between stream depth and estimated stream flow shown in Figure 19. With this relationship established, the flow could be estimated at any time by referring to the appropriate level recorder reading.

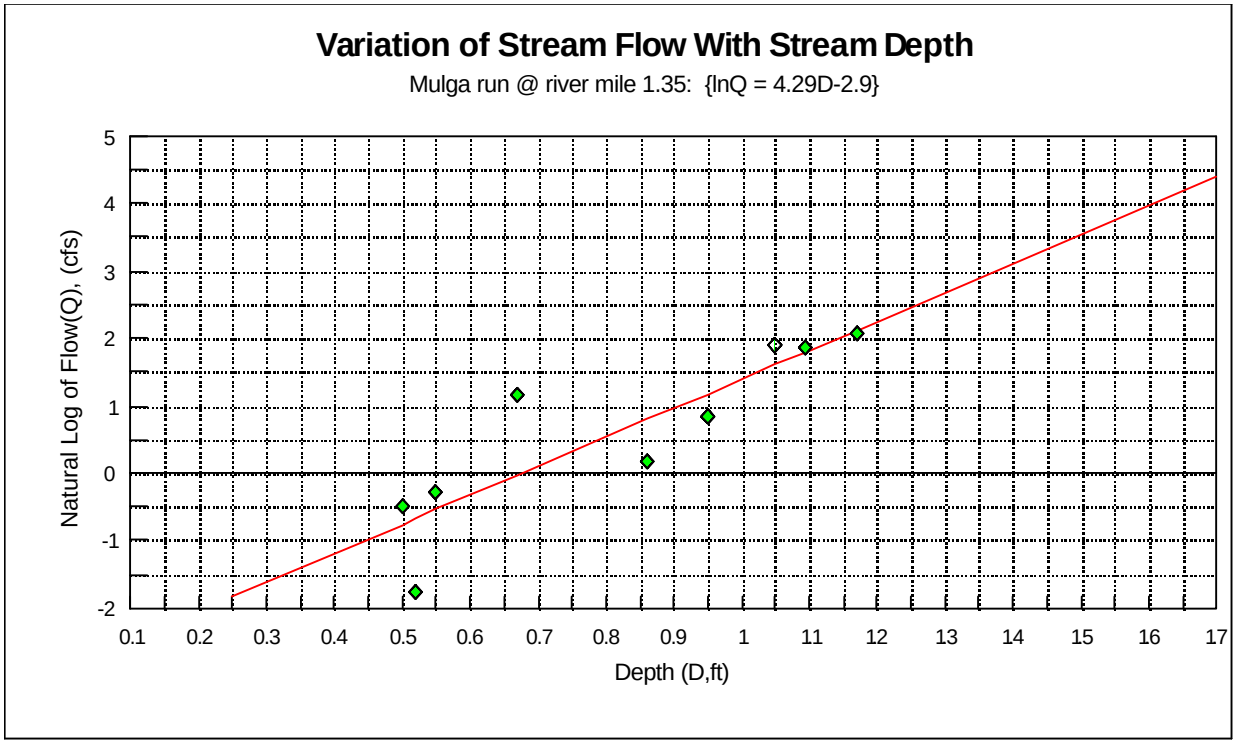


Figure 19. Variation of stream flow with stream depth at river mile 1.35 (site 4) on Mulga Run.

Storm Event Sampling Results

Five to six storm event (wet weather) grab samples were collected at site 4 on Mulga Run and at site 6 on Scott creek during an approximately 1 inch rainfall lasting about 12 hours on October 4th and 5th, 1995. The grab samples were analyzed for aluminum, iron and manganese. pH was monitored hourly at both sites as well. Figures 20 through 22 show the aluminum, iron and manganese concentrations, respectively, at various stages of the storm hygrograph measured at site 4. For comparison, Figures 20 through 22 show the concentrations measured just prior to the storm, concentrations on average over the dry sampling period for Mulga Run and concentrations on average over the dry sampling period at Scott Creek. Figure 23 illustrates the change in stream pH with flow during the storm for site 4 along with comparison values for pH from measurements just prior to the storm and long term measured pH values from Mulga Run and Scott Creek.

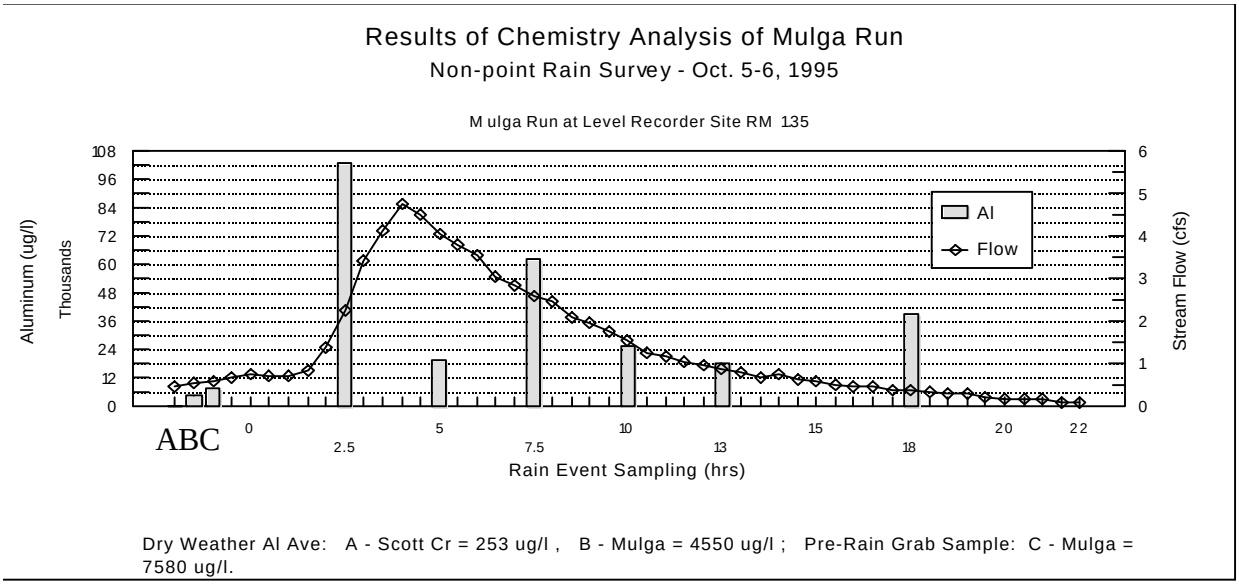


Figure 20. Variation of Stream Aluminum Concentration with Stream Flow For Storm Event of October 4-5, 1996 at River Mile 1.35 on Mulga Run.

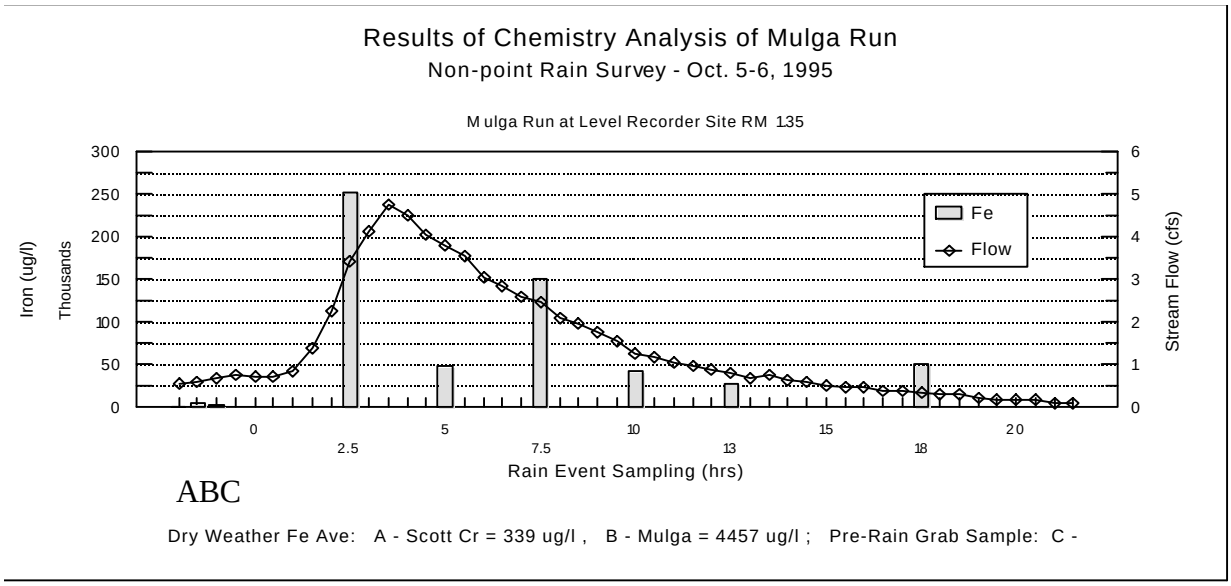


Figure 21. Variation of Stream Iron Concentration with Stream Flow For Storm Event of October 4-5, 1996 at River Mile 1.35 on Mulga Run

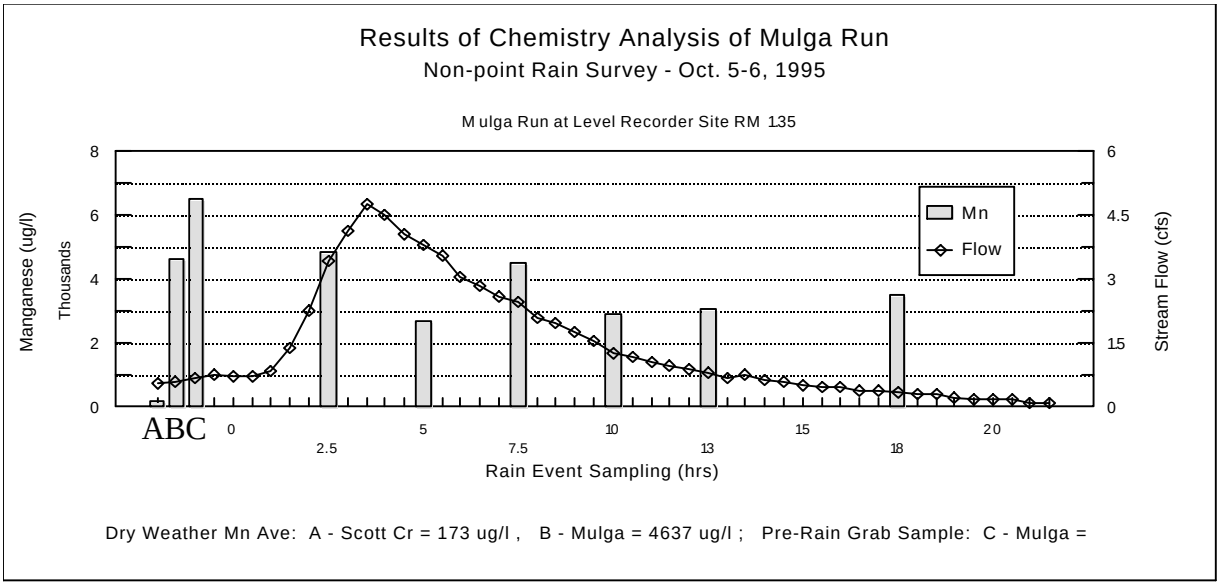


Figure 22. Variation of Stream Manganese Concentration with Stream Flow For Storm Event of October 4-5, 1996 at River Mile 1.35 on Mulga Run

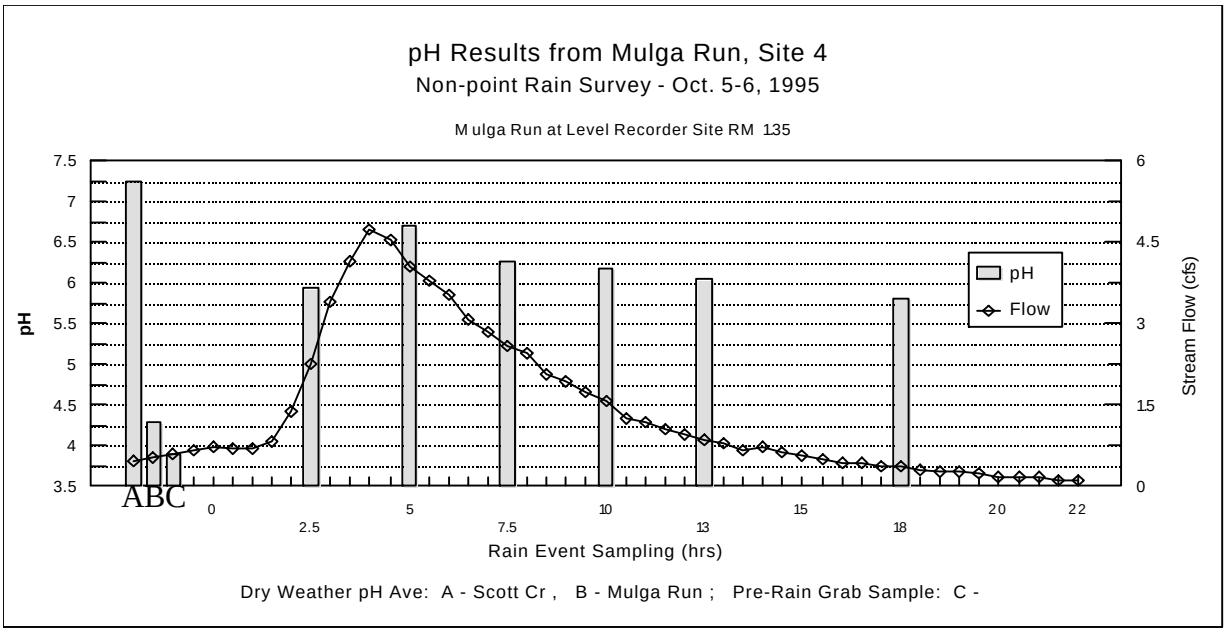


Figure 23. Variation of Stream pH with Stream Flow For Storm Event of October 4-5, 1996 at River Mile 1.35 on Mulga Run

Figures 24 through 26 show the variation of metals concentrations in Scott Creek (site 6) during the storm run-off of October 4-5. (Flows in Scott Creek were estimated using the ratio of drainage areas for Mulga Run upstream from site 4 (7.9 square miles) and Scott Creek upstream from site 6 (1.28 square miles) and multiplying by the known flows in Mulga Run for corresponding points on the storm hydrograph. Stream depth measurements were also available at Site 6 for the rain event. Peak concentrations for the storm run-off in Scott Creek were less than or roughly equal to dry weather averages in Mulga Run and one to two orders of magnitude less than peak concentrations for the storm run-off into Mulga Run.

Estimated Average Loading Comparison

With instream metals concentrations and flow data available for both wet and dry conditions, it was possible to develop relationships between flow and concentration on Mulga Run. These relationships are presented in Figures 27 through 29. Concentrations of aluminum and iron tend to increase during the run-off while instream manganese concentrations became more diluted. With a stage discharge relationship established on Mulga Run and a record of the stage between June and October available, it was possible to estimate the load for any of the three metals at site 4 on Mulga Run at any time between June and October. Monthly average flow values were determined for site 4 and the aluminum, iron and manganese concentration was estimated from the relationships in Figures 27, 28, and 29, respectively. The product of the average monthly flow and estimated concentrations (the estimated average monthly loads) are shown in Tables 7 through 9. In order to allow for a comparison of the relative impacts of Mulga Run on Little Raccoon Creek and Scott Creek on the Hocking River, the average monthly metal loadings in Scott Creek were also estimated. The ratio of the Scott Creek and Mulga Run drainage areas was multiplied by the average monthly flow in Mulga Run and used as the average monthly flow in Scott Creek. The ratio of the baseline (dry weather) sampling averages for metals concentrations was multiplied by the estimated monthly concentration in Mulga Run to estimate average monthly concentrations in Scott Creek. Although Scott Creek drains about one fourth the area of Mulga Run, these estimates indicate that it contributes only about one twentieth of the load of Mulga Run at the observed sites. That is, Mulga Run's abnormally large metal load is one to two orders of magnitude larger than that of Scott Creek at the sites measured.

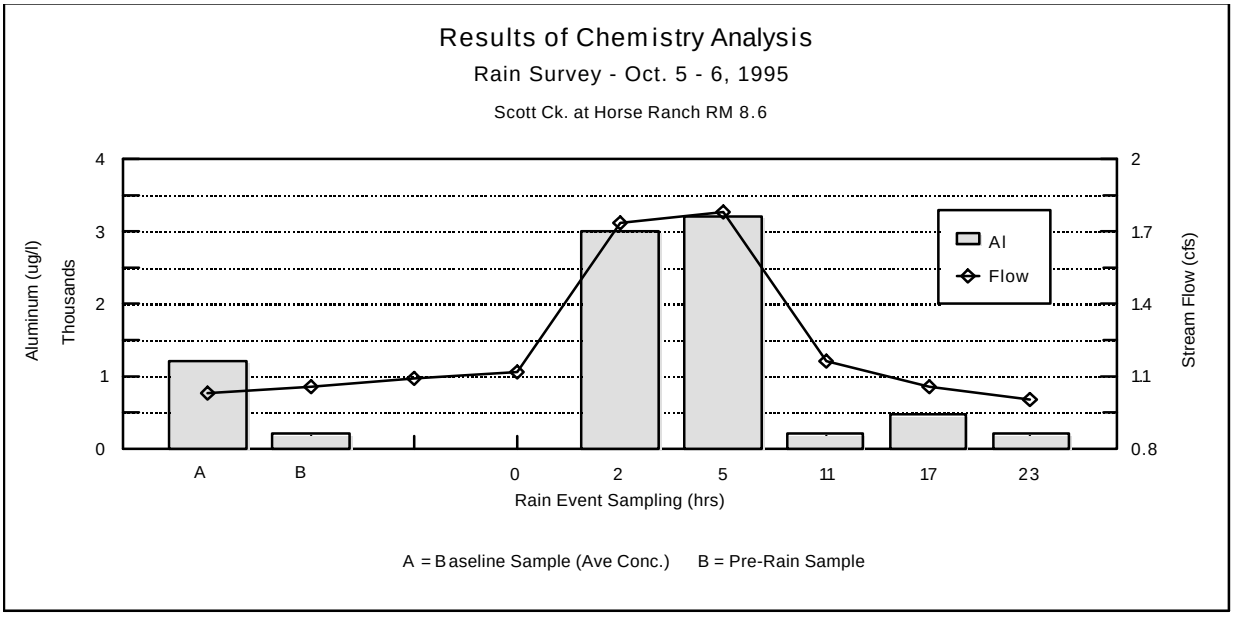


Figure 24. Variation of Stream Aluminum Concentration with Stream Flow For Storm Event of October 4-5, 1996 at River Mile 8.6 on Scott Creek.

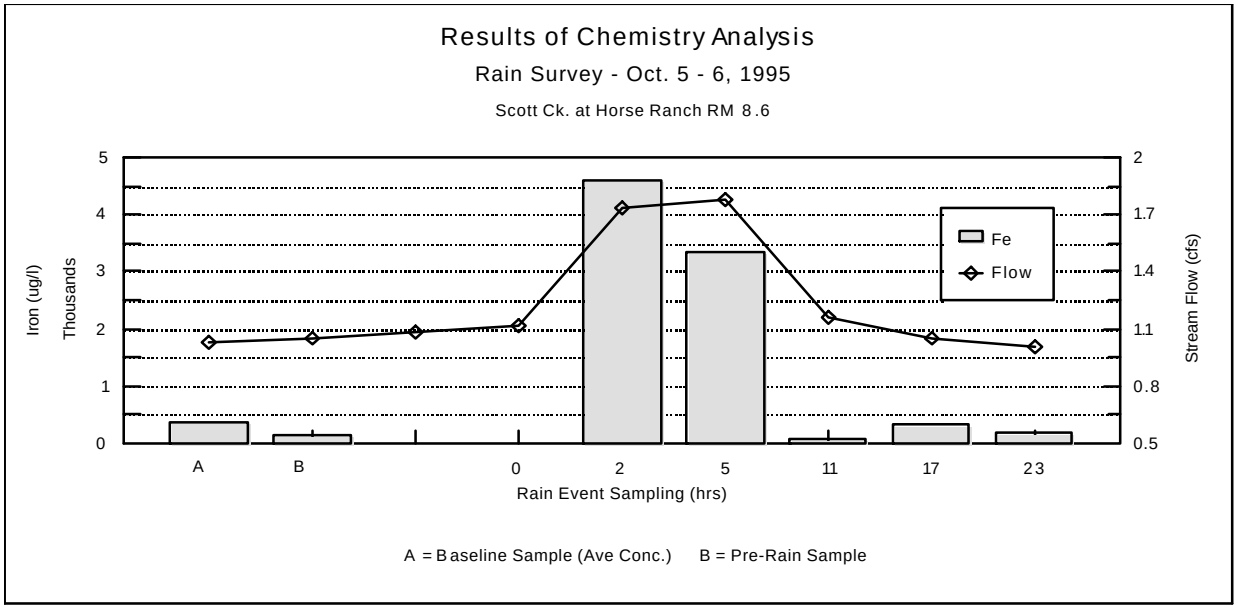


Figure 25. Variation of Stream Iron Concentration with Stream Flow For Storm Event of October 4-5, 1996 at River Mile 8.6 on Scott Creek.

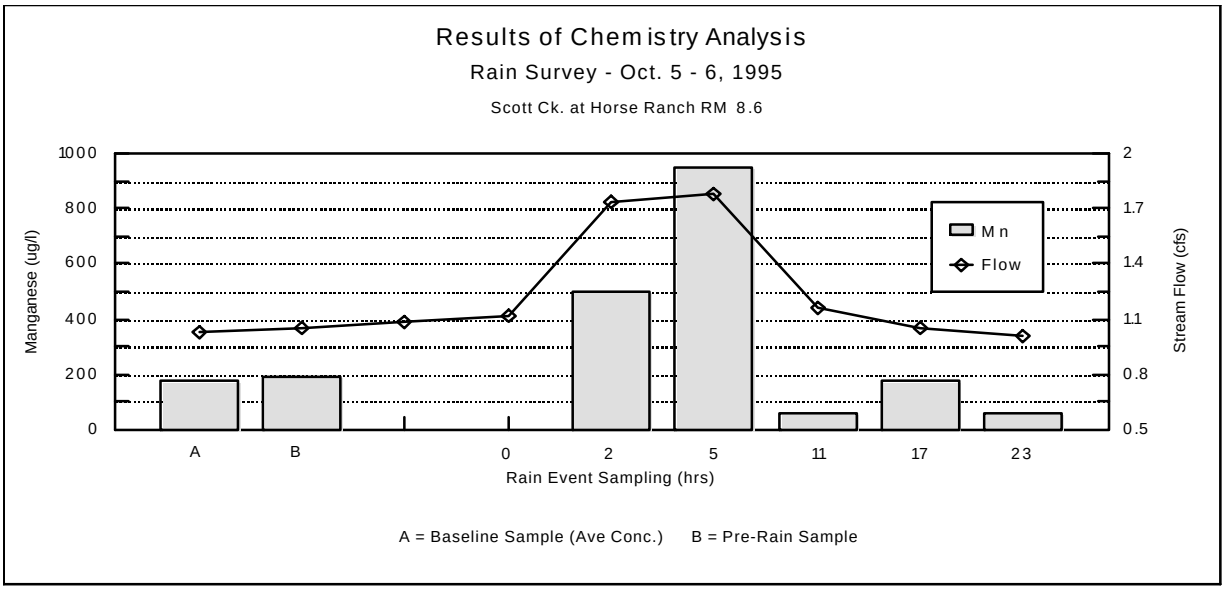
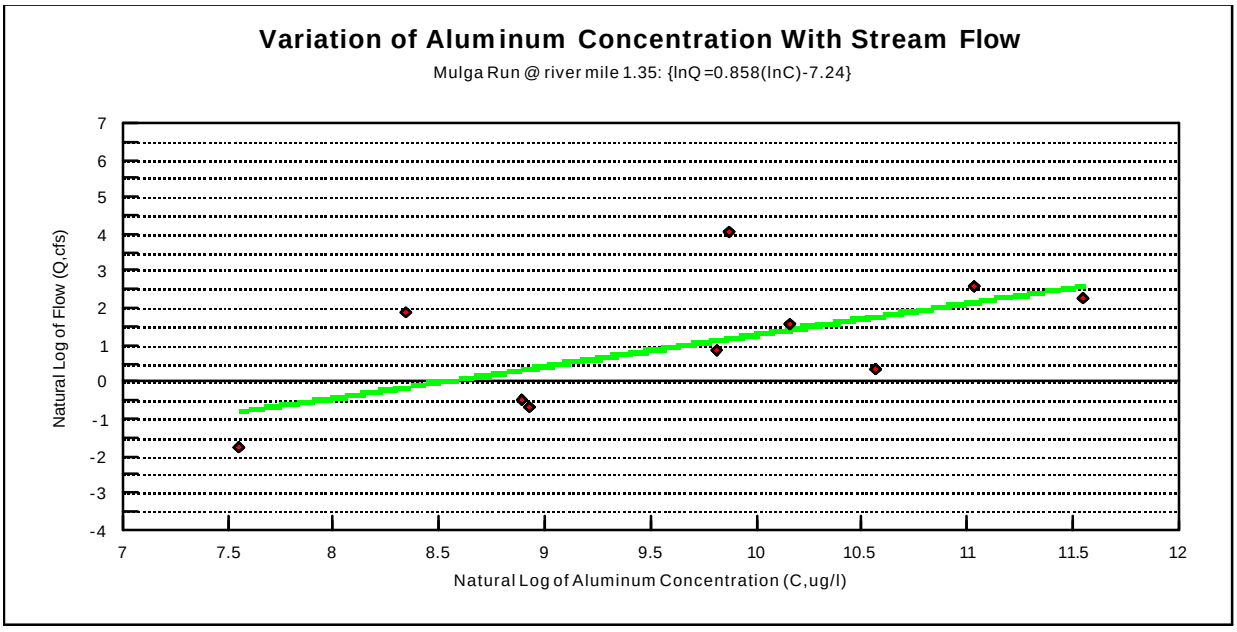


Figure 26. Variation of Stream Manganese Concentration with Stream Flow For Storm Event of October 4-5, 1996 at River Mile 8.6 on Scott Creek.

Figure 27. Variation of Stream Aluminum Concentration with the Natural Log of Stream Flow For



Storm Event of October 4-5, 1996 at River Mile 1.35 on Mulga Run.

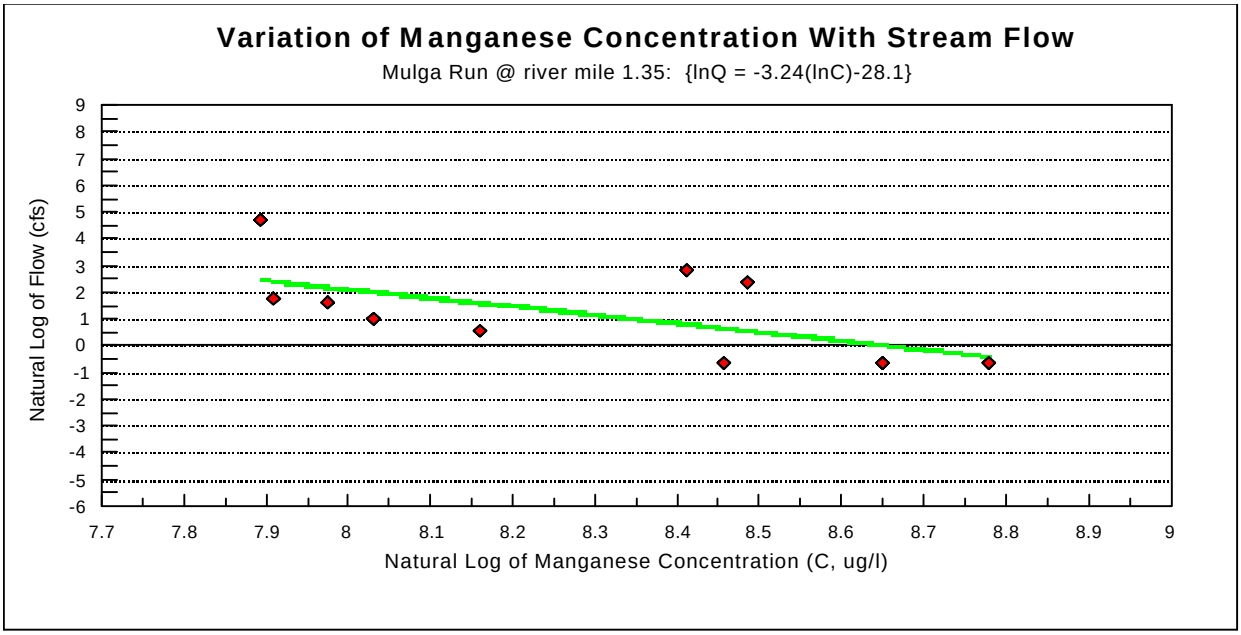


Figure 28. Variation of Stream Manganese Concentration with the Natural Log of Stream Flow For Storm Event of October 4-5, 1996 at River Mile 1.35 on Mulga Run.

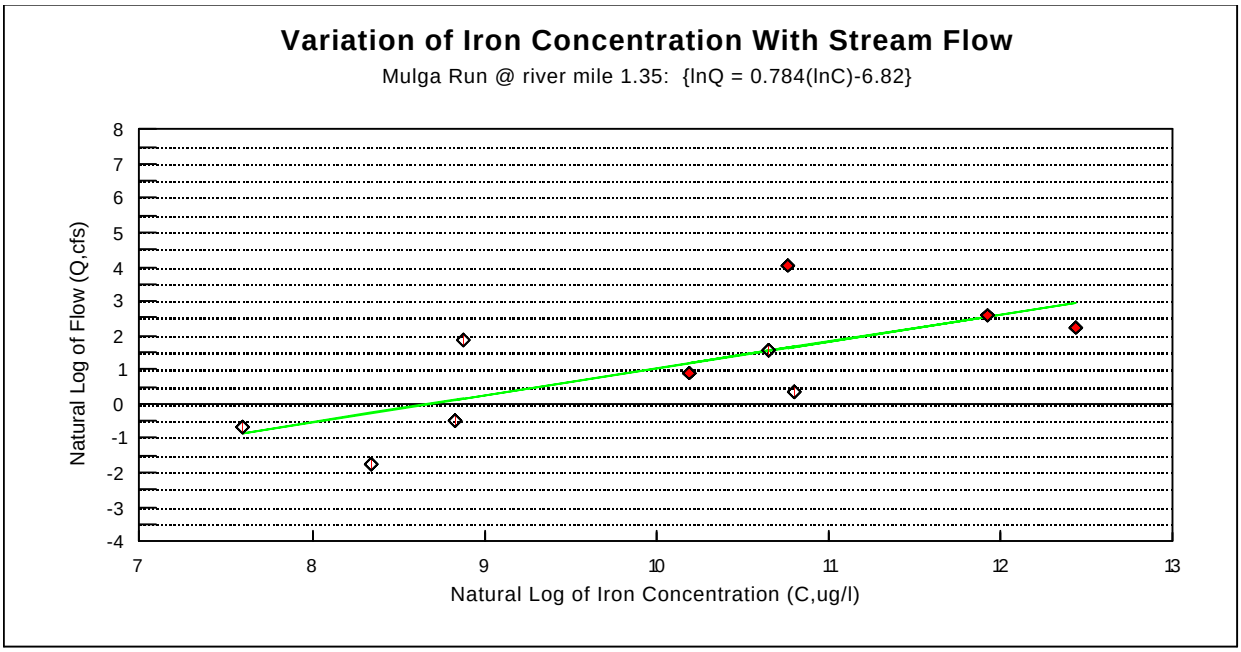


Figure 29. Variation of Stream Iron Concentration with the Natural Log of Stream Flow For Storm Event of October 4-5, 1996 at River Mile 1.35 on Mulga Run

Table 7. Estimated Average Projected Load for Instream Aluminum

Month (1995)	Projected Average Flow (cfs)		Projected Average Conc. (mg/l)		Projected Average Load (lb/day)	
	Mulga Run	Scott Creek	Mulga Run	Scott Creek	Mulga Run	Scott Creek
July	2.61	0.42	14100	3270	198400	7400
August	0.75	0.12	3300	770	13300	500
September	0.43	0.07	1730	400	4000	150
October	0.86	0.14	3880	900	18000	680

Table 8. Estimated Average Projected Load for Instream Iron

Month (1995)	Projected Average Flow (cfs)		Projected Average Conc. (mg/l)		Projected Average Load (lb/day)	
	Mulga Run	Scott Creek	Mulga Run	Scott Creek	Mulga Run	Scott Creek
July	2.61	0.42	20400	720	287000	1630
August	0.75	0.12	4150	150	16800	97
September	0.43	0.07	2040	72	4728	27
October	0.86	0.14	4950	174	22900	130

Table 9. Estimated Average Projected Load for Instream Manganese

Month (1995)	Projected Average Flow (cfs)		Projected Average Conc. (mg/l)		Projected Average Load (lb/day)	
	Mulga Run	Scott Creek	Mulga Run	Scott Creek	Mulga Run	Scott Creek
July	2.61	0.42	4340	290	61100	660
August	0.75	0.12	6380	430	25800	280
September	0.43	0.07	7580	510	17600	190
October	0.86	0.14	6120	410	28400	310

Sediment Quality (Table 10, 11)

Sediment samples were collected from three sites on Meadow Run in October 1995 and analyzed for metals and organics. These sites were located above Pillsbury's facility, at the 14th St. bridge, and at the Chaetwood Rd. bridge (RMs 3.1, 1.47, and 0.72, respectively). Additionally, three sites sampled for dioxin were located in the Wellston WWTP mixing zone, at the 14th St. bridge, and at the Chaetwood Rd. bridge (RMs 1.47, 1.16, and 0.72, respectively). All samples were collected to assess levels of contaminants present in stream sediments in Meadow Run.

A portion of Meadow Run from the State Route 327 bridge (RM 2.05) to approximately 200 feet below Wellston's current outfall (RM 1.17) was dredged in 1989 by the city. Therefore, the sediment samples taken at the 14th Street bridge and in the Wellston WWTP mixing zone represent an accumulation of sediment not exceeding five years. The remaining sites were not affected by the dredging. Sediment accumulation was very sparse at the site upstream from the Pillsbury mixing zone and minimal at the 14th Street bridge site. However, heavy deposits of sediment were found in the Wellston WWTP mixing zone and at the Chaetwood Rd. bridge site.

Sediment samples were evaluated using *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* (Persaud, *et.al*, 1994). These guidelines define levels of ecotoxic effects and are based on the chronic, long-term effects of contaminants on benthic organisms. Metals were screened according to the following categories:

> No Effect Level-At this level, no toxic effects are observed on aquatic organisms. Water quality and use guidelines are usually met.
>
> Lowest Effect Level (LEL)-This level indicates some sediment contamination, but at a level that can be tolerated by most benthic organisms.
>
> Severe Effect Level (SEL)-At this level, there is a pronounced disturbance of the organisms which normally reside in the sediment and is usually detrimental to the majority of the benthic species. If any parameters are at or above the Severe Effect Level guideline, the material is considered highly contaminated and will most likely have a significant effect on benthic biological resources.

Nine metal parameters were tested and results are presented in Table 10. Of those nine metals, only one metal exceeded the Severe Effect Level, manganese at 14th Street (RM 1.47). Manganese was below the Lowest Effect Level at the upstream station at RM 3.1 and at the downstream station at RM 0.72. This trend was also obvious in the chemical water quality sampling which showed higher levels of manganese at RM 2.1 and RM 1.47 compared to lower levels at RMs 3.1 and 0.72 (see Figure 16, in the Chemical Water Quality section). One possible cause may be an identified mining problem located upstream from RM 2.1 and north of the Pillsbury plant (Figure 4).

Arsenic and iron exceeded the Lowest Effect Level at all three locations. There were higher sediment concentrations of chromium, copper, lead, and zinc downstream (RM 0.72) from the Pillsbury and Wellston WWTP discharges compared to upstream (RM 1.47). The concentrations of these metals at RM 0.72 exceeded the Lowest Effect Level, but not the Severe Effect Level.

The organic analyses at RM 3.1 and RM 1.47 revealed no detectable levels of volatile or semi-volatile organics. The pesticides d-BHC and y-BHC were detected at RM 3.1, and heptachlor epoxide was detected at RM 1.47; all were at concentrations barely above detection limits. At RM 0.72, four semi-volatile organics were detected at very low levels. Four pesticides were also detected, the most prevalent pesticide being dieldrin, at 42 ug/kg. Also present were d-BHC, heptachlor epoxide, and methoxychlor.

The Total Toxicity Equivalent (TTE) is a measure of the toxicity potential of a sample. It is computed by multiplying each 2,3,7,8 chlorinated dioxin and dibenzofuran congener by its Toxicity Equivalence Factor (TEF), which is the toxicity of the congener compared to the toxicity of 2,3,7,8-TCDD (which is 1.0). These are then summed for each 2,3,7,8 congener in the sample (see Table 11).

Dioxin contamination was evident in the sediments in Meadow Run downstream from the Wellston WWTP to Chaetwood Road. The Total Toxicity Equivalent increased a hundredfold from 3.9 ppt TTE at RM 1.47 (upstream from the Wellston WWTP), to 362 ppt and 246 ppt TTE downstream at RMs 1.16 and 0.72, respectively.

Table 10. Dry weight concentrations of heavy metals (mg/kg or ppm) in sediments of Meadow Run, l995. All parameter concentrations were ranked based on stream sediment classification system[1] described in the *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* (Persaud, *et.al.*,1994.)

	Sediment Concentration (mg/kg,dry weight)								
River Mile	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Mn**	**Ni***	**Zn**
LEL[2]	6	0.6	26	16	20000	31	460	16	120
SEL[3]	33	10	110	110	40000	250	1100	75	820
Meadow Run									
3.1	*13.1*[2]	0.12	*29.6*[2]	10	*24400*	<17.7	*506*[2]	<23.6*	85.7
1.47	*12.6*[2]	<0.14	<20.9	9.75	*28900*	<20.9	**5330**[3]	<27.8*	86.3
0.72	*12.4*[2]	0.53	*38.8*[2]	*50.5*[2]	*26400*	*88.5*[2]	*607*[2]	<36.1*	*244*[2]

[1]Below Lowest Effect Level-no notation after reported value.
[2]*Exceeds Lowest Effect Level*
[3]**Exceeds Severe Effect Level**
*The values for nickel could not be accurately screened since the detection limit was above LEL.

Table 11. Dioxin and dibenzofuran levels in sediment collected from Meadow Run, 1995, by the Ohio EPA. Concentrations are in ng/kg (ppt).

	Upst. Wellston RM 1.47	Wellston Mix RM 1.16	Dst. Wellston RM 0.72	Toxicity Equivalence Factor (TEF)
Dioxins				
2378-TCDD	<0.3	33.9	29.7	1
12378-PeCDD	<0.5	199	93.4	0.5
123478-HxCDD	<0.5	59.1	24.2	0.1
123678-HxCDD	0.51	379	181	0.1
123789-HxCDD	0.66	536	133	0.1
1234678-HpCDD	38.9	5610	5320	0.01
OCDD	3420	48620	71150	0.001
Total TCDD	<0.3	91.1	100	
Total PeCDD	<0.5	967	412	
Total HxCDD	5.0	6230	3090	
Total HpCDD	99.6	14660	13950	
Dibenzofurans				
2378-TCDF	<0.3	4.1	7.5	0.1
12378-PeCDF	<0.4	10.5	6.5	0.05
23478-PeCDF	<0.4	8.9	3.7	0.5
123478-HxCDF	<0.4	40.6	26.9	0.1
123678-HxCDF	<0.3	64.0	13.8	0.1
234678-HxCDF	0.23	40.1	5.6	0.1
123789-HxCDF	<0.4	1.6	<2.7	0.1
1234678-HpCDF	0.5	463	259	0.01
1234789-HpCDF	<0.4	19.5	10.8(E)	0.01
OCDF	0.78	1480	1100	0.001
Total TCDF	<0.3	48.3	66.1	
Total PeCDF	<0.4	441	235	
Total HxCDF	0.59	1690	472	
Total HpCDF	0.87	1130	768	
2378 TCDD Total Toxicity Equivalent-TTE	3.9	361	245	
(includes one half of the not detected limit)	(4.9)	(361)	(246)	

Fish Tissue (Table 12)
All 2,3,7,8-chlorinated dioxin and dibenzofuran congeners were analyzed in fish collected upstream and downstream from the Wellston WWTP at RMs 1.6 and 0.8. Samples included both a yellow bullhead composite and a black bullhead composite at each site (Table 12). All dioxin/dibenzofuran results from 1995 samples were below the U.S. Food and Drug Administration (FDA) Action Level (50 parts per trillion, ppt), as well as below the FDA reduced consumption level of 25-50 ppt.

Comparison of fish tissue data and sediment data showed very few correlations. The fish tissue data showed relatively insignificant differences between the different congeners for the same fish species when comparing upstream to downstream results, except for a greater than tenfold increase in yellow bullhead concentrations of OCDD and OCDF when comparing upstream to downstream concentrations. Sediment concentrations of all dioxin and dibenzofuran congeners showed significant increases from upstream to downstream from the WWTP.

Table 12. Dioxin and dibenzofuran levels in whole body fish tissue samples collected from Meadow Run, 1995, by the Ohio EPA. Concentrations are in ng/kg (ppt).

	Toxicity Equivalence Factor(TEF)	Upst. Wellston WWTP (RM 1.6)		Dst. Wellston WWTP (RM 0.8)	
		Yellow Bullhead	Black Bullhead	Yellow Bullhead	Black bullhead
Dioxins					
2378-TCDD	1	10.0	8.4	8.8	7.2
12378-PeCDD	0.5	16.6	15.4	15.2	12.7
123478-HxCDD	0.1	1.9	<1.4	1.7	1.1
123678-HxCDD	0.1	11.9	9.2	10.8	7.5
123789-HxCDD	0.1	3.8	2.4	3.6	2.0
1234678-HpCDD	0.01	16.4	8.8	34.2	7.7
OCDD	0.001	17.6	50.8	252	39.1
Total TCDD		10.3	8.4	8.8	7.4
Total PeCDD		19.1	17.0	17.4	14.2
Total HxCDD		22.9	16.2	21.7	14.3
Total HpCDD		17.5	13.5	48.6	11.9
Dibenzofurans					
2378-TCDF	0.1	<0.1	<0.2	<0.2	<0.2
12378-PeCDF	0.05	<0.67	0.42	<0.62	0.33
23478-PeCDF	0.5	1.1	<0.76	1.1	0.68
123478-HxCDF	0.1	0.99	0.41	1.0	<0.34
123678-HxCDF	0.1	0.71	0.43	0.61	0.37
234678-HxCDF	0.1	0.38	0.29	<0.38	0.28
123789-HxCDF	0.1	<0.1	<0.2	<0.2	<0.2
1234678-HpCDF	0.01	0.75(E)	0.42(E)	3.9(E)	0.2(E)
1234789-HpCDF	0.01	<0.1	<0.3	0.38	<0.2
OCDF	0.001	<0.3	0.88	29.8	0.98
Total TCDF		<0.1	<0.2	<0.2	<0.2
Total PeCDF		4.3	1.4	3.6(Q)	1.9
Total HxCDF		4.2	3.2	5.6	2.3
Total HpCDF		<1.1	1.2(E)	13.7	0.61
2378 TCDD Total Toxicity Equivalent-TTE (includes one half the not detected limit x TEF)		21.4 (21.6)	17.5 (18.1)	19.3 (19.5)	15.2 (15.3)

Physical Habitat For Aquatic Life (Table 13, Figure 30)

Raccoon Creek

As part of the 1995 sampling effort, the macrohabitats of Raccoon Creek were evaluated at 12 fish sampling stations. Qualitative Habitat Evaluation Index (QHEI) values ranged between 47.0 (RM 40.2, Vinton dam pool) and 69.5 (RM 10.0, downstream from the Northup dam) with a mean reach QHEI value of 59.4 (Table 13). A mean reach value near or greater than 60.0 typically indicates aggregate macrohabitat quality consistent with the maintenance of WWH assemblages (Rankin 1989).

Macrohabitat quality appeared fairly stable throughout the mainstem. For the most part, Raccoon Creek appeared physically unmodified, excluding the dam pool at Vinton and the lower reach impounded by the Ohio River (RM 5.4, SR 218). Nearly every station was found to include a continuous mature wooded riparian corridor. This critical stream feature stabilizes stream banks, impedes the delivery of sediment derived from overland runoff, attenuates sunlight, and provides in-stream cover in the form of fallen timber and woody debris.

The mainstem is characterized by low stream gradient, as the evaluated reach averaged 1.7 ft/mile. Instream features of this low energy stream included: abundant pools, slow and monotonous current speeds, predominance of fine (shifting and unstable) substrates, and few well-developed riffle/run/pool complexes.

Abundant deep water areas and substrate composition were by far the most influential habitat features. The pools encountered at most stations were typically > 1 meter in depth and well structured with woody debris and fallen timber. As such, species associated with this habitat type (e.g., centrarchids) would find highly favorable conditions throughout much of the mainstem. Sand, silts, and accumulated detritus were the predominant substrate types. These materials created shifting and unstable benthic conditions. The predominance of fine and embedding substrates would strongly disadvantage substrate dependant species (e.g., lithophils and non-centrarchid insectivores).

The general habitat conditions observed throughout the mainstem appeared a result of both the natural characteristics of the basin as well as the chemical and physical stressors derived from unreclaimed mining areas. Given the natural low gradient of this system, sediment delivered from the previously mined uplands, and to a lessor extent agricultural areas, has accumulated within the channel, embedding native substrates and contributed to overall channel and substrate simplification. Sedimentation appeared to constitute the most significant nonchemical factor affecting the suitability of Raccoon Creek for typical warmwater assemblages of aquatic organisms. The physical effects of mine drainage were evident at most stations, but most severe within the upper portion of the mainstem. Iron and aluminum precipitates were often observed within this segment. These deposits further degraded substrate quality.

East Branch and West Branch Raccoon Creek

Macrohabitat quality of both the East Branch and West Branch Raccoon Creek was evaluated at two fish sampling stations located on each of these Raccoon Creek tributaries. All stations included (at least) a

minimum compliment of positive habitat features commonly associated with warmwater faunas. The channel configuration at all stations appeared unmodified, representing natural or recovered conditions. Coarser substrates were more abundant than observed in the Raccoon Creek mainstem. Nearly all stations scored a predominance of WWH QHEI attributes. QHEI values and field observation indicated sufficient macrohabitat quality in these subbasins.

Unnamed Raccoon Creek Tributary

Macrohabitat quality of this tributary was evaluated at one fish sampling station located at RM 0.1. This station achieved a QHEI score of 37.0. This value indicated severely deficient physical habitat, far below the WWH threshold of 60.0 (Rankin 1989). The reach evaluated had been clearly modified in the past, although limited channel recovery was evident. Pools and abundant instream cover were the dominant positive features. However, the station was overwhelmingly predominated by negative modified attributes (Table 13). The substrates consisted entirely of silts, clay, and accumulated detritus. The channel was straight (an artifact of past modification), lacking functional sinuosity. Channel development was almost nonexistent, lacking even rudimentary riffle-run-pool complexes. The highly simplified physical features of this stream would exert a strong negative influence on ambient biological performance.

Elk Fork

The macrohabitats of Elk Fork were evaluated at seven fish sampling stations. Qualitative Habitat Evaluation Index in these subbasins values ranged between 52.0 (RM 11.0, TR 8) and 75.0 (RM 13.3, US 50) with a mean reach QHEI value of 63.1 (Table 13). A mean reach value near or greater than 60.0 typically indicates aggregate macrohabitat quality consistent with the maintenance of a WWH aquatic fauna (Rankin 1989).

Positive habitat features commonly encountered in Elk Fork included natural or recovered channel morphology, an abundance of deep pools, sinuous course, and a persistent wooded riparian corridor. Nearly all stations were found to include a fairly diverse array of positive physical attributes. Unfortunately fine sifting and unstable substrates derived primarily from unreclaimed mined areas within the basin appeared the most significant limiting habitat feature. The abundance of deep water areas and the nearly pervasive embeddedness would tend to favor species adapted to structured pools and strongly disadvantage more substrate dependent species. Despite the substrate limitations, Elk Fork appeared to possess (in the aggregate) macrohabitats of a sufficient quality to support and maintain an assemblage of aquatic organisms minimally consistent with the WWH aquatic life use.

Puncheon Fork

Macrohabitat quality of Puncheon Fork was evaluated at two stations located at RMs 1.5 and 0.3 (upstream and downstream from the McArthur WWTP, respectively). QHEI values at both station indicated habitat conditions fully consistent with warmwater aquatic fauna potential. The substrates were mixed, though predominantly coarse, and instream cover was diverse and fairly abundant. Channel development was fair, but deep pools and small riffles were present.

Selected Raccoon Creek Tributaries

Macrohabitat quality of sixteen Raccoon Creek tributaries was evaluated in 1995. Habitat evaluations were conducted at one station per stream, typically placed less than a mile from the mouth. The streams evaluated included: Rockcamp Creek, Coal Run, Onion Creek, Tedroe Run, Twomile Run, Grass Run, Merrit Run, Russell Run, Flat Run, Long Run, Zinns Run, Pierce Run, Rockcamp Run, Indiancamp Run, Karr Run, and Opossum Run.

Most stations appeared to represent natural or unmodified conditions, typical of headwater environments found within the unglaciated Western Allegheny Plateau (WAP) ecoregion. Very good to exceptional habitat quality was indicated in Indiancamp Run, Onion Creek, Long Run, and Zinns Run, as QHEI values ranged between 69.0 and 82.0 (Figure 30). Habitat driven impairment did not appear likely in these streams.

Deficient habitat conditions were observed in only three Raccoon Creek tributaries: Flat Run, Russell Run, and Pierce Run. QHEI values in these streams ranged between 48.0 and 52.0. The physical habitat of both Russell Run and Flat Run appeared impacted by sediment laden runoff derived from unreclaimed mine lands. The substrates were primarily fine, shifting and unstable clays and silt. This sediment load embedded native substrates greatly limiting the function of this important habitat feature. The diminished conditions observed in Pierce Run appeared a result of direct physical modification. Nearly half of the reach evaluated has been channelized and stripped of much of its riparian vegetation. These activities have diminished the biological potential of this small stream.

The remaining Raccoon Creek tributaries were found to score sufficient positive habitat features. QHEI values within these streams ranged between 55.0 and 64.0. Although optimal habitat was not consistently observed, biological impairment driven solely by habitat condition did not appear likely within these streams.

Little Raccoon Creek

The macrohabitats of Little Raccoon Creek were evaluated at three fish sampling stations. QHEI values ranged between 60.0 (RM 28.3, upstream from Meadow Run) and 47.5 (RM 24.6, downstream from Meadow Run) with a mean reach QHEI value of 54.7 (Table 13). A mean reach value near or greater than 60.0 typically indicates aggregate macrohabitat quality consistent with the maintenance of a WWH aquatic fauna (Rankin 1989). The mean reach value for Little Raccoon Creek would suggest diminished near and instream macrohabitats. These conditions would likely exert a negative influence on ambient biological performance.

Modified habitat attributes were predominant at all stations. Substrates consisted primarily of sand and detritus, creating unstable benthic conditions. Substrate quality was further diminished by moderate to heavy siltation. Configuration of the wetted channel was monotonous, as deep water areas were by far the most common channel feature. Most pooled areas were well structured with woody debris and fallen timber. As observed in other large streams within the Raccoon Creek study area, pool habitats and substrate composition appeared the most prominent and influential habitat component. The conditions in Little Raccoon Creek undoubtedly favored species associated with pools and strongly disadvantaged more

substrate dependant species.

Substrate composition appeared a result of sediment laden drainage from unreclaimed mine lands within the basin. Little Raccoon Creek receives discharge from a series of known mine influenced tributaries, most prominently Mulga Run. Mine drainage, funneled through this and other tributaries appeared to significantly degrade the physical habitat of Little Raccoon Creek through the significant contribution of fine sediment to the existing bedload.

Meadow Run

The macrohabitats of Meadow Run were evaluated at four fish sampling stations. Qualitative Habitat Evaluation Index values ranged between 56.0 (RM 3.1, adjacent to the Pillsbury facility) and 43.0 (RM 2.1, SR 327), with a mean reach value of 50.3. Stream segment average QHEI values equal to or greater than 60.0 typically indicate aggregate macrohabitat quality sufficient to support a community of aquatic organisms consistent with the WWH aquatic life use designation (Rankin 1989 and Rankin 1995). The observed mean reach value of 50.3 strongly suggests deficient stream habitats. These conditions likely exerted a negative influence upon the ambient biological performance in Meadow Run.

All stations evaluated possessed a predominance of high and moderate influence modified habitat attributes (Table 13). Substrates often were derived from silts or consisted of naturally occurring clay hardpan. If coarser substrates were present, they were typically embedded by finer sediments, greatly limiting the functionality of this important component of stream macrohabitat. Channel heterogeneity was low, as well developed riffle-run-pool complexes were absent from the study area. The only positive habitat attributes commonly encountered included well developed pools (max depth > 70 cm) and the presence of instream structure, mainly in the form of woody debris and/or deadwood snags.

Depauperate habitat conditions were most pronounced within the reach extending from RM 2.1 (SR 327) downstream to RM 1.5 (upstream from the Wellston WWTP and Pillsbury WWTP outfalls). This segment was extensively channelized by the city of Wellston in 1989 as an attempt to locally increase stream flow. The channel configuration was trapezoidal in cross section and excavation activities likely reduced stream-fall to near base gradient. At RM 2.1 (SR 327), no physical recovery from the channel modification was evident. Accumulated sediments and established beds of emergent aquatic macrophytes reflected the slack water conditions. The vegetation and sediment deposits reduced channel capacity and likely contributed to the diminished stream discharge. Conditions were slightly improved by RM 1.5; however, habitat quality was still well below that required to support an assemblage consistent with the WWH use.

At RM 0.8 (Chaetwood Rd., downstream from the Wellston and Pillsbury WWTPs), macrohabitat quality was modestly improved and appeared in a more natural state. The channel at this station appeared unmodified or recovered and moderately sinuous. Pool habitats were developed and well structured with abundant woody debris. Despite these positive attributes, fine substrates were still dominant and channel development was limited.

Despite local gradients as high as 15.6 ft./mile and an average of 11.6 ft./mile, actual stream conditions were much more indicative of a low gradient/low energy water course. Based upon the previous investigation (Ohio EPA 1985) the $Q_{7,10}$ (0.6 cfs) and the time-of-travel (0.1 ft./sec.) for Meadow Run were well below that typically encountered for streams averaging gradients as high as 11.0 ft./mile. Additionally, habitat features observed throughout the study area (e.g., monotonous channel development, a lack of riffle-run development, predominance of fine substrates, wetland areas, and little discernible flow) were *not* characteristic of medium-high gradient/higher energy streams. The discrepancy between the gradients calculated from topographic maps and actual stream flow, discharge, and habitat characteristics were striking and difficult to explain. Stream gradients were determined from 7.5' USGS topographic maps, by measuring the distance of contour interval(s) that crossed Meadow Run. Contour lines are derived from interpolated points of a known elevation. It is possible the Meadow Run valley is cut deeper (at a lower elevation) than the interpolated contour interval would suggest. This cartographic anomaly may explain the apparent discrepancy observed in 1995.

Ultimately, the question of gradient pertains mainly to the recovery potential of Meadow Run. In the absence of conflicting ambient stream data, it could be expected that a stream possessing an average gradient approaching 11.0 ft./mile could reestablish many positive habitat features (through natural fluvial processes) lost by channelization. However, the *true* characteristics of Meadow Run strongly suggest a low energy stream system, despite a high average stream fall. As a result, the simplified habitats observed will likely persist into the foreseeable future, for the fluvial processes governing the stream's physical characteristics are not likely sufficient to reclaim the habitat deficit accrued. Therefore, it is doubtful that the reach of Meadow Run from the headwaters to approximately RM 1.5 has or will develop the requisite macrohabitats consistent with the maintenance of a WWH assemblage of aquatic organisms.

Little Raccoon Creek Tributaries

Macrohabitat quality of six Little Raccoon Creek tributaries was evaluated in 1995. Habitat evaluations were conducted at one station per stream, typically placed less than a mile from the mouth. The streams evaluated included: Rich Run, Flint Run, Goose Run, Buffer Run, Coal Run, and Greasy Run.

Most stations appeared to representative of natural or unmodified conditions, typical of headwater environments found within the unglaciated Western Allegheny Plateau (WAP) ecoregion. Very good to marginally good habitat quality was indicated in: Rich Run, Flint Run, Buffer Run, Coal Run, and Greasy Run (Figure 30). QHEI values of these streams ranged between 54.0 and 72.0, near or greater than the WWH threshold. Most stations were found to score a compliment of QHEI habitat attributes commonly associated with WWH aquatic faunas. Although optimal habitat was not consistently observed, biological impairment driven solely by diminished physical conditions was not likely within these streams.

Deficient habitats were observed only in Goose Run (QHEI=44). The physical habitat of this stream appeared impacted by sediment laden runoff derived from unreclaimed mine lands. The substrates were primarily fine, shifting and unstable clays and silts. This sediment load embedded native substrates greatly limiting functionality of this important physical feature. Diminished habitat quality of Goose Run likely exerted a strong negative influence on ambient biological performance.

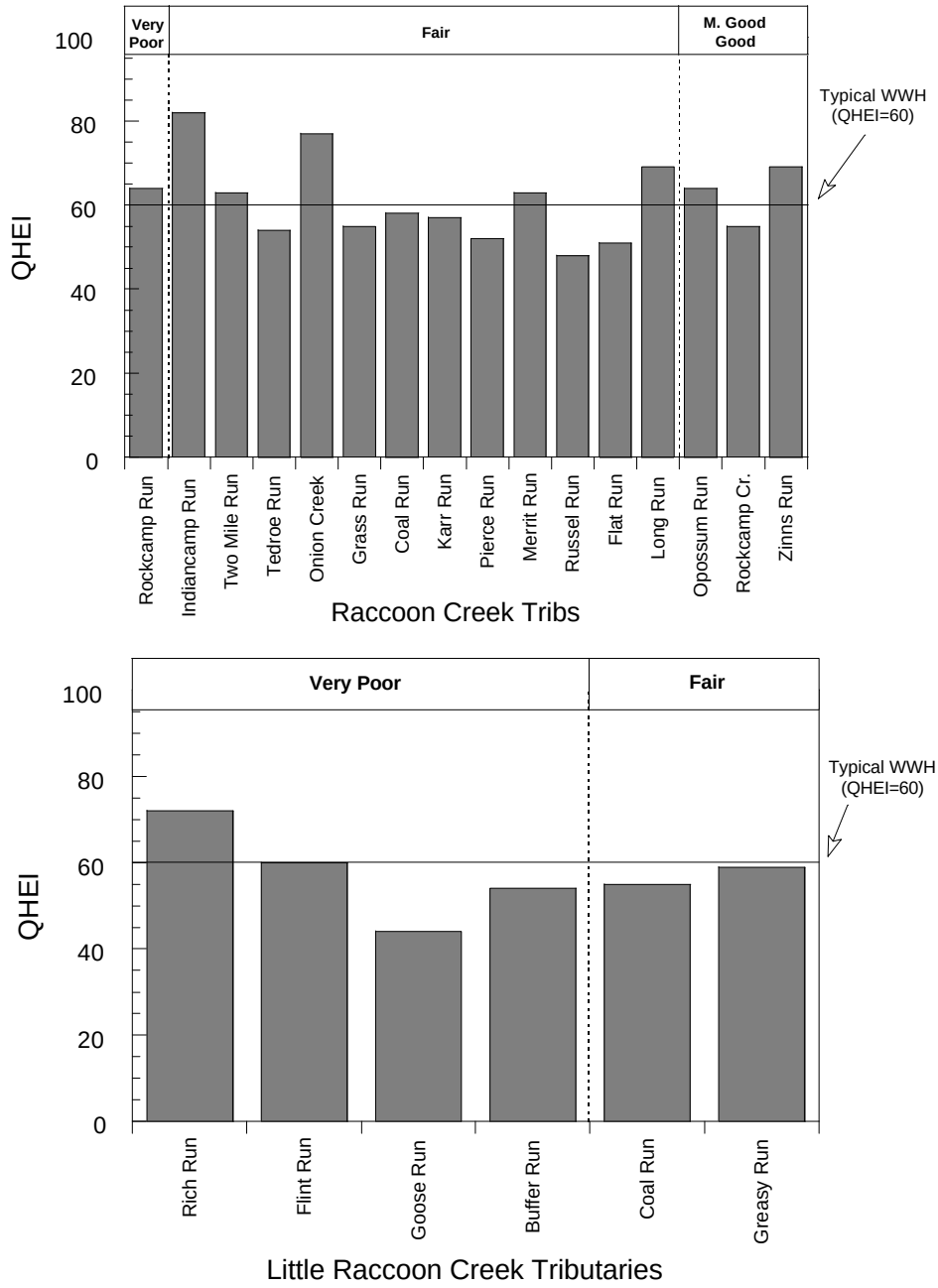


Figure 30. Qualitative Habitat Evaluation Index (QHEI) scores for selected Raccoon Creek and Little Raccoon Creek tributaries, 1995. Horizontal line indicates typical WWH QHEI threshold. Narrative biological evaluations (top) were derived from corresponding IBI scores.

Biological Assessment: Macroinvertebrates (Table 14, Figures 31-33)
A total of 133 macroinvertebrate taxa were collected from Raccoon Creek mainstem in 1995. A cumulative total of 280 taxa were collected throughout the watershed. By sampling location, the highest cumulative total number (59) of macroinvertebrate taxa collected on the Raccoon Creek mainstem occurred at Adamsville (RM 29.1), and the highest cumulative number (18) of EPT taxa (mayflies, stoneflies, and caddisflies) collected occurred between the confluences with Laurel Creek and Onion Creek (RM 84.3). Throughout the watershed, the highest cumulative total number (69) of taxa occurred in Meadow Run at 14th Street (RM 1.5) and highest number of EPT taxa (22) in Elk Fork (RM 14.1) upstream from Puncheon Fork.

There were some macroinvertebrate taxa collected in Raccoon Creek that characteristically inhabit high quality rivers and streams in Ohio. Sensitive taxa collected included the mayflies *Acerpenna macdunnoughi* (two sites) and *Labiobaetis propinquus* (eight sites), the stonefly genus *Acroneuria* (one site) and the midge *Rheotanytarsus distinctissimus* (ten sites). A rare taxon collected was the midge genus *Pagastiella* (one site).

Six coolwater macroinvertebrate taxa collected in Raccoon Creek were the megalopteran *Nigronia faciatus* (RM 84.3), and the midges *Meropelopia* sp. (RM 98.3), *Diplocladius cultriger* (RM 39.9), *Orthocladius (O.)* sp. (RM 72.3), *Parametriocnemus* sp. (RM 108.9), and *Polypedilum (P.) aviceps* (RM 50.1).

Raccoon Creek
Macroinvertebrate assemblages were sampled and evaluated at 12 sites on Raccoon Creek from below the confluence of the East Branch and West Branch Raccoon Creek (RM 108.9) to Northup (RM 10.2). Narrative evaluations of the assemblages ranged from fair quality in the upper section below the East Branch and West Branch confluence to Lake Hope (RM 108.9 to RM 98.3), and marginally good to exceptional quality from Lake Hope to Northup (RM 92.3 to RM 10.2). Invertebrate Community Index (ICI) scores ranged from a low of 14 (downstream from the East Branch and West Branch at RM 108.9) to a high of 48 (upstream Radcliff at RM 63.8, and at Northup at RM 10.2).

Sites in the upper section of Raccoon Creek (RM 108.9 to RM 98.3), upstream from Lake Hope, scored ICI values in the lower fair range (14 to 18). Macroinvertebrate communities on artificial and natural substrates were characterized by low densities, low numbers of taxa, and the absence of mayflies. The characteristic orange stained substrates and precipitates of acid mine drainage were common at these sites, obviously impacted from the East Branch Raccoon Creek which was also orange stained.

Macroinvertebrate communities improved substantially downstream from Lake Hope, where ICI scores ranged from 36 (good) at RM 92.3 to 48(exceptional) at RM 63.8. Eight to ten taxa of mayflies were collected at the sites between Lake Hope and Radcliff, compared to no mayflies in the Raccoon Creek mainstem upstream from this segment. Also, densities of tanytarsini midges increased from less than 17% upstream from Lake Hope, to over 40% downstream from Lake Hope to Radcliff .

The decline in the ICI score to 32 (marginally good) at Humpback Bridge (RM 50.1) may have reflected additional mining impacts to the Raccoon Creek mainstem downstream from Radcliff from such tributaries as Pierce Run, Rockcamp Run, and Karr Run. The lower ICI score may also be reflective of an acid mine slug deposited in 1994 during a high water period.

Macroinvertebrate community performance improved from Vinton to Northup into the good and exceptional range (ICI scores ranged from 38 to 48). These sites had relatively high numbers of total taxa and EPT taxa, and high densities of tanytarsini midges.

East Branch Raccoon Creek
Samples were collected at RM 6.6 and RM 0.1. Invertebrate Community Index (ICI) scores at both sites were in the poor range (8 and 10, respectively). The characteristic orange stained substrates and precipitates of acid mine drainage were common at these sites, and this impact continued into the Raccoon Creek mainstem which was also orange stained from RM 108.9 to RM 98.30.

West Branch Raccoon Creek
A qualitative sample, collected at RM 5.7, had 6 EPT taxa and a QCTV score (35.6) below ecoregional expectations. This site was evaluated as fair, with nonattainment of WWH attributed to low flow conditions. The next site at RM 0.1 had 8 qualitative EPT taxa and an increased QCTV score (36.8); the quantitative sample from this site scored an ICI of 38 which was in the good range.

Tributary to Raccoon Creek (Austin Powder Tributary, confluence with Raccoon Creek RM 98.96)
Habitat was limited on this tributary, with flow over the top of a beaver dam representing the only riffle. This site was evaluated as fair with only 3 EPT taxa and a low QCTV score (29.0) based on the qualitative natural substrate collection.

Elk Fork
The two sites on Elk fork upstream from Puncheon Fork had ICI scores of 36 (RM 16.2) and 54 (RM 14.1), in the good and exceptional range. These sites had high numbers of total taxa (63 and 65) and high numbers of qualitative EPT taxa (16).

Coal fines were noted as depositional material on the artificial substrate samplers at all sites on Elk Fork, but most abundantly at RM 16.2, 13.3, and 10.1. A drop in the macroinvertebrate community performance was observed at RMs 13.3, 10.1, and 0.1 where only 5 to 6 qualitative EPT taxa were collected from the natural substrates, compared to 16 qualitative EPT taxa at the two upstream sites. During qualitative sampling at RM 13.3, thick deposits of silt were observed in slow current areas, possibly due to mine drainage entering Elk Fork from a tributary just upstream from this station.

Although sampling the natural substrates yielded only 5 EPT taxa at RMs 10.1 and 0.1, macroinvertebrate communities collected from the artificial substrates scored ICI values in the very good range (42 to 44). Since the artificial substrates were covered with silt at RM 13.3, this site was evaluated as marginally good based on the qualitative sample. Although the number of EPT taxa was similar to RMs 10.9 and 0.1, the

QCTV score was below ecoregional expectations at RM 13.3. .

Puncheon Fork
Macroinvertebrates were collected from the natural substrates at RM 1.6 and RM 0.3, upstream and downstream from the McArthur WWTP. The upstream station was evaluated as good with 11 EPT taxa and a QCTV score (39.2) above ecoregional expectations. Downstream from the WWTP the benthic community was composed of more tolerant organisms indicated by a lower QCTV score (34.2) and had fewer EPT taxa (9). Compared to upstream, the mayfly density decreased and tolerant midge density increased at RM 0.3. The lower site was evaluated as marginally good.

Tributary to Elk Fork (Austin Powder Trib.)
Despite good flow and habitat conditions, only 18 total taxa and only 3 EPT taxa were collected from the natural substrates at this site. The benthic community was considered fair.

Little Raccoon Creek
A good macroinvertebrate community (ICI=36) was collected upstream (RM 28.3) from Meadow Run. Downstream from Meadow Run (RM 24.6) there was a lower density of mayflies accompanied by higher densities of tolerant organisms resulting in a fair community with an ICI score of 28. RM 11.8 was the most downstream macroinvertebrate site on Little Raccoon Creek and had the lowest ICI score (18) on the mainstem.

These sites were characterized by a series of long pools and substrates composed mostly of sand and silt. There was a small stick/log riffle at RM 28.3, and a more extensive stick/log riffle area at RM 11.8. Artificial substrates downstream from Meadow Run at RM 24.6 had algae and possibly the sewage bacteria Sphaerotilus on them as did the substrates at the Chaetwood Road site (RM 0.8) on Meadow Run. The decrease in ICI scores from upstream to downstream Meadow Run appeared to be a result of the poor water quality observed in the lower mile of Meadow Run. The subsequent decrease in ICI score from 28 to 18 at the next site was apparently in response to mine affected tributaries between RMs 24.8 and 11.8. Orange stained margins and logs were observed at RM 11.8. The artificial substrates at RM 11.8 had lower numbers of mayfly, caddisfly, and overall taxa, and there were no heptagenid mayflies collected from the artificial or the natural substrates. Mulga Run, Flint Run, Buffer Run, and Greasy Run are tributaries in this reach that were sampled and found to be mine impacted.

Meadow Run
Macroinvertebrate communities collected in the upper section of Meadow Run from upstream the Pillsbury Plant (RM 3.1) to 14th St. (RM 1.5) reflected fair biological conditions with ICI scores ranging from 20 to 28. The headwaters have historically been affected by mine drainage impacts. The natural substrates were predominated by red midges and the megalopteran genus *Sialus* in low densities, characteristic of many of the other mine impacted streams in the Raccoon Creek basin. Meadow Run flows through a marshy area just upstream from the station at SR 327 (RM 2.1). Although diversity and numbers of mayfly and caddisfly taxa increased at this downstream site (RM 2.1), the benthic community still reflected fair conditions.

Macroinvertebrate community performance remained fair (ICI=28) at 14th St. despite better riffle habitat and flow conditions. This was the only site on Meadow Run where heptagenid mayflies and hydropsychid caddisflies were collected. A total of ten mayfly, caddisfly, and tanytarsini midge taxa comprised 17 % of the organisms collected from the artificial substrates. Following a rainstorm on 8/21/95, a tributary about 50 yards upstream from 14th St. was observed entering as gray water (possibly an indication of raw sewage from an unsewered residential area) mixing with the brown water color of Meadow Run.

The Pillsbury effluent (RM 1.19) and Wellston WWTP effluent (RM 1.17) discharge into a sluggish pooled section of Meadow Run. Qualitative samples collected in these mixing zones on 7/12/95 and 8/21/95 showed very poor macroinvertebrate community performance. The natural substrates were dominated by the tolerant midges *Chironomus (C.)* spp. and *Glyptotendipes* prob. *barbipes* with no caddisfly or tanytarsini midge taxa. Only a single individual of the mayfly genus *Caenis* was collected in the Pillsbury mixing zone on 7/12/95 and in the Wellston WWTP mixing zone on 8/21/95.

At the next station downstream from these dischargers, Chaetwood Road (RM 0.8), sediments were composed of muck and sewage solids. The sewage bacteria Sphaerotilus was present on the artificial substrate samplers. Tolerant aquatic worms, midges, and pond snails comprised 80% of the organisms collected form the artificial substrates. No mayflies, caddisflies, or tanytarsini midges were collected at this site. The ICI score of 0 has been consistent over the years at this station, and represented very poor benthic community performance.

Raccoon Creek and Little Raccoon Creek tributaries

Buffer Run, Goose Run, Flint Run, and Greasy Run in the Little Raccoon Creek basin supported very poor macroinvertebrate communities. No mayfly, stonefly, caddisfly, or tanytarsini midge taxa were collected in these tributaries. There were less than 10 total taxa collected from the natural substrates at each of these sites. The water column and sediments were orange stained in most of these tributaries, characteristic of the AMD impacts in the basin. In Buffer Run coal fines made up a significant portion of the natural stream substrates and a gob pile was observed adjacent to the stream upstream from the sampling location.

Poor quality macroinvertebrate communities were collected from Coal Run and Rich Run in the Little Raccoon Creek basin, and also in the Raccoon Creek tributaries Merrit Run, Karr Run, Pine Run, Rockcamp Run, and Pierce Run. These tributaries each had only one EPT or one tanytarsini taxa (except Karr Run had 3 EPT taxa) and 7 to 15 total qualitative taxa. Karr Run and Pine Run were the only tributaries where EPT taxa were common on the natural substrates. The water column and sediments were orange stained in most of these tributaries, characteristic of the AMD impacts in the basin.

Long Run, Coal Run, Opossum Run, Tedroe Run, Indiancamp Run, and Rockcamp Creek supported fair macroinvertebrate communities. These tributaries each had 1 to 7 EPT taxa, and 12 to 31 total qualitative taxa.

Twomile Run, Laurel Run, Zinns Run, Russell Run, Flat Run, and Grass Run supported macroinvertebrate communities characteristic of marginally good stream condition. These tributaries each had 4 to 10 EPT

taxa and 29 to 37 total qualitative taxa. Onion Run supported a very good macroinvertebrate community including 13 EPT taxa and 39 total qualitative taxa.

Table 14 . Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and from natural substrates (qualitative sampling) in the Raccoon Creek basin, 1995. Also included are historical collection summaries from 1981-94, where available.

	Quantitative Evaluation							
Stream/River Mile	Density (#/sq.ft.)	Quant Taxa	Qual Taxa	Qual EPT[a]	Total Taxa	QCTV Score	ICI[b]	Evaluation
Raccoon Creek (1995)								
Western Allegheny Plateau -LRW-AMD Use Designation (Recommended)								
108.9	11	15	15	1	25	37.7	14	Fair
101.2	97	26	19	4	36	39.1	18	Fair
98.3	88	26	20	5	36	39.2	18	Fair
Western Allegheny Plateau - WWH Use Designation (Existing)								
92.3	211	25	30	10	41	39.8	36	Good
84.3	2430	27	31	12	47	40.5	38	Good
72.3	379	43	29	10	58	39.1	46	Exceptional
63.8	316	37	30	11	52	40.3	48	Exceptional
50.1	147	32	21	7	42	40.1	32[ns]	Marg. good
39.9	1494	32	44	12	56	39.7	38	Good
35.6	-	-	36	13	-	41.3	E	Exceptional
29.1	656	41	41	13	59	40.5	46	Exceptional
10.2	212	36	40	14	54	40.1	48	Exceptional
Raccoon Creek (1994)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
50.1	230	26	10	2	30	38.5	22*	Fair
39.9	217	34	35	6	54	33.9	22*	Fair
29.1	531	36	33	7	54	31.4	26*	Fair
Raccoon Creek (1993)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
50.1	1546	38	41	9	65	38.9	42	Very good
39.1	3174	32	36	4	54	34.8	26*	Fair
29.1	1572	52	41	7	74	38.2	30*	Fair
Raccoon Creek (1990)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
63.0	518	28	29	8	45	38.9	42	Very good
40.1	1378	37	48	12	61	39.2	46	Exceptional
10.2	689	28	31	10	42	40.0	46	Exceptional

Table 14. (Continued)

Stream/River Mile	Density (#/sq.ft.)	Quant Taxa	Qual Taxa	Qual EPT[a]	Total Taxa	QCTV Score	ICI[b]	Evaluation
			Quantitative Evaluation					
East Branch Raccoon Creek (1995)								
Western Allegheny Plateau - LRW-AMD Use Designation (Existing)								
6.6	232	11	14	1	18	35.6	8	Poor
0.1	169	9	11	1	14	38.5	10	Poor
West Branch Raccoon Creek (1995)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
5.7	-	-	20	6	-	35.6	F*	Fair
0.1	266	28	31	8	44	36.8	38	Good
Elk Fork (1995)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
16.2	183	40	48	16	65	39.6	36	Good
14.1	132	50	38	16	63	39.2	54	Exceptional
Western Allegheny Plateau - WWH Use Designation (Recommended)								
13.3	-	-	31	6	-	37.7	[14][c]	Marginally Good
10.9	181	46	18	5	55	39.1	44	Very Good
0.1	176	40	25	5	52	39.1	42	Very Good
Elk Fork (1981)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
16.2	-	-	28	9	-	40.3	E	Exceptional
15.2	-	-	21	0	-	25.5	P*	Poor
13.9	-	-	28	5	-	31.0	F*	Fair
Western Allegheny Plateau - WWH Use Designation (Recommended)								
13.3	-	-	32	8	-	32.6	G	Good
11.3	-	-	15	4	-	33.6	F*	Fair
10.9	-	-	29	6	-	33.2	G	Good
0.1	-	-	31	5	-	30.1	G	Good
Little Raccoon Creek (1995)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
28.3	177	41	33	5	58	32.9	36	Good
24.6	486	38	35	5	55	29.0	28*	Fair
Western Allegheny Plateau - WWH Use Designation (Recommended)								
11.8	313	23	24	7	39	37.5	18*	Fair

Table 14. (Continued)

Stream/River Mile	Density (#/sq.ft.)	Quant Taxa	Qual Taxa	Qual EPT[a]	Total Taxa	QCTV Score	ICI[b]	Evaluation
			Quantitative Evaluation					
Little Raccoon Creek (1990)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
28.3	195	43	30	6	42	37.5	42	Very Good
24.5	205	37	29	3	52	26.4	24*	Fair
Little Raccoon Creek (1984)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
28.4	158	20	30	6	37	34.7	12*	Poor
24.5	305	25	40	2	56	27.5	16*	Fair
Western Allegheny Plateau - WWH Use Designation (Recommended)								
11.0	257	11	12	2	19	38.9	8*	Poor
Meadow Run (1995)								
Western Allegheny Plateau - WWH Use Designation (Recommended)								
3.1	304	20	24	1	35	26.3	20*	Fair
Western Allegheny Plateau - WWH Use Designation (Existing)								
2.1	472	31	44	3	58	30.3	26*	Fair
1.5	430	46	35	5	69	32.6	28*	Fair
1.18	-	-	*23*	*1*	-	*15.6*	*VP**	*Very Poor*
1.16	-	-	*20*	*0*	-	*13.2*	*VP**	*Very Poor*
0.8	2448	11	20	0	23	15.6	0*	Very Poor
Meadow Run (1990)								
Western Allegheny Plateau - WWH Use Designation (Recommended)								
3.2	97	7	13	0	16	19.2	14*	Fair
Western Allegheny Plateau - WWH Use Designation (Existing)								
1.5	594	33	37	3	50	31.3	20*	Fair
0.8	89	3	6	0	6	-	0*	Very Poor
Meadow Run (1984)								
Western Allegheny Plateau - WWH Use Designation (Recommended)								
3.1	37	8	9	1	15	-	2*	Poor
Western Allegheny Plateau - WWH Use Designation (Existing)								
0.9	1241	3	15	0	15	13.2	0*	Very Poor

Table 14. (Continued)

				Qualitative Evaluation		
Stream/River Mile	Qual Taxa	QCTV Score	Qual EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation
Raccoon Creek (1995)						
35.6	36	41.3	13	Moderate	Mayflies, nonred midges, *Chimarra obscura, Corydalus cornutus*	Exceptional
West Branch Raccoon Creek (1995)						
5.7	20	35.6	6	Low	None	Fair
Trib. To Raccoon Creek (RM 98.96) ***(1995)***						
0.1	29	29.0	3	Low-Mod	Midges	Fair
Elk Fork (1995)						
13.3	31	37.7	6	Low-Mod.	Hydropsychid caddisflies, midges	Marg. Good
Puncheon Fork (1995)						
1.6	29	39.2	11	Low	Mayflies, midges	Good
0.3	42	34.2	9	Moderate	Midges	Marg. Good
Trib. To Elk Fork (Austin Powder) ***(1995)***						
0.4	18	38.9	3	Low	Midges	Fair
Meadow Run (1995)						
(7/12/95)1.2	12	13.2	0	Low	Red midges	Very Poor
(8/21/95)1.2	23	15.6	1	Moderate	Red midges, corixids	Very Poor
(7/12/95)1.17	14	17.7	1	Low	Red midges	Very Poor
(8/21/95)1.17	20	13.2	0	Moderate	Red midges, corixids	Very Poor
Little Raccoon Creek Tributaries (1995)						
Rich Run						
0.1	9	-	0	Low	Red midges	Poor
Coal Run						
0.2	11	32.9	1	Low	Crayfish, odonates	Poor
Flint Run						
1.2	6	-	0	Low	Alderflies, red midges	Very Poor

Table 14. (Continued)

				Qualitative Evaluation		
Stream/River Mile	Qual Taxa	QCTV Score	Qual EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation
Buffer Run						
0.2	2	-	0	Low	None	Very Poor
Greasy Run						
0.2	10	30.3	0	Low	Dragonflies	Very Poor
Goose Run						
0.4	4	-	0	Low	Alderflies	Very Poor
Raccoon Creek Tributaries (1995)						
Twomile Run						
0.1	29	39.1	6	Low	Midges Hydropsychid caddisflies	Good
Grass Run						
0.1	37	35.6	5	Low	Alderflies, midges	Good
Pine Run						
0.1	12	30.3	1	Low	None	Poor
Rockcamp Creek						
1.6	31	29.6	2	Low-Mod.	Midges, caenid mayflies	Fair
Coal Run						
0.1	15	34.7	1	Low	Midges, corixids, beetles	Fair
Laurel Creek						
0.1	31	36.4	6	Low-	Hydropsychid caddisflies,	Good
Onion Creek						
1.4	39	38.9	13	Low-Moderate	Hydropsychid caddisflies mayflies, elmid beetles	Very Good
Tedroe Run						
0.1	21	38.5	2	Low	Red midges, beetles	Fair

Table 14. (Continued)

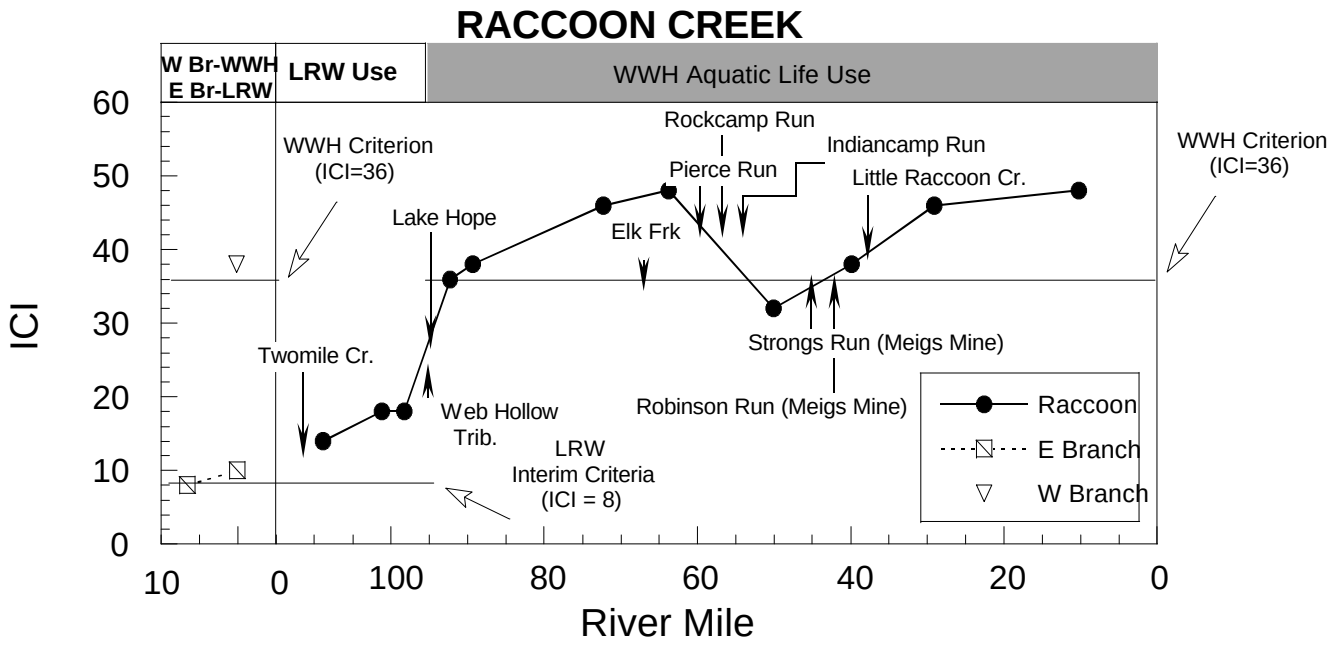
				Qualitative Evaluation		
Stream/River Mile	Qual Taxa	QCTV Score	Qual EPT[a]	Relative Density	Predominant Organisms	Narrative Evaluation
Merrit Run						
0.1	7	-	1	Low	None	Poor
Russel Run						
0.7	33	39.2	11	Moderate	Caddisflies	Good
Flat Run						
1.3	34	31.4	4	High-Moderate	Odonates hydropsychid caddisflies, Burrowing mayflies	Good
Long Run						
1.4	13	40.9	2	Low	None	Fair
Zinns Run						
0.5	32	35.6	5	Moderate	Caddisflies, midges	Good
Pierce Run						
1.7	15	27.5	1	Low-Mod.	Odonates	Poor
Rockcamp Run						
0.3	13	35.6	1	Low	Crayfish	Poor
Indiancamp Run						
0.4	28	39.1	7	Low-Mod.	Craneflies, elmid beetles	Fair
Karr Run						
0.2	7	-	3	Low	Alderflies	Poor
Opossum Run						
0.1	20	37.8	3	Low-Mod.	Scuds	Fair

Table 14. (Continued)

Ecoregion Biocriteria: Western Allegheny Plateau (WAP)

INDEX - Site Type	WWH	EWH	MWH[d]	LRW-AMD[e]
ICI	36	46	22/30	8

a - EPT = total Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness.
b - Qualitative Community Tolerance Value (QCTV) derived as the median of the tolerance values calculated for each qualitative taxon present (see discussion in text).
c - The quantitative sample was affected by slow current speed; evaluation was based primarily on the qualitative sample.
d - Modified Warmwater Habitat for channelized/mine affected habitats.
e - Limited Resource Water - acid mine drainage (LRW-AMD) benchmarks based on best professional judgment driven by the need to protect against acutely toxic stream conditions.
ns - Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb uits). Underlined scores are in the Poor or Very Poor range.



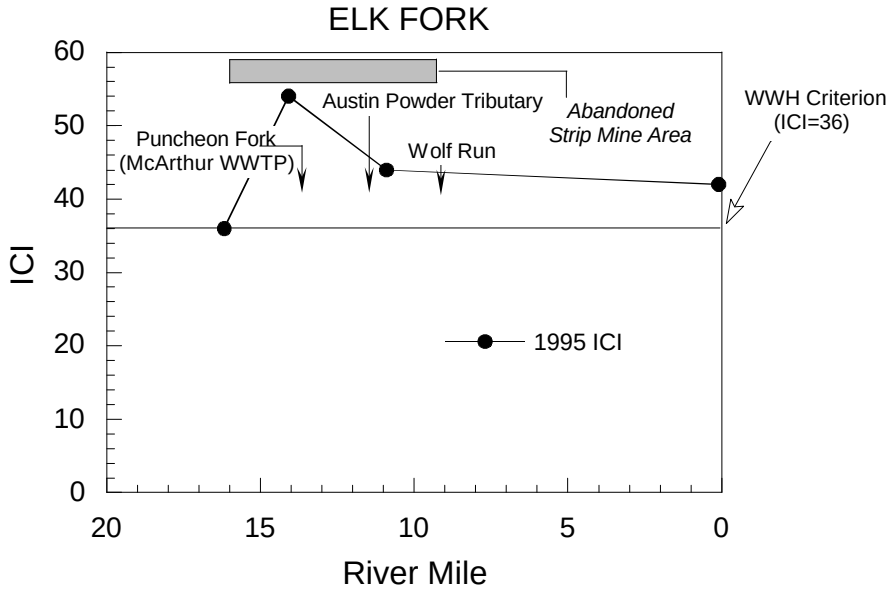


Figure 31. Longitudinal trend of the Invertebrate Community Index (ICI) in Raccoon Creek and Elk Fork, 1995.

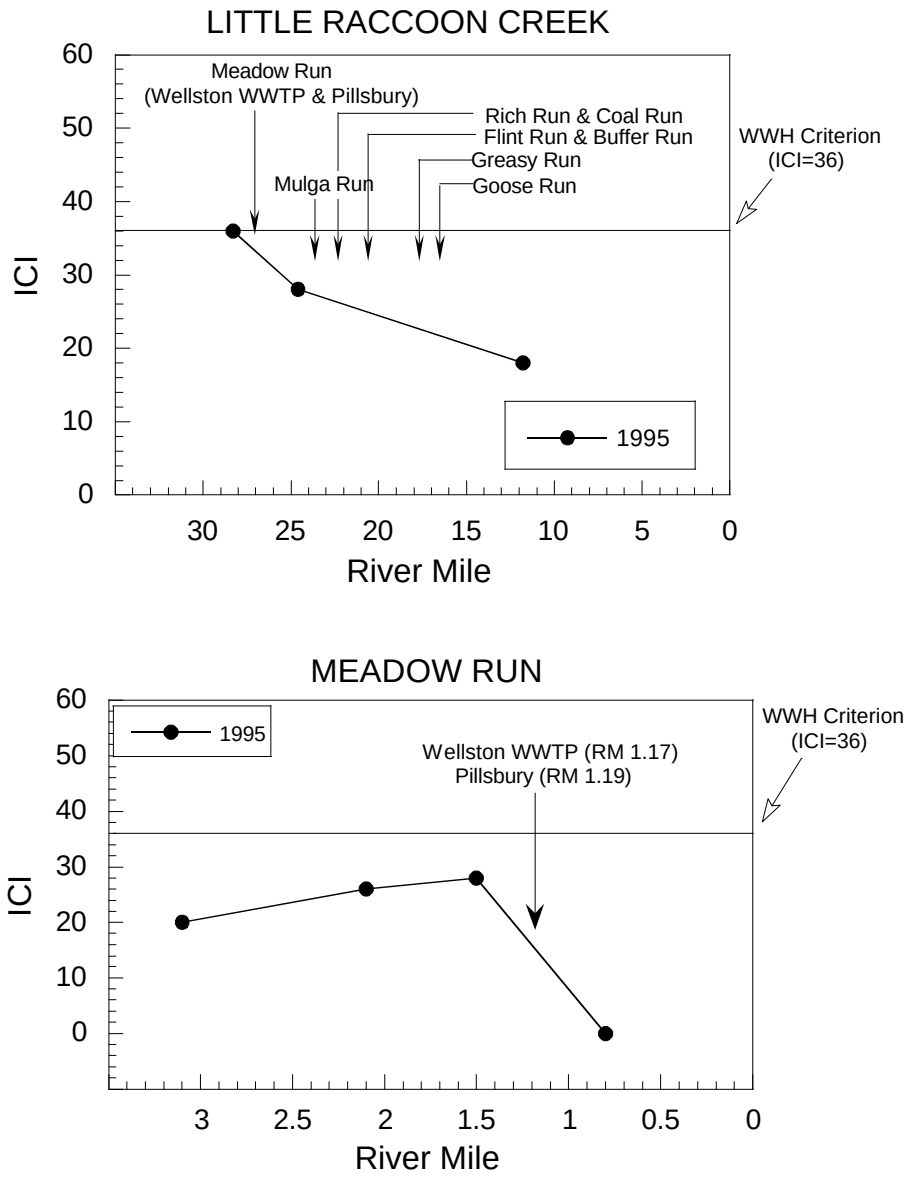


Figure 32. Longitudinal trend of the Invertebrate Community Index (ICI) in Little Raccoon Creek and Meadow Run, 1995.

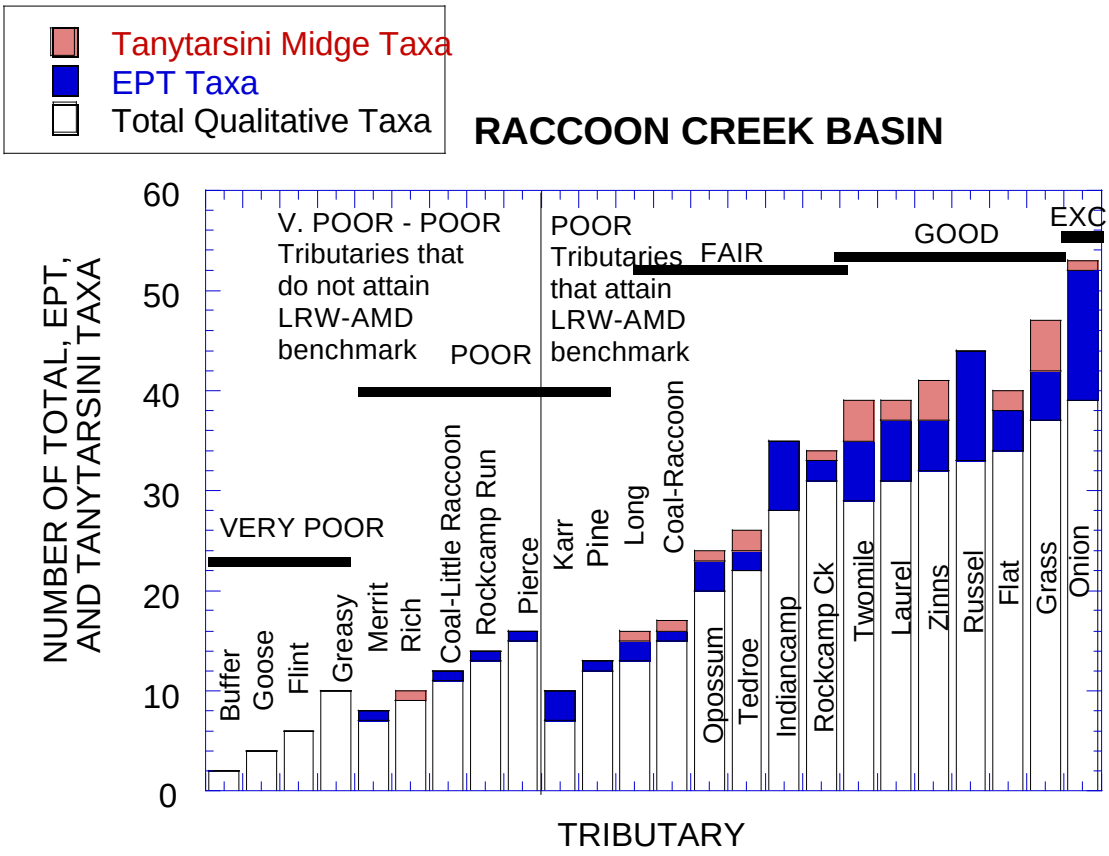


Figure 33. Number of tanytarsini midge, EPT, and total taxa collected in Raccoon Creek and Little Raccoon Creek tributaries, 1995. For qualitative only data in a LRW-AMD stream , a very poor narrative evaluation or a poor evaluation at a site where EPT taxa were not considered to be common or predominant on the natural substrates, was assessed as non-attainment status. A poor narrative evaluation at a qualitative only site was assessed as achieving the LRW-AMD benchmark if there were any EPT taxa observed to be common or predominant on the natural substrates.

Biological Assessment: Fish Community (Table 15, Figures 34-39)

Raccoon Creek

A total of 5,145 fish comprising 53 species and six hybrids was collected from Raccoon Creek between July 25 and September 7, 1995. The sampling effort included 13 stations located between RM 109.1 (SR 328) and RM 5.4 (SR 218), providing an assessment coverage of 103.7 river miles.

Numerically predominant species included longear sunfish (38.1%), bluntnose minnow (7.2%), spotted bass (6.9%), bluegill (6.2%), emerald shiner (6.1%), and golden redhorse (4.3%). Species that predominated in terms of biomass included common carp (23.9%), golden redhorse (16.0%), longear sunfish (14.6%), channel catfish (8.2%), and spotted bass (5.7%).

In terms of numerical abundance, centrarchids (e.g., bluegill, longear sunfish, and spotted bass) comprised over 50% of the fish collected. As most centrarchids are strong associates of the pooled, low gradient channel features that typify much of the Raccoon Creek basin, the dominance of this group of species appeared reflective of existing natural conditions. In terms of biomass, the exotic and highly tolerant common carp comprised a large proportion of the total (23.9%). The common carps position within the community appeared fairly typical in comparison with other medium sized river systems within Ohio. This highly adaptable species is well distributed (Trautman 1981) and commonly occupies a prominent position within the fish assemblages of some of the state's high quality waterways. As observed with relative abundance, the remaining dominant species (in terms of biomass) appeared reflective of the abundance of well-structured pool habitat that are characteristic of Raccoon Creek throughout its course.

Fish community sampling between RM 109.1 (SR 328) and RM 98.4 (F-3 Rd.) employed standard wading methodologies (Ohio EPA 1987b). The remaining downstream segment, extending from RM 92.3 (downstream from Lake Hope) to RM 5.4 (SR 218), was sampled with standard boat methods. The condition of the fish community was evaluated with both the MIwb and IBI, as the study area did not include any true headwater stations (i.e., stations with a drainage area $\leq$ 20 miles^2). Community performance and the accompanying narrative evaluations ranged between poor-very poor (IBI=18 and MIwb=1.7) at RM 109.1 and exceptional-very good (IBI=48 and MIwb=9.3) at RM 29.9 (SR 35). As a whole the assemblage was considered in marginally good to fair condition. Longitudinal performance of the IBI and MIwb is presented in Figure 34.

The upper portion of Raccoon Creek in 1995 was clearly suffering the effects of unabated mine drainage. Depauperate fish assemblages were consistently found within the upper limits of the study area, which extended from the confluence of the East Branch and West Branch of Raccoon Creek (RM 109.1) to RM 98.4 (F-3 Rd.). Both indices (IBI and MIwb) strongly deviated from the applicable ecoregional criteria, yielding very poor to poor narrative evaluations. The fish assemblages of this reach were characterized by low species richness, low numerical abundance, and extremely low relative weight (Table 15; Figure 35). Compositionally, the community primarily consisted of a few highly tolerant species, with the trophic structure strongly skewed in favor of omnivorous and generalist feeders. These very poor to poor index scores were attributed to the effects of chronic acidic conditions emanating from unreclaimed previously mined lands within the watershed. Observational evidence indicative of chronic acid mine runoff included

aluminum and/or iron precipitates blanketing the natural substrates, as well as the sterile aquamarine color of the water column.

Drainage ways that have been identified as carrying a significant mine drainage burden within the upper Raccoon Creek watershed included the East Branch and West Branch Raccoon Creek, Twomile Creek, and a direct unnamed tributary flowing through Web Hollow (Web Hollow trib.) (Ohio DNR 1985). Theses tributaries appeared the majors stressors within this segment.

Downstream from the confluence of the reservoir release from Lake Hope, instream biological performance was markedly improved. Both the community indices (IBI and MIwb) as well as basic community statistics (e.g., species richness, numerical abundance, relative weight) were increased in comparison with the upper limits of the mainstem. Steady progress was indicated longitudinally as no significant mine affected tributary joins Raccoon Creek between Lake Hope and the confluence of Elk Fork.

By RM 72.2 (CR 436), community performance was further advanced and found fully consistent with the WWH aquatic life use. Within the remaining downstream portion of the mainstem, the fish assemblages were diverse and well organized, as the IBI consistently met or surpassed the WWH criterion. However, the MIwb delineated an area of degradation between approximately RM 60.0 and RM 40.0. This segment receives discharge from a series of direct tributaries with identified historic or recent mine drainage problems. The MIwb is particularly sensitive to shifts in relative abundance, relative weight, and the distribution of these measures within the assemblage. The departure of this index from the WWH criterion was likely a result of the effects of mine drainage. Direct tributaries, with long standing mine issues, that discharge to this segment of Raccoon Creek included Pierce Run, Rockcamp Run, and Indiancamp Run. Strongs Run and Robinson Run have only recently been burdened with mine drainage, following the massive discharge of untreated and partially treated water from the Meigs # 31 mine during July - September 1993 (Ohio EPA 1994). However, the results of recent surveys found that stream recovery from the Meigs impact was well underway in these two streams. As such, the influence of Strongs Run and Robinson Run on Raccoon Creek in 1995 may have been minimal in comparison with the historically impacted tributaries located upstream.

Full recovery was indicated further downstream at RM 35.6 (Woods Mill Rd.). Fish community performance, as measured by both the MIwb and IBI, was found fully consistent with the WWH criteria at this site and all additional downstream Raccoon Creek sampling locations within the study area..

East Branch and West Branch Raccoon Creek

Two sampling stations were located on each the East Branch and West Branch Raccoon Creek during the summer of 1995. Sampling from both streams yielded poor to very poor results. The East Branch Raccoon Creek appeared severely impacted by mine drainage, as this stream was found completely devoid of fish. The West Branch Raccoon Creek did support an assemblage; however, the community lacked sufficient diversity, was poorly organized, and dominated by highly tolerant species. IBI and MIwb scores indicated poor to very poor conditions.

Notorious mine drainage problems (e.g., unreclaimed mines, numerous large gob piles, sedimentation) have been identified within both the East Branch and the West Branch subbasins (Ohio DNR 1985). Both streams were impaired, to varying degrees, as a result of unabated mine drainage.

Unnamed Raccoon Creek Tributary

A total of 578 fish comprising 12 species and one hybrid was collected from this Raccoon Creek tributary between August 8 and September 13, 1995. The sampling effort included one station located at RM 0.1, downstream from the recently installed Austin Powder Co. 001 outfall.

In terms of numerical abundance, the assemblage was dominated by sunfish species (centrarchids). The prominence of the family attested to highly favorable conditions offered by this tributary for sunfish in general. The reach evaluated had clearly been channel modified in the past. Channel development was greatly limited, consisting mainly of shallow pools. Instream cover in the forms of aquatic macrophytes and woody debris were considered abundant. As sunfish are strong associates of quiet pooled areas, their abundance appeared directly reflective of instream habitat conditions. The remaining compliment of species appeared typical of modified headwater streams within the unglaciated portion of Ohio (e.g., grass pickerel, golden shiner, and creek chub).

As the drainage area of this tributary was $\leq$ 20.0 mile^2, only the IBI was employed to evaluate the condition of the fish community. The mean IBI and narrative evaluation were 37 and fair, respectively. Community performance, below the minimum WWH threshold, was attributed to overall poor quality habitat. Although the predominant habitat feature (well-structured pools) was highly suitable for sunfish species, the station simply did not possess a level of habitat complexity sufficient to support a diverse WWH aquatic assemblage. As such, failure of the fish assemblage to perform at a WWH level was not attributed to the Austin Powder Co. effluent.

Elk Fork

A total of 6,607 fish comprising 30 species and three hybrids was collected from Elk Fork between July 27 and September 12, 1995. The sampling effort included seven stations located between RM 16.2 (SR 93) and RM 0.2 (CR 438), providing an assessment coverage of 16 river miles.

Numerically predominant species were bluntnose minnow (18.5%), creek chub (16.6%), striped shiner (13.6%), longear sunfish (11.3%), and green sunfish (7.9%). Species that predominated in terms of biomass included creek chub (16.0%), longear sunfish (13.7%), yellow bullhead (11.0%), green sunfish (10.4%), and white sucker (8.0%). Both in terms of numerical abundance and biomass, over 40% of the assemblage was comprised of species highly tolerant of environmental disturbances (e.g., creek chub, white sucker, green sunfish, bluntnose minnow and yellow bullhead).

All community samples were collected with standardized wading methodologies. Due to the undesirable effects of drainage area on the MIwb, related primarily to attributes of headwater fish assemblages, community performance within the headwaters of Elk Fork was evaluated with the IBI only. The headwaters included two stations located at RM 16.2 (SR 93) and RM 14.0 (CR 12). The condition of the fish

community within the remaining downstream (non headwater) segment of Elk Fork (RMs 13.3 - 0.2) was evaluated with both the MIwb and IBI. Community performance and the accompanying narrative evaluations ranged between fair at RMs 16.2 and 14.0 (IBIs 39 and 38, respectively) and marginally good to good at RM 11.0 (IBI=48 and MIwb=9.3). As a whole the fish community was considered in marginally good condition. Longitudinal performance of the IBI and MIwb is presented in Figure 36.

IBI and MIwb (where applicable) scores indicated a level of community performance very near or fully consistent with the WWH criteria throughout Elk Fork. Both indices, particularly the MIwb, appeared longitudinally stable. Overall, departure from the WWH criteria was primarily driven by *fair* performance of the IBI at RMs 16.2, 14.0, 8.6, and 0.2. Community deficiencies identified at these stations included the lack of intolerant or environmentally sensitive species and low abundance of simple lithophils. All other IBI metrics indicated community composition and organization consistent with ecoregionally derived WWH biological criteria. The primary stressors to Elk Fork are derived from previously mined areas contained within the watershed. Sediment bedload from runoff from unreclaimed mined lands appeared the most significant factor limiting instream biological performance. Bedload sediments affect habitat quality by embedding coarse substrates and creating shifting and unstable conditions. Chemical contamination (e.g., low pH and heavy metals) emanating from these areas did not appear as significant as observed in the previous investigations, as the fish assemblage only appeared moderately perturbed. Instream biological performance appeared unaffected by the McArthur WWTP (via Puncheon Fork).

Puncheon Fork

A total of 951 fish comprising 21 species and one hybrid was collected from Puncheon Fork between July 28 and September 8, 1995. The sampling effort included two stations located at RM 1.5 (upstream from the McArthur WWTP) and RM 0.3 (downstream from the McArthur WWTP).

Numerically predominant species were striped shiner (31.7%), creek chub (18.7%), bluegill (13.8%), green sunfish (8.4%), and silver jaw minnow (7.9%). Species that predominated in terms of biomass included creek chub (20.4%), white sucker (17.5%), striped shiner (15.9%), bluegill (13.4%), and green sunfish (11.5%).

Community performance as measured by the IBI and the accompanying narrative evaluations ranged between marginally good and good. The stations bracketing the McArthur WWTP were found to support fish communities fully consistent with the WWH aquatic life use. No impact was evident downstream from the WWTP.

Selected Raccoon Creek Tributaries

The fish communities of sixteen Raccoon Creek tributaries were evaluated in 1995. The sampling effort included one station per stream, typically placed less than a mile from the mouth. Primary objectives of the sampling were to determine the appropriate use designation (LRW-AMD, MWH, WWH, or EWH) for undesignated streams and to redesignate streams currently classified as LWH. All of the streams evaluated were classified as headwaters (drainage area $\leq$ 20 miles^2). Therefore, only the IBI was employed to measure community performance.

Three streams (8.8%) were found to support fish communities fully consistent with the WWH aquatic life use (*i.e.,* Opossum Run, Rockcamp Creek, and Zinns Run). Only Rockcamp Run appeared impacted by chronic acid mine drainage, as the stream was found devoid of fish. The remaining twelve streams (75%) supported fair fish assemblages, with IBI scores ranging between 28 and 38. Viewed collectively, instream biological performance did not appear mediated by macrohabitat quality as most streams possessed a compliment of positive habitat features commonly associated with WWH assemblages. Mine drainage, to varying degrees, appeared the major arbiter of community performance. Aggregated biological performance of these tributaries is presented in Figure 39.

Little Raccoon Creek

A total of 1,092 fish comprising 25 species and two hybrids was collected from Little Raccoon Creek between August 2 and September 7, 1995. The sampling effort included three stations located between RM 28.3 (upstream from Meadow Run) and RM 11.0 (adjacent Keystone Furnace), providing an assessment coverage of 17.3 river miles.

Numerically predominant species were bluegill (42.7%) and longear sunfish (22.7%). Collectively, these centrarchids (bluegill and longear sunfish) comprised over 65% of the fish collected. As most centrarchids are strong associates of the pooled, low gradient habitat features that typify much of the Little Raccoon Creek basin, the dominance of this group of species appeared reflective of existing habitat conditions. One species, the common carp, clearly predominated in terms of biomass; this species comprised nearly 70% of the total catch. This exotic and highly tolerant species commonly occupies a prominent position throughout the waterways of the state, its overwhelming dominance in Little Raccoon Creek was indicative of a disturbed environment.

All community samples were collected with standard boat methodologies (Ohio EPA 1987b). The condition of the fish community was evaluated with both the MIwb and IBI, as the study area did not include any headwater stations (i.e., stations with a drainage area $\leq$ 20 miles^2). Community performance and the accompanying narrative evaluations were uniformly marginally good - fair throughout the study area. Longitudinal performance of the IBI and MIwb is presented in Figure 37.

Despite the lack of intolerant species and very low proportions (by number) of lithophils, minimally acceptable species richness and community organization were observed, as IBI scores remained within the range of non-significant departure from the WWH criterion. Conversely, the structural evenness of the fish community (as measured by the MIwb) was consistently below WWH expectations. Both the IBI and MIwb were longitudinally stable. No instream impact was evident downstream from the Wellston WWTP (via Meadow Run). Diminished community performance was attributed to the effects of mine drainage within the watershed.

Meadow Run

A total of 2,224 fish comprising 21 species was collected from Meadow Run between July 10 and September 13, 1995. The sampling effort included four stations located between RM 3.1 (Pillsbury facility) and RM 0.8 (Chaetwood Rd.), providing an assessment coverage of 2.3 river miles. All samples collected within the

Meadow Run study area employed standard wading methodology (Ohio EPA 1987b). The IBI is the only applicable community index to evaluate the condition of the fish assemblage in headwater streams (i.e., drainage area ≤ 20 miles^2) (Ohio EPA 1987b).

Numerically predominant fish species included bluntnose minnow (19.5%), bluegill (18.0%), longear sunfish (12.9%), white sucker (10.9%), and creek chub (7.0%). Species that predominated in terms of biomass included common carp (23.4%), white sucker (21.4%), yellow bullhead (13.1%), bluegill (8.5%), and black bullhead (7.8%).

In terms of numerical abundance, the majority of the species encountered are classified as highly tolerant of water quality and physical habitat degradation (e.g., bluntnose minnow, white sucker, and creek chub) (Ohio EPA 1987b). The remaining dominant forms included species typical of pooled or slack water macrohabitats. A similar pattern was observed in terms of the distribution of biomass within the assemblage, the majority being concentrated in highly tolerant taxa and species adapted to pool habitats or streams of low gradient.

Performance of the fish community from RM 3.1 to RM 2.1 ranged between poor and fair. The assemblage appeared most influenced by poor macrohabitat quality. An additional community stressor may have included pulsed or periodic acidic runoff from unreclaimed mining areas. However, given the persistence of fish within this reach, it is doubtful that acidic conditions are chronic.

Community performance, as measured by the IBI, from RM 2.1 to RM 0.8 was similar to that encountered in the upper segment. Fish collections from this segment failed to yield results consistent with the WWH aquatic life use (Figure 38). Longitudinal performance of the IBI indicated fair to poor conditions. The structure, composition, and diversity of the assemblage appeared negatively influenced by marginal habitat conditions. However, an impact was clearly indicated at RM 0.8 (Chaetwood Rd.) downstream from both the Wellston WWTP and Pillsbury 001 discharge, as the IBI was reduced from 32 (fair-upstream) to 26 (poor-downstream). Septic conditions were observed in Meadow Run on the sampling dates of August 13 and September 14, 1995. The natural substrates throughout the sampling station were covered with coarse particulate organic matter derived from sewage solids, with growths of the sewage bacteria Sphaerotilus scattered throughout. The water column was bright green due to the abundance of suspended phytoplankton. Anoxic benthic conditions were indicated by black (reduced) sediments.

Community response to this chronic stress included a significant increase in the incidence of Deformities, Eroded fins, Lesions, and Tumors (DELT) anomalies, reduced relative abundance and biomass, shifts in the composition, and reduced species richness (Table 38). In comparison with upstream sampling stations, the mean percent occurrence of gross external anomalies increased from 0.5% to 3.0%. Based upon Ohio EPA regionally derived biological criteria, percent occurrence greater than 1.3% is considered highly elevated (Ohio EPA 1987b). Elevated DELTs have been found to be reliable indications of stream degradation (Leonard and Orth 1986). Mean species richness declined from 16.5 (upstream) to 8.5 at the Chaetwood Rd. station. A similar longitudinal pattern of decline was observed for relative abundance and biomass statistics. Based upon field observations and the condition of the fish assemblage, the combined influence of waste

water discharged by the Wellston WWTP and the Pillsbury facilities have clearly exceeded the capacity of Meadow Run to safely assimilate oxygen demanding wastes without accruing significant environmental damage.

Selected Little Raccoon Creek Tributaries

Fish community samples were collected from six Little Raccoon Creek tributaries in 1995. Evaluated streams included Rich Run, Flint Run, Goose Run, Buffer Run, Coal Run, and Greasy Run. The sampling effort included one station per stream, typically placed less than a mile from the mouth. The primary objective of the sampling effort was to determine an appropriate use designation (LRW-AMD, MWH, WWH, or EWH) for these currently designated LWH streams. All of the streams evaluated were classified as headwaters (drainage area $\leq$ 20 miles^2). Therefore, only the IBI was employed to measure community performance.

All of the Little Raccoon Creek tributaries evaluated in 1995 were clearly suffering the effects of chronic mine drainage. Flint Run, Goose Run, and Buffer Run were found to be completely devoid of fish. The communities encountered in the remaining streams (Rich Run, Coal Run, and Greasy Run) were poorly organized, and dominated by a few highly tolerant species. Viewed collectively, instream biological performance did not appear mediated by macrohabitat quality as most streams possessed a compliment of positive habitat features commonly associated with WWH assemblages. Mine drainage appeared the major arbiter of community performance. Aggregated biological performance of these tributaries is presented in Figure 39.

Table 15. Fish community indices and descriptive statistics based on samples collected by Ohio EPA from the Raccoon Creek study area, 1981-1995.

Stream **River Mile**	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)	Mean Rel. Wt. (Wt./km)	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Raccoon Creek (1995)								
Western Allegheny Plateau - LRW-AMD Use Designation (Recommended)								
109.1[(W)]	4.0	6	148.5	0.6	60.0	18	1.7*	Poor-V.Poor
99.7[(W)]	10.0	13	103.5	1.1	61.0	22	5.4	Poor
98.4[(W)]	9.5	12	59.3	1.2	49.0	22	4.9	Poor
Western Allegheny Plateau - WWH Use Designation (Existing)								
92.3[(B)]	15.0	17	194.0	8.1	69.0	35*	7.0*	Fair
84.1[(B)]	13.0	17	215.0	18.1	48.0	36[ns]	6.8*	M.Good-Fair
72.2[(B)]	20.5	24	707.8	30.5	62.0	40	8.1[ns]	Good-M.Good
63.8[(B)]	23.0	26	619.0	37.6	61.0	44	8.7	Good
50.1[(B)]	18.0	22	518.0	29.9	63.0	44	7.6*	Good-Fair
40.2[(B)]	16.0	19	620.0	25.8	47.0	41	7.9*	Good-Fair
35.6[(B)]	21.0	25	395.0	41.5	63.0	41	8.5ns	Good-M.Good
29.9[(B)]	26.5	32	510.5	67.3	68.0	48	9.3	Exceptional-V.Good
10.0[(B)]	26.0	34	463.0	69.5	70.0	40	9.5	Good-V.Good
5.4[(B)]	19.0	26	471.0	24.4	55.0	40	8.4[ns]	Good
(1994)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
39.9[(B)]	25.0	25	340.0	49.1	-	44	9.5	V.Good
(1993)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
50.2[(B)]	14.0	14	278.0	26.2	63.0	36[ns]	6.8*	M.Good-Fair
39.9[(B)]	23.0	23	309.0	39.2	71.0	35*	9.0	Fair-M.Good
29.3[(B)]	18.0	18	262.0	70.9	-	44	8.4[ns]	Good-M.Good
(1990)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
40.2[(B)]	16.5	22	191.0	18.3	49.0	35*	7.5*	Fair
10.0[(B)]	19.5	24	221.0	58.6	81.0	35*	8.8	Fair-Good

Table 15. (Continued)

Stream **River Mile**	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)	Mean Rel. Wt. (Wt./km)	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
West Branch Raccoon Creek (1995)								
Western Allegheny Plateau - WWH Use Designation (Recommended)								
5.7(H)	2.0	2	601.0	2.5	54.0	22*	N/A	V. Poor
0.2(W)	11.0	13	446.3	2.6	62.0	27*	5.0*	Poor
East Branch Raccoon Creek (1995)								
Western Allegheny Plateau - LRW-AMD Use Designation (Recommended)								
6.6(H)	0.0	0	0.0	0.0	63.0	12*	N/A	V. Poor
2.1(H)	0.0	0	0.0	0.0	74.0	12*	N/A	V. Poor
Trib to Raccoon Creek (RM 98.96) (1995)								
Western Allegheny Plateau - WWH Use Designation (Recommended)								
0.1(H)	12	10.5	523.2	2.66	37	37*	N/A	Fair
Elk Fork (1995)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
16.2(H)	18.5	20	1289.8	6.1	70.0	39*	N/A	Fair
14.0(H)	19.5	21	1170.8	13.0	68.0	38*	N/A	Fair
Western Allegheny Plateau - WWH Use Designation (Recommended)								
13.3(W)	18.0	19	650.3	9.9	75.0	44	7.6*	Good-Fair
11.0(W)	21.0	23	500.3	7.6	52.0	43	8.0ns	Good-M. Good
8.6(W)	20.0	24	276.8	10.4	54.0	37*	8.0ns	Fair-M. Good
2.2(W)	20.0	23	396.8	8.4	66.0	42ns	8.3ns	M. Good
0.2(W)	21.0	24	935.3	9.3	58.0	36*	8.3ns	Fair-M. Good
(1981)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
17.6(H)	11.0	11	220.9	-	70.0	30*	N/A	Fair
16.2(H)	13.0	13	243.0	-	65.0	32*	N/A	Fair
14.7(H)	10.0	10	272.5	-	-	36*	N/A	Fair
13.9(H)	12.0	12	290.8	-	-	22*	N/A	Poor
Western Allegheny Plateau -WWH Use Designation (Recommended)								
13.3(W)	4.0	4	78.5	-	-	22*	-	Poor
11.8(W)	1.0	1	17.5	-	-	12*	-	V. Poor
10.9(W)	7.0	7	50.0	-	-	12*	-	V. Poor
8.5(W)	4.0	4	17.5	-	-	12*	-	V. Poor
0.2(W)	7.0	7	60.0	-	-	18*	-	V. Poor

Table 15. (Continued)

Stream **River Mile**	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)	Mean Rel. Wt. (Wt./km)	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Puncheon Fork (1995)								
Western Allegheny Plateau - WWH Use Designation (Recommended)								
1.5$^{(H)}$	17.5	21	844.4	11.0	66.0	44	N/A	Good
0.3$^{(H)}$	19.0	21	587.3	11.2	65.0	40^{ns}	N/A	M. Good
(1981)								
Western Allegheny Plateau -WWH Use Designation (Recommended)								
0.3(H)	2.0	2	17.5	-	-	12*	N/A	V Poor
Little Raccoon Creek (1995)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
28.3$^{(B)}$	17.5	20	666.3	116.3	60.0	38^{ns}	7.6*	M. Good-Fair
24.6$^{(B)}$	15.0	16	418.2	65.9	48.0	36^{ns}	7.7*	M. Good-Fair
Western Allegheny Plateau - WWH Use Designation (Recommended)								
11.0$^{(B)}$	12.5	17	111.0	9.7	57.0	37^{ns}	6.8*	M. Good-Fair
(1990)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
27.9$^{(B)}$)	16	14.0	428.0	100.4	55.0	34*	7.1*	Fair
24.6$^{(B)}$	12	10.5	302.0	19.6	64.0	26*	6.8	Poor-Fair
(1984)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
36.7$^{(B)}$	11.7	15	278.7	23.1	-	32*	7.4*	Fair
30.9$^{(B)}$	5.3	10	43.3	4.4	59.0	23*	4.0*	Poor-V. Poor
28.1$^{(B)}$	12.0	15	118.9	15.2	62.0	30*	7.3*	Fair
24.8$^{(B)}$	10.7	13	131.7	151.1	-	31*	6.7*	Fair
Western Allegheny Plateau - WWH Use Designation (Recommended)								
11.0$^{(B)}$	0.3	1	2.0	0.1	-	12*	0.2*	V. Poor
1.8$^{(B)}$	0.5	1	3.3	0.1	-	12*	0.5*	V. Poor
Meadow Run (1995)								
Western Allegheny Plateau - WWH Use Designation (Recommended)								
3.1$^{(H)}$	12.0	15	323.3	8.0	56.0	27*	N/A	Poor
2.1$^{(H)}$	16.0	19	866.3	22.6	43.0	33*	N/A	Fair
Western Allegheny Plateau - WWH Use Designation (Existing)								
1.5$^{(H)}$	16.5	20	370.5	8.4	51.0	32*	N/A	Fair
0.8$^{(H)}$	8.5	11	108.0	3.5	52.0	26*	N/A	Poor

Table 15. (Continued)

Stream **River Mile**	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)	Mean Rel. Wt. (Wt./km)	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Meadow Run(1990)								
Western Allegheny Plateau - WWH Use Designation (Existing)								
1.4(H)	10.0	10	258.0	-	-	30*	N/A	Fair
1.2(H)	4.0	4	228.0	-	-	24*	N/A	Poor
1.1(H)	8.0	8	335.0	-	-	26*	N/A	Poor
(1984)								
Western Allegheny Plateau - WWH Use Designation (Recommended)								
3.1(H)	0.3	1	1.7	0.01	-	12*	N/A	Poor
Western Allegheny Plateau - WWH Use Designation (Existing)								
0.9(H)	0.3	1	0.3	0.01	-	12*	N/A	Poor
Raccoon Creek Tributaries (1995)								
Western Allegheny Plateau - WWH Use Designation (Recommended)								
Twomile Run								
0.2	8.0	8	588.0	2.3	63.0	28*	N/A	Fair
Grass Run								
0.1	8.0	8	652.5	-	55.0	30*	N/A	Fair
Rockcamp Creek								
1.8	19.0	19	487.6	-	55.0	44	N/A	Good
Coal Run								
0.1	6.0	6	282.5	1.4	58.0	30*	N/A	Fair
Onion Creek								
1.4	16.0	16	1055.5	-	77.0	30*	N/A	Fair
Tedroe Run								
0.1	7.0	7	311.3	-	54.0	28*	N/A	Fair
Merrit Run								
0.1	12.0	12	248.4	1.3	63.0	34*	N/A	Fair
Russell Run								
0.6	10.0	10	620.0	-	48.0	36*	N/A	Fair
Flat Run								
1.6	15.0	15	1448.0	-	51.0	36*	N/A	Fair
Long Run								
1.4	7.0	7	1883.7	1.1	69.0	38*	N/A	Fair
Zinns Run								
0.5	17.0	17	892.0	7.6	69.0	44	N/A	Good
Opossum Run								
0.2	10.0	10	382.5	-	64.0	42ns	N/A	M. Good

Table 15. (Continued)

Stream River Mile	Mean Number Species	Cumulative Species	Mean Rel. No. (No./km)	Mean Rel. Wt. (Wt./km)	QHEI	Mean IBI	Mean MIwb	Narrative Evaluation
Raccoon Creek Tributaries (1995)								
Western Allegheny Plateau -LRW-AMD Use Designation (Recommended)								
Pierce Run								
1.7	9.0	9	68.3	-	52.0	34	N/A	Fair
Rockcamp Run								
0.2	0.0	0	0.0	0.0	55.0	*12**	N/A	V. Poor
Indiancamp Run								
0.3	9.0	9	475.5	-	82.0	28	N/A	Fair
Karr Run								
0.2	5.0	5	394.7	-	57.0	32	N/A	Fair
Little Raccoon Creek Tributaries (1995)								
Western Allegheny Plateau - LRW-AMD Use Designation (Recommended)								
Rich Run								
0.1	1.0	1	2.0	0.01	72.0	12*	N/A	V. Poor
Flint Run								
0.5	0.0	0	0.0	0.0	60.0	12*	N/A	V. Poor
Goose Run								
0.4	0.0	0	0.0	0.0	44.0	12*	N/A	V. Poor
Buffer Run								
0.1	0.0	0	0.0	0.0	54.0	12*	N/A	V. Poor
.Greasy Run								
0.1	5.0	5	34.0	-	59.0	30	N/A	Fair
Western Allegheny Plateau - WWH Use Designation (Recommended)								
Coal Run								
0.1	6.0	6	214.0	-	55.0	34*	N/A	Fair

Ecoregion Biocriteria

Western Allegheny Plateau (WAP)

Index - Site Type	WWH	EWH	LRW-AMD[a]
IBI - Headwater/Wading	44	50	18
IBI - Boat	40	48	18
MIwb - Wading	8.4	9.4	4.0
MIwb - Boat	8.6	9.6	4.0

[a] - Limited Resource Water - acid mine drainage (LRW-AMD) benchmarks based on best professional judgment driven by the need to protect against acutely toxic stream conditions.

Table 15. (Continued)

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* - Significant departure from applicable criteria (>4 IBI or >0.5 MIwb units), poor or very poor results are underlined.
ns - Nonsignificant departure from biocriteria (≤4 IBI or ≤0.5 MIwb units).
H - Headwater station (drainage area ≤ 20 mile^2), the MIwb is not applicable.
W - Wading station.
B - Boat station.
WWH - Warmwater Habitat Use Designation.
LRW-AMD - Limited Resource Water - Acid Mine Drainage Use Designation.

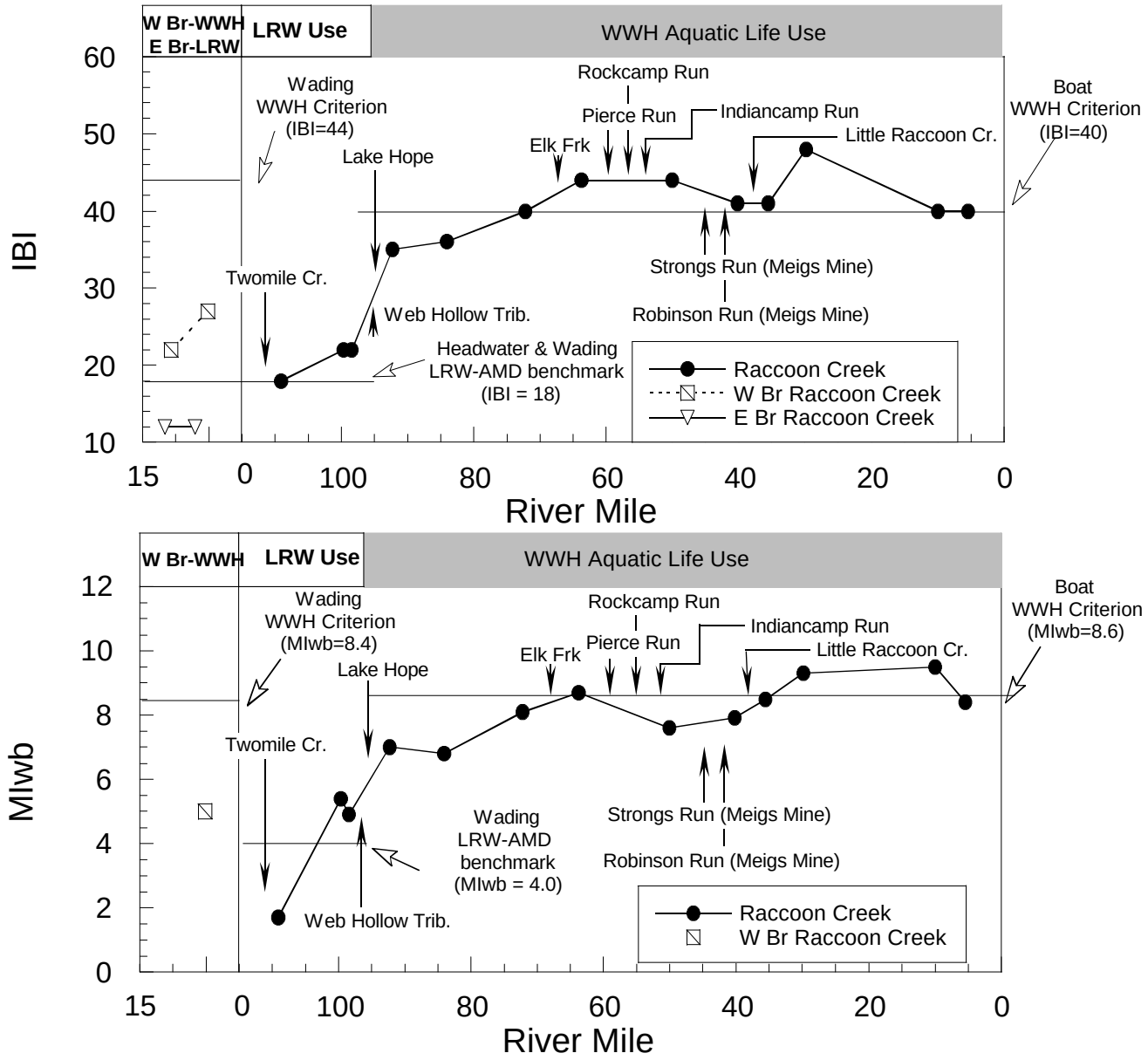


Figure 34. Longitudinal performance of the Index of Biotic Integrity (IBI) and Modified Index of well-being (MIwb) from Raccoon Creek and the East Branch and West Branch Raccoon Creek, 1995. Points of entry for various mine affected tributaries are indicated by solid arrows. The solid lines indicate numerical criteria in support of the WWH aquatic life use designations and LRW-AMD benchmarks.

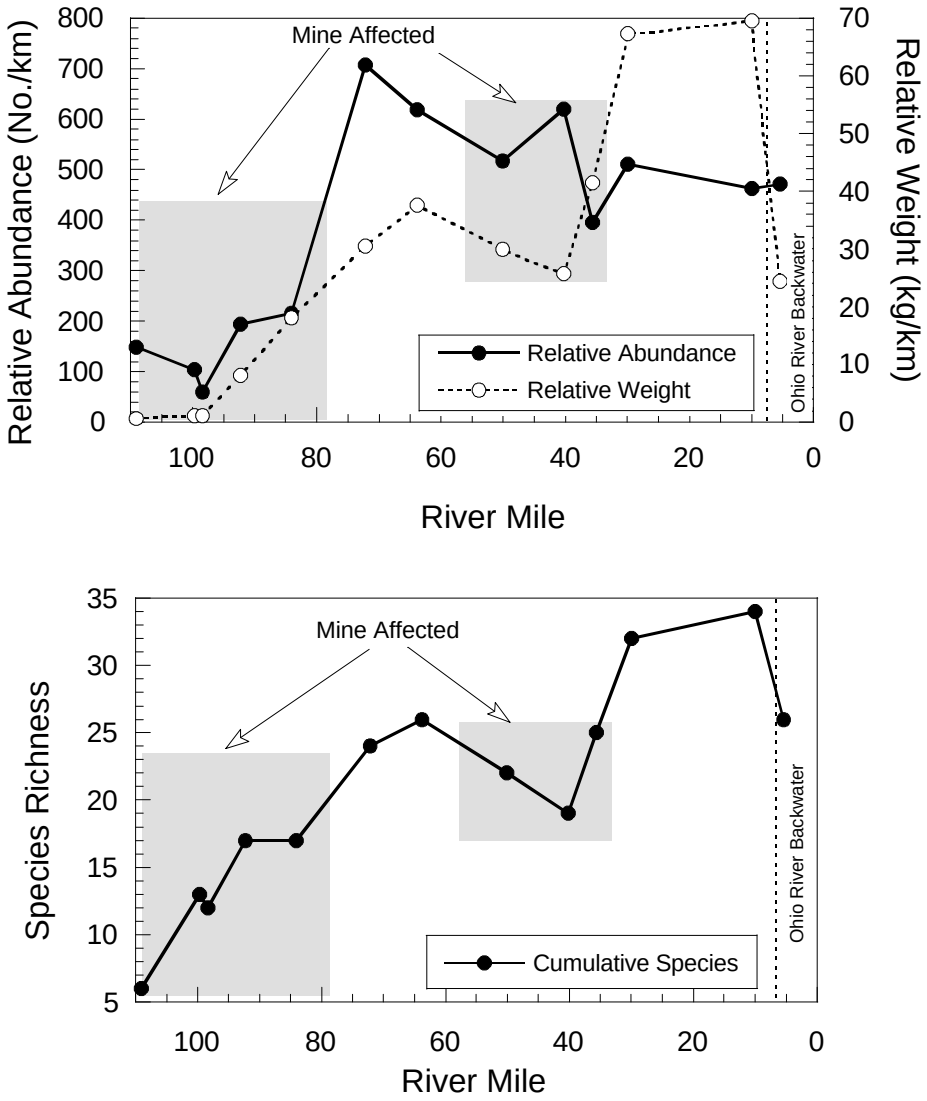


Figure 35. Cumulative species richness, mean relative abundance (No./km), and mean relative weight (kg/km) for Raccoon Creek, 1995.

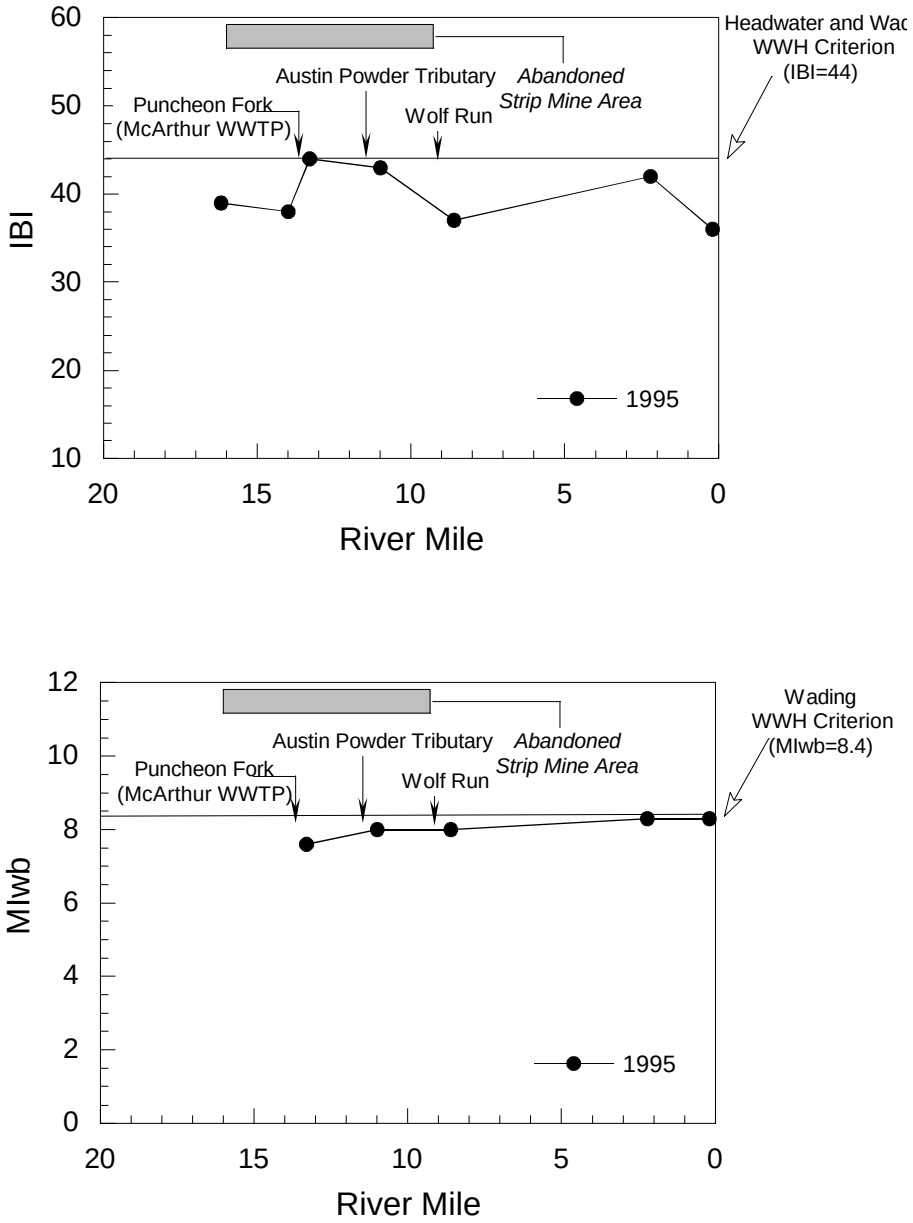


Figure 36. Longitudinal performance of the Index of Biotic Integrity (IBI) and Modified Index of well-being (MIwb) from Elk Fork, 1995. Points of entry for various mine affected tributaries and point source discharges (via Puncheon Fork) are indicated by solid arrows. The solid lines indicate numerical criteria in support of the WWH aquatic life use designations, Western Allegheny Plateau (WAP) Ecoregion.

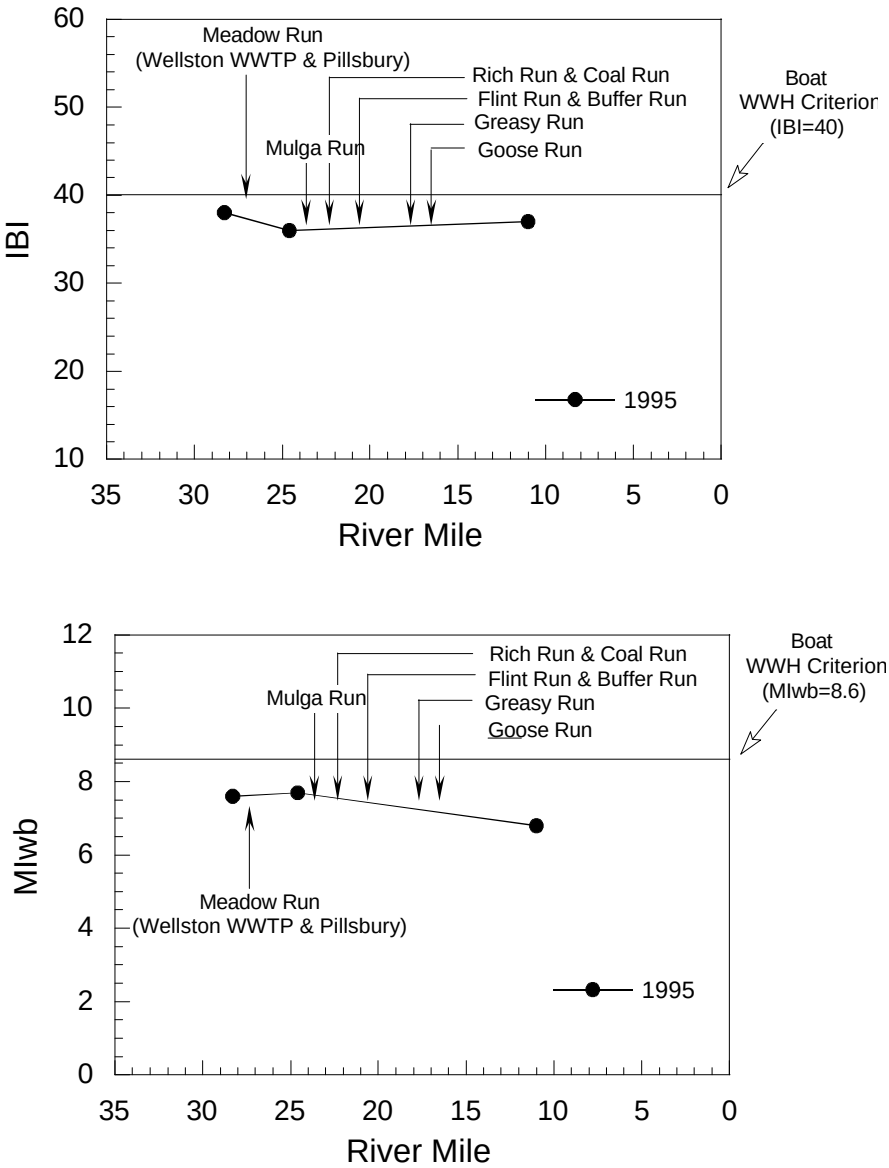


Figure 37. Longitudinal performance of the Index of Biotic Integrity (IBI) and Modified Index of well-being (MIwb) from Little Raccoon Creek, 1995. Points of entry for various mine affected tributaries and point source discharges (via Meadow Run) are indicated by solid arrows. The solid lines indicate numerical criteria in support of WWH aquatic life use designations, Western Allegheny Plateau (WAP) Ecoregion.

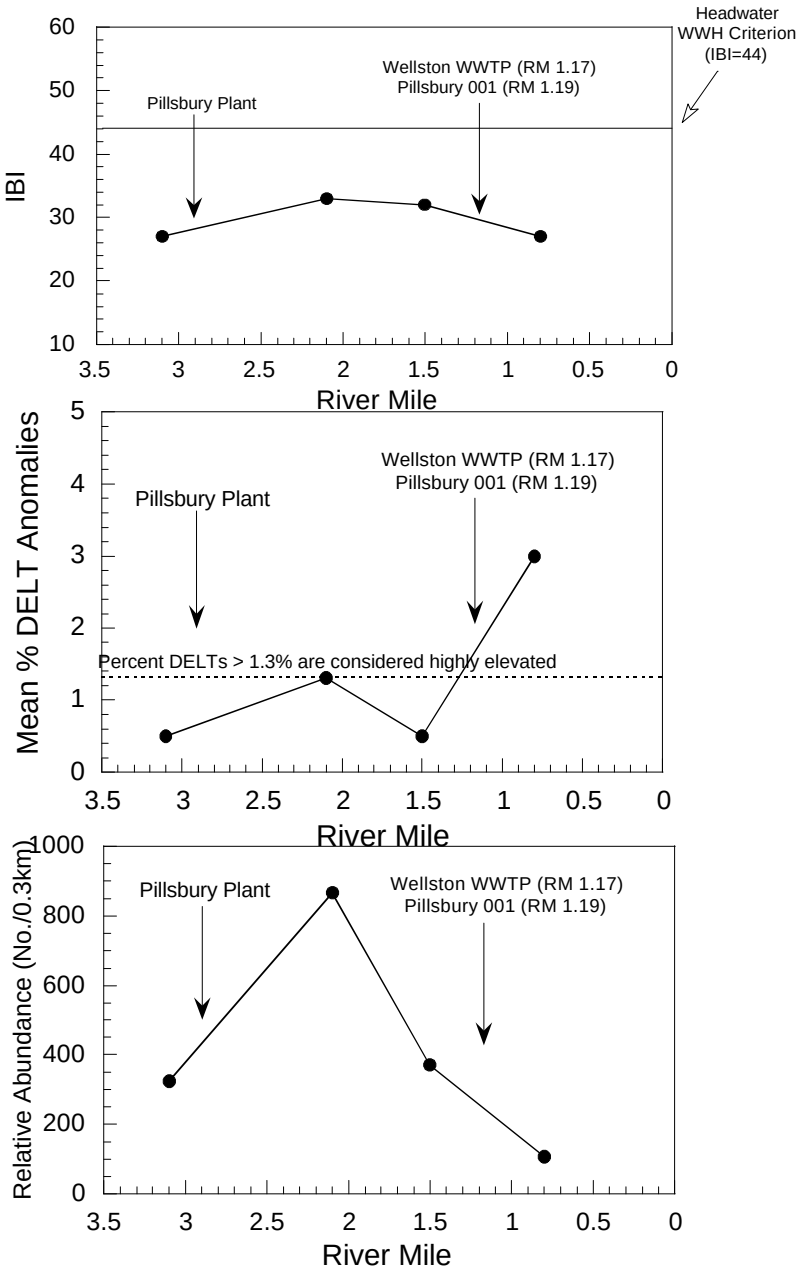


Figure 38. Longitudinal performance of the Index of Biotic Integrity (IBI), mean relative abundance (#/0.3km) and the incidence (percentage) of Deformities, Erosions, Lesions, and Tumors (DELT) anomalies for Meadow Run, 1995. Points of entry for various mine affected tributaries and point source discharges are indicated by solid arrows.

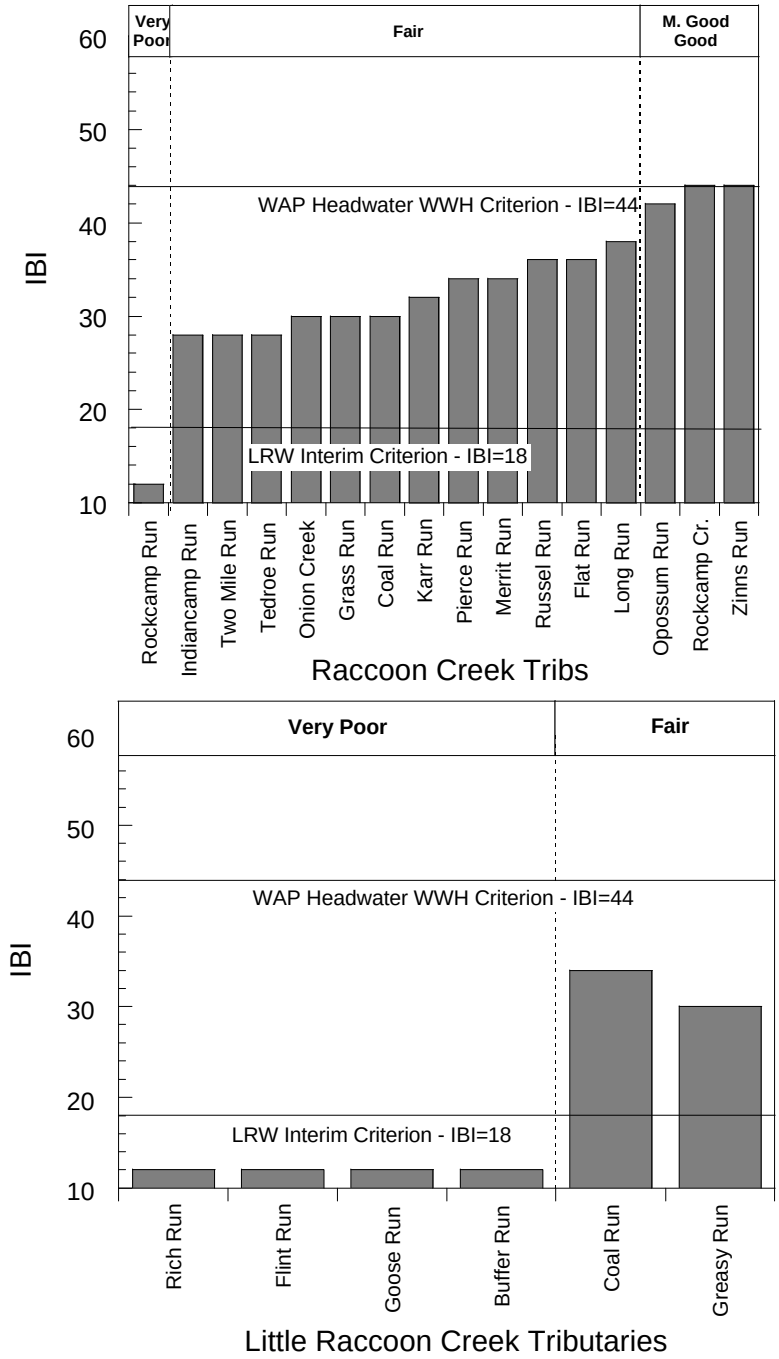


Figure 39. Index of Biotic Integrity (IBI) scores and corresponding narrative evaluation from selected Raccoon Creek and Little Raccoon tributaries, 1995. Solid lines indicate criteria in support of the WWH aquatic life use designation and the LRW-AMD benchmark.

TRENDS

Chemical Water Quality Trends (Tables 16-17; Figures 40-43)

Raccoon Creek
The Ohio EPA has had an ambient water quality station on Raccoon Creek for many years. It was originally located at the US 35 bridge near Rio Grande (RM 29.20), but was abandoned by the USGS and moved to Garners Ford (RM 27.07). In late 1990, the Ohio EPA moved its monthly ambient station to the Garners Ford site. The new site is 2.13 miles downstream from the old site and there are no known discharges or impacts between the two sites. Data used for the discussion of the trends is from 1988 to 1995 (Figures 40 and 41).

There was very little change in the mean values over the period from 1988 to 1995 for many of the chemical parameters. Included were calcium, arsenic, iron, dissolved oxygen, ammonia, total kjeldahl nitrogen, sulfates, conductivity (except for a spike in 1993), nitrate-nitrite (except for a slight decrease in 1995), and cadmium (except for a spike in 1993).

Parameters which showed a decrease over the same time period included zinc (decreased from greater 70 ug/l to less than 20 ug/l), and manganese (decreased from 1500 mg/l to 900 mg/l). Chemical oxygen demand and suspended solids also showed slight decreases.

Alkalinity and pH both showed increases throughout the period. Alkalinity showed improvement from the 10 mg/l level to greater than 30 mg/l, with a spike in 1993 of over 60 mg/l. pH has improved from the 6.2 S.U. levels seen in 1988 to the 7.2 to 7.4 S.U. levels measured in 1992 to 1995.

Those parameters showing an improvement during the period are generally considered mine drainage parameters. These improvements are most likely the result of many projects undertaken throughout the basin by various agencies to abate mine drainage problems.

In 1993, there were unusually high mean chemical values which appeared to be outliers in comparison to the established trends at the Garners Ford ambient station (RM 27.07). Those parameters were sulfates, manganese, zinc, conductivity, cadmium, arsenic, alkalinity, and calcium. It was during the late summer of 1993 that the Southern Ohio Coal Company discharged untreated minewater overflow from the Meigs #31 mine which had flooded. Although most of the minewater was discharged to the Leading Creek watershed, a significant amount was discharged to Raccoon Creek via Strongs Run and Sugar Run. The water was treated to control toxicity from pH and ferric iron after the initial emergency release. Under these circumstances, the higher levels of the 8 parameters in Raccoon Creek during late 1993 was not unexpected. Samples collected by the Ohio EPA after 1993 reflected concentrations more in line with established trends.

Elk Fork

The Elk Fork basin was previously sampled in 1981. The McArthur WWTP at that time discharged into Elk Fork (RM 15.2) . In addition, Austin Powder had several overflows of its ponds which discharged to an unnamed tributary (RM 11.17) of Elk Fork. Since that study, the McArthur discharge has been relocated to the Puncheon Fork tributary of Elk Fork. Austin Powder has changed its flow regimes and the major treatment facility now discharges to an unnamed tributary to Raccoon Creek. In addition there are several smaller discharges from Austin Powder which still discharge to the unnamed trib to Elk Fork which were not assessed in 1995. Comparison of the 1995 data with the 1981 data may be misleading in respect to the historical discharge points, but will still give an overall picture of the water quality in the basin (Figure 42).

Manganese, total suspended solids, and ammonia levels had similar trends for both studies. The ammonia levels peaked at Elk Fork RM 13.9 in both studies. In the 1995 study this site was immediately downstream from the confluence of Puncheon Fork which receives the McArthur WWTP discharge. As noted earlier, ammonia levels were elevated in Puncheon Fork downstream from the WWTP. In 1981, ammonia levels were lower than those reported at this site for 1995, but the WWTP discharge was 1.3 miles further upstream. Manganese levels peaked in 1995 at RM 13.9 and peaked at RM 13.3 in 1981. Both of these sites are downstream from the confluence of Puncheon Fork and indicates a mine drainage input from Puncheon Fork. From these points, levels of manganese continue to drop downstream to the confluence with Raccoon Creek.

Dissolved oxygen, iron, zinc, sulfates, and aluminum show different results between the two studies. Dissolved oxygen in both studies was the lowest at RM 13.9. In 1981, the mean was less than 4.0 mg/l whereas in 1995 the mean level was less than 5.0 mg/l. This appeared to be a result of the WWTP discharge. In 1995 and 1981, the peaks were at RM 13.3 indicating a quick recovery had taken place. The dissolved oxygen decreased at both sites at the next downstream site (RM 10.9) but more precipitously in 1981. In 1995, the downstream value (RM 0.1) recovered to 7 mg/l but in 1981 the value declined further. Aluminum values were similar both years until RM 10.9; the 1995 survey showed a significant increase over the values found in 1981 at this location. From this station to the mouth, there was a decline to slightly above detection levels. Most of the coal mining occurs in the upper basin and the lower watershed is mostly forested, so dilution may be the reason for the lower levels near the mouth. Iron levels were erratic between the two surveys. The upstream sites in both surveys were below the WWH criterion. At downstream sites, the levels were often above the criterion and the two studies showed divergent levels at the same site. During both years zinc and sulfates generally increased from the upstream sites to RM 10.9 at which point, values decreased at downstream sampling locations. The 1981 values for sulfates and zinc were higher at RM 10.9 in comparison to 1995 values.

Alkalinity, pH, chloride and lead showed more significant variations between the two studies. pH levels were consistently higher in 1995. The mean values for each of the sites sampled were greater than 7.0 S.U. In the 1981 study the pH levels started a gradual decline after the confluence of Puncheon Fork, bottoming out at less than 5.0 S.U. From RM 10.9 to the mouth, there was a slight improvement to 5.6 S.U. As expected, alkalinity showed a completely opposite

trend to the pH. In 1995, mean alkalinity increased slightly to 110 mg/l at RM 13.3 and declined to 60 mg/l by RM 0.1. In contrast, the 1981 survey values started at 100 mg/l (RM 13.9) dipped to 60 mg/l and then rose to 185 mg/l. Chlorides in 1981 and 1995 were near 80 mg/l at the upstream site. In the 1981 survey, the levels at downstream sites rose to above 100 mg/l and then dipped near the mouth to 30 mg/l. In 1995, the chlorides ranged in the 10-40 mg/l levels throughout the watershed. This improvement in chloride levels may be attributable to less oil and gas drilling in the watershed. It may also be that more stringent regulations concerning brine disposal has meant better treatment and maintenance practices in this industry. Lead was found at all sites sampled during the 1981 survey and the means ranged from 4 to 17 ug/l. In 1995, there was only minor amounts found at one site, RM 10.9. At this time, there is no known source for this contribution.

Many parameters peaked at RM 10.9 in 1981 (Zn, Pb, So_4, Cl, Al and Alkalinity) as did a number in 1995 (Fe, Al, So_4). This was the first site downstream from the unnamed tributary from Austin Powder and downstream of the village limits of McArthur . The unnamed tributary from Austin Powder has abandoned mine lands on it and obviously contributes mine drainage parameters to the mainstem as does Puncheon Fork.

Little Raccoon Creek

The only common sites from previous studies on Little Raccoon Creek that could be used for comparison with this survey were at RM 27.9 and RM 24.55, upstream and downstream from the confluence of Meadow Run. The following table reflects the chemical data results collected during three Ohio EPA surveys.

Table 16. Comparison of mean values for sites chemically sampled on Little Raccoon Creek above and below the confluence of Meadow Run during the 1984, 1990 and 1995 Ohio EPA surveys.

	RM 27.9			RM 24.55		
Parameter	1984	1990	1995	1984	1990	1995
Dissolved oxygen (mg/l)	5.18	6.7	5.9	1.62	4.8	4.3
pH (S.U.)	6.46	6.9	7.39	6.8	7.0	7.43
Sulfates (mg/l)	143	60	114	121	76	79
Ammonia (mg/l)	0.16	0.08	0.41	1.69	0.8	0.55
Dissolved solids (mg/l)	293	147	235	383	218	260
Iron (ug/l)	478	-	873	436	-	1591
Aluminum (ug/l)	427	412	267	230	445	320
Manganese (ug/l)	2290	707	720	1548	1345	895
Zinc (ug/l)	82.5	-	12	25	-	19

At RM 27.9, pH, zinc, aluminum, and manganese levels have steadily improved over the course of the three studies. Dissolved solids, dissolved oxygen, ammonia and sulfates reflected improvement since the 1984 study, but showed some decline during the 1995 field season. Iron levels clearly increased, probably attributed to some mine drainage from tributaries above this site.

At RM 24.55, dissolved oxygen levels were lower during this survey than during the previous study. Iron data from 1990 was not available, but a significant increase from 1984 data was noted in this survey. This may be attributed to a mine shaft overflow (RM 0.4) downstream from RM 0.72 on Meadow Run. The Ohio DNR sampled this overflow which indicated iron levels of 3.21 mg/l. Ohio EPA field measurements of the overflow discharge revealed anoxic water. Flows from this source have not been measured, but it constitutes a substantial part of the flow within Meadow Run. Since Meadow Run does not have much gradient, especially near the mouth, the water has very little chance for reaeration prior to entering Little Raccoon Creek. This is one possible cause for the drop in dissolved oxygen in Raccoon Creek downstream from Meadow Run (RM 24.55), in addition to the high organic load from the Pillsbury and Wellston WWTP effluents.

Similar to the upstream site on Little Raccoon Creek, improvement in pH conditions were noted in the 1995 survey. Ammonia, aluminum, manganese, and zinc levels declined at RM 24.55 during the 1995 survey when compared with previous studies. Sulfates and dissolved solids remained somewhat steady or slightly increased. Some of these conditions could be attributed to small, unnamed tributaries which drain previously mined areas. Since a site at the mouth of Meadow Run was not sampled during this survey, it cannot be determined what levels of pollutants are being contributed by Meadow Run and the large mine shaft overflow.

Meadow Run

Comparison of data from Meadow Run is somewhat difficult due to the outfalls of Pillsbury and the Wellston WWTP changing locations. During the 1984 survey, the outfalls for both facilities were located across from each other on the banks of Meadow Run (RM 1.20). For the 1990 survey, Wellston was still located where it was in 1984, but Pillsbury separated their process water from their non-contact cooling water and discharged the two flows separately at RM 3.00 and 3.02 respectively. For the 1995 survey, the Wellston WWTP discharge point has moved downstream to RM 1.17, due to the plant upgrade. In 1995, Pillsbury was discharging from the original outfall in use during the 1984 survey, this time only as a process water outfall. The non-contact cooling water currently continues to discharge at RM 3.02. The sites which have been chemically sampled during previous surveys were at RM 3.1, upstream from Pillsbury, and at RM 0.72, located at Chaetwood Road. Meadow Run at Chaetwood Road, however, was not sampled during the 1990 study. The following table reflects the chemical data results collected during three Ohio EPA surveys.

Table 17. Comparison of mean values for sites chemically sampled on Meadow Run during the 1984, 1990, and 1995 Ohio EPA surveys.

	RM 3.1			RM 0.72		
Parameter	1984	1990	1995	1984	1990	1995
Dissolved oxygen (mg/l)	8.32	7.05	7.6	1.38	-	2.9
pH (S.U.)	3.6	5.3	7.5	7.26	-	7.83
Sulfates (mg/l)	512	234	98	109	-	85
Iron (ug/l)	8294	1065	688	754	-	749
Zinc (ug/l)	296	116	69	15	-	15
Ammonia (mg/l)	0.29	-	0.05	6.2	-	5.5
BOD_5 (mg/l)	<1.0	-	<2.0	18	-	12
Manganese (ug/l)	7046	-	386	662	-	539

At RM 3.1, dissolved oxygen has shown a decline when comparing 1990 data with the 1984 data; however, an increase in the dissolved oxygen level was apparent in 1995. The remaining parameters showed improvement over the years at this location, specifically, pH, sulfates, and metals showed substantial recovery since 1984.

At RM 0.72, slight improvement was noted for dissolved oxygen, pH, and sulfates. The remaining parameters appear to be somewhat steady, in spite of noted improvements at Pillsbury and the Wellston WWTP.

Figure 43 shows the trends on Meadow Run for the following parameters: ammonia, BOD_5, dissolved oxygen, pH, and sulfates. With the exception of sulfates, water quality downstream from the discharges from Wellston and Pillsbury continues to decline at RM 0.72. pH remained somewhat consistent throughout the basin in 1995, but had shown increasing levels in previous surveys as you proceed downstream on Meadow Run.

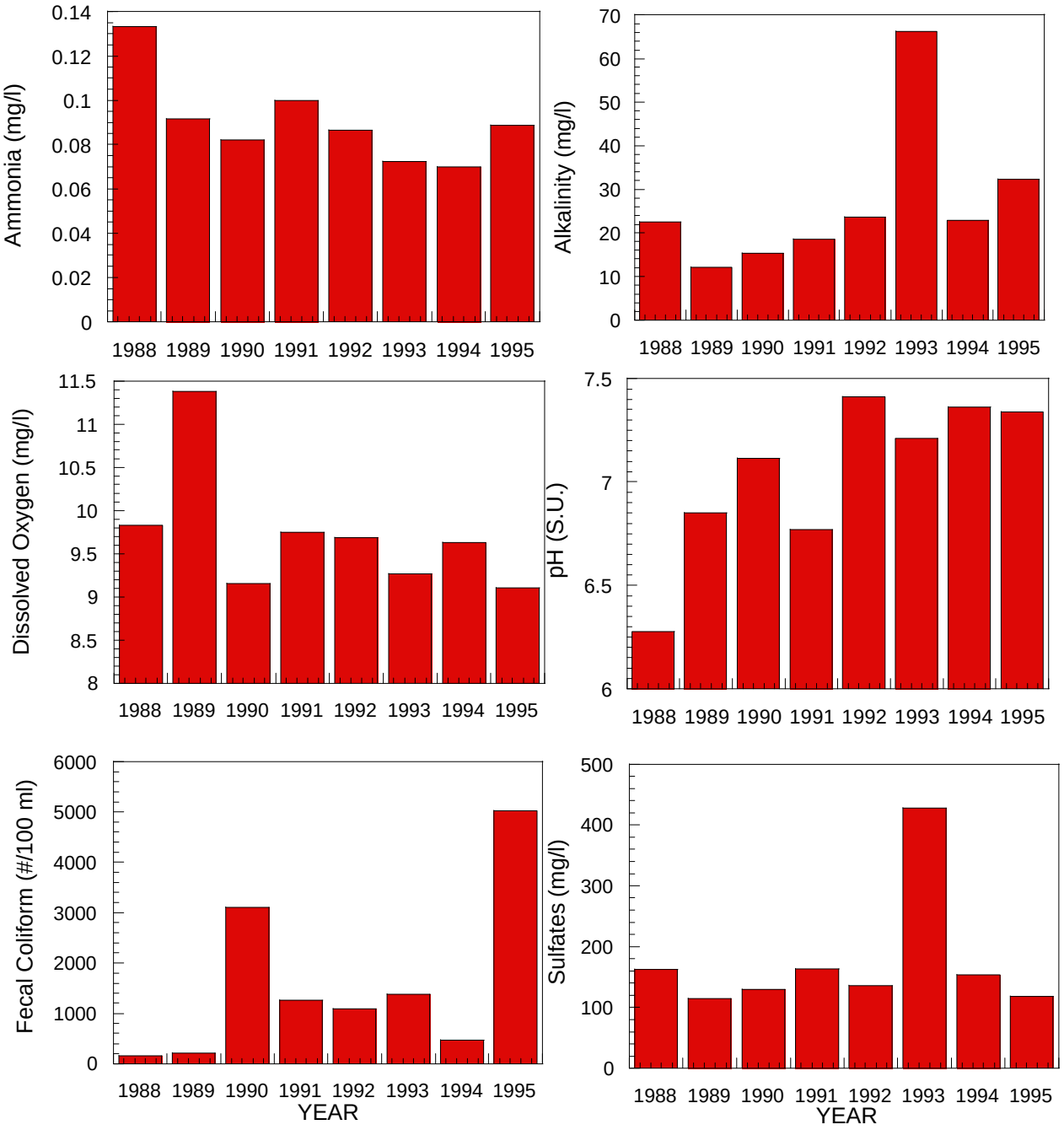


Figure 40 . Trend data for yearly average concentrations (one sample per month) of alkalinity, ammonia, dissolved oxygen, fecal coliform bacteria, pH, and sulfates in Raccoon Creek at Garners Ford (RM 27.07).

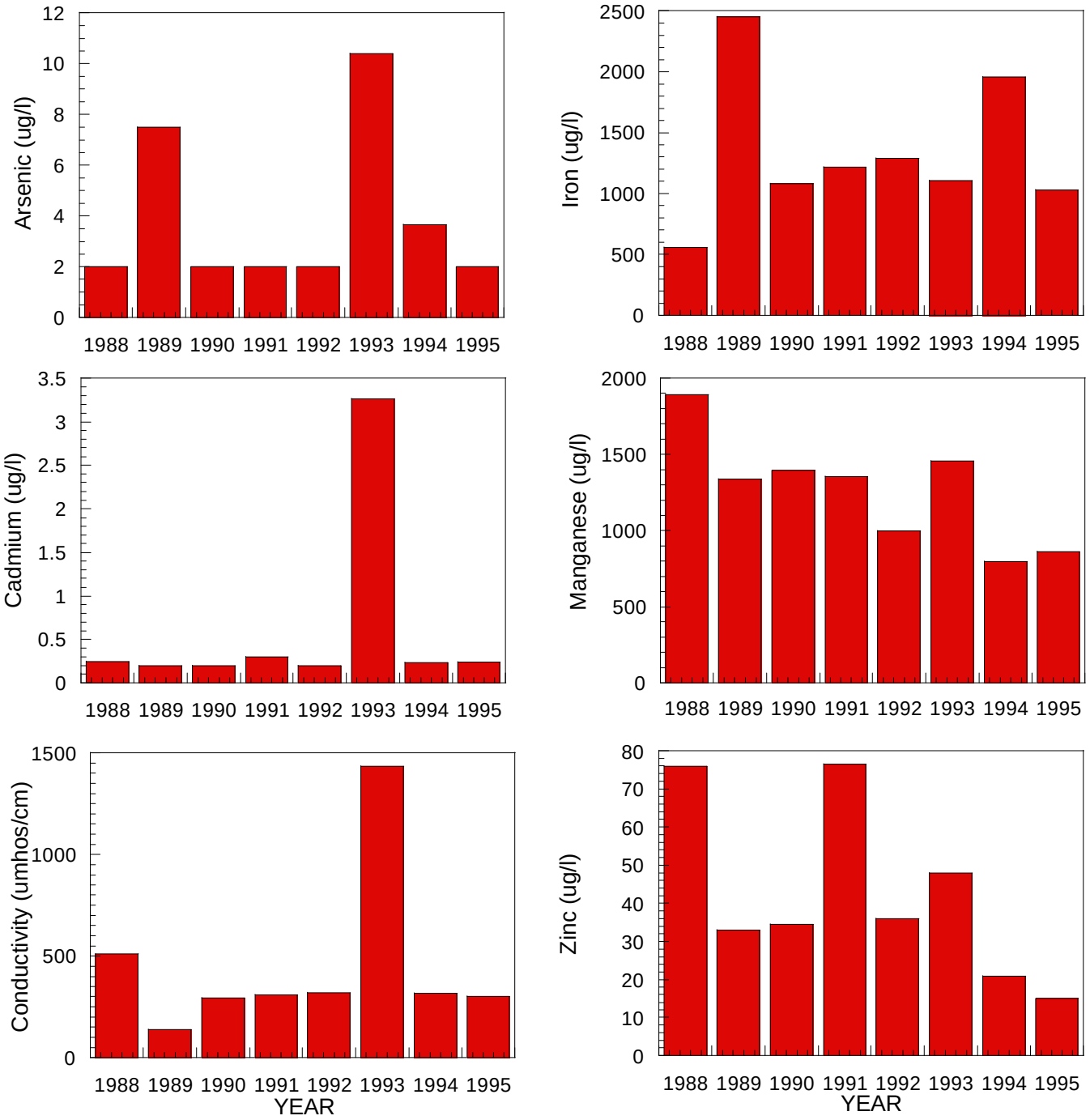


Figure 41. Arsenic, cadmium, conductivity, iron, manganese, and zinc trend data (yearly average, one sample/month) in Raccoon Creek at Garners Ford (RM 27.07).

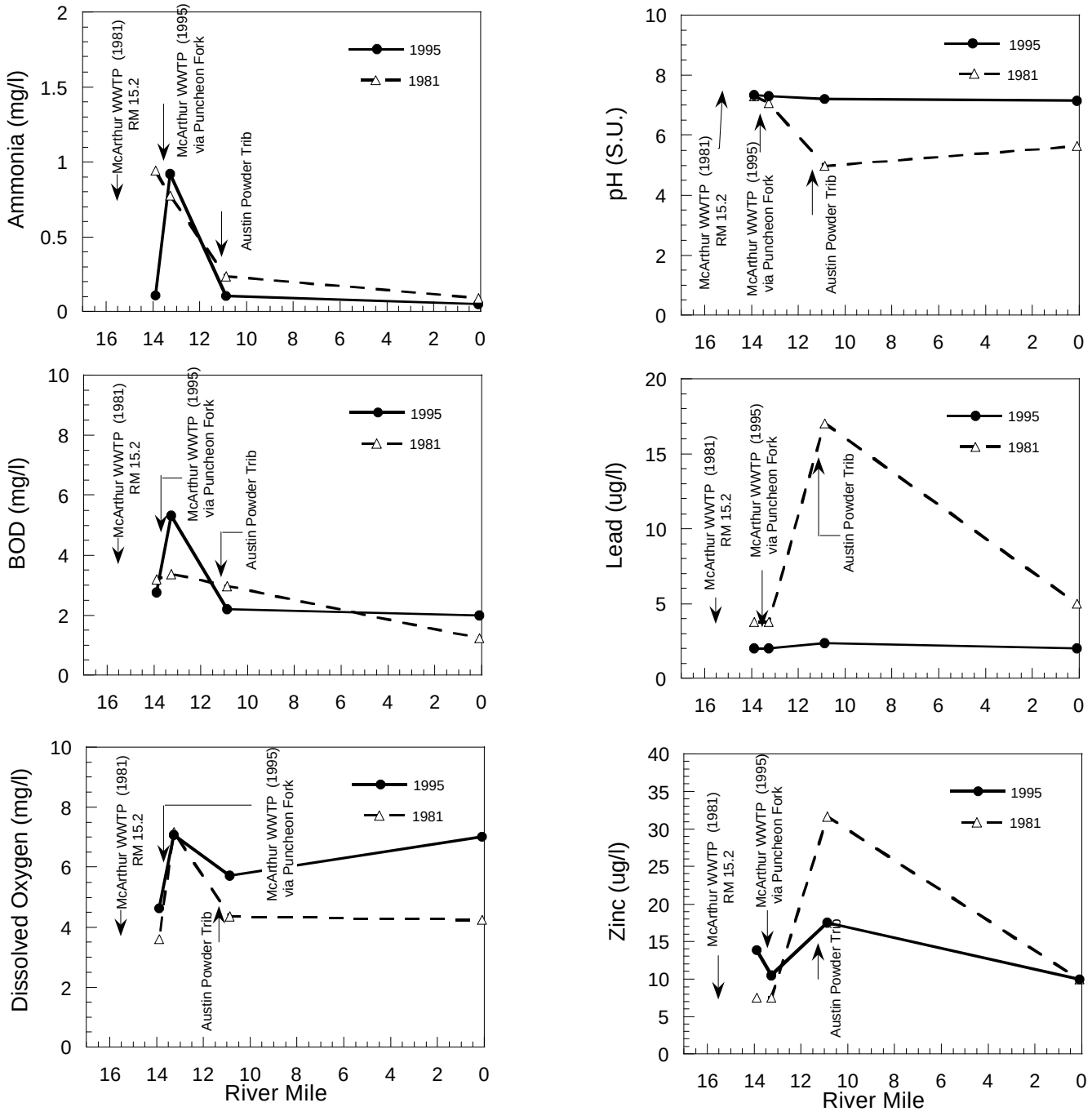
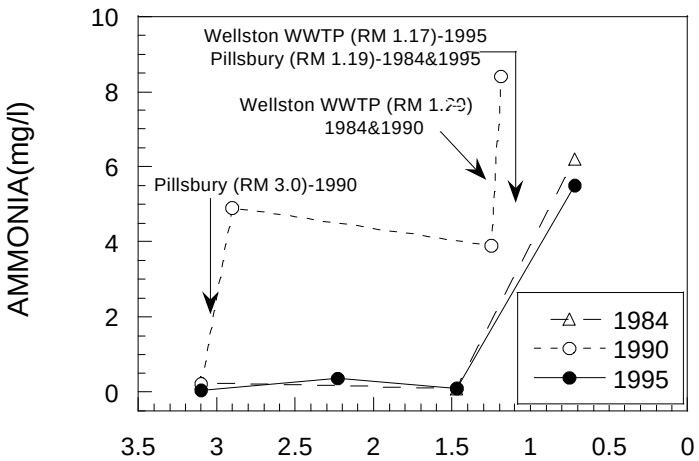
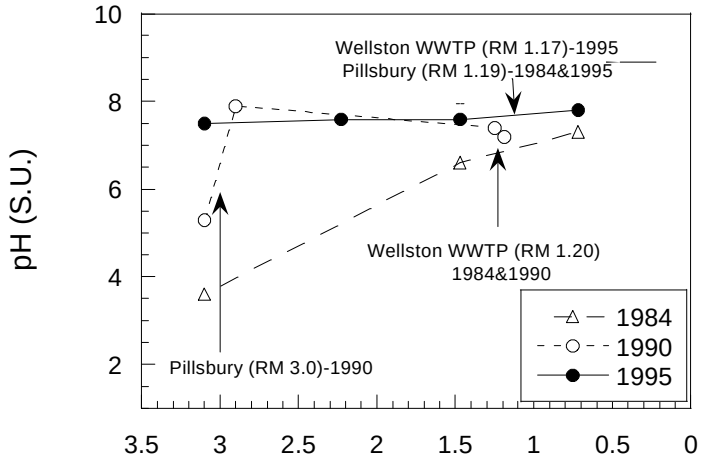
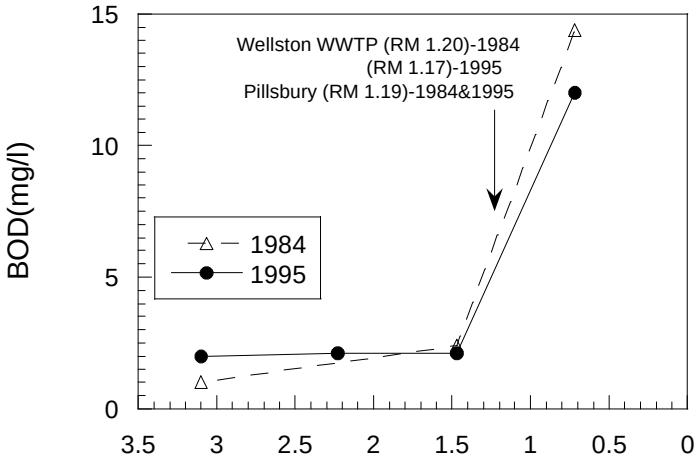
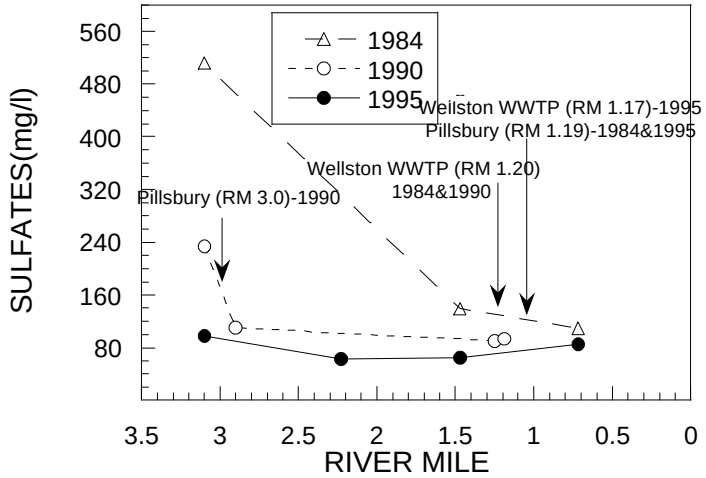


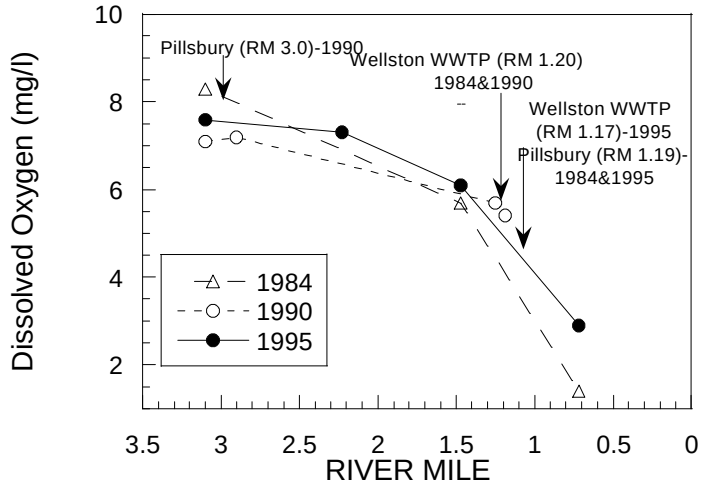
Figure 42. Survey sampling trend data for ammonia, BOD, dissolved oxygen, pH, lead, and











zinc in Elk Fork, 1981 and 1995.

Figure 43. Survey sampling trend data for ammonia, BOD, dissolved oxygen, pH, and sulfates in Meadow Run for the years1984, 1990, and 1995.

Sediment Quality Trends (Tables 18-19; Figure 44)

Meadow Run
Sediment metals were sampled in Meadow Run in 1990 and 1995 (Table 18). The concentration of most metals in the sediments at 14th Street (RM 1.4/1.42) were lower in 1995. This may have been a result of the change in discharge location of Pillsbury (*a.k.a.* Jeno's) outfall 001 which discharged at RM 3.0 in 1990, and at RM 1.19 in 1995. Sediment results upstream at RM 3.1 and downstream from the Wellston WWTP (RM 1.1 and 0.72) showed little change between the years.

The Total Toxicity Equivalent (TTE) is a measure of the toxicity potential of a sample. It is computed by multiplying each 2,3,7,8 chlorinated dioxin and dibenzofuran congener by its Toxicity Equivalence Factor (TEF), which is the toxicity of the congener compared to the toxicity of 2,3,7,8-TCDD (which is 1.0). These are then summed for each 2,3,7,8 congener in the sample. To account for differences in detection limits from 1988 to 1995, one half of the not detected limit (for those congeners listed below detection) was added to the calculations for TTEs and these values are shown parenthetically in Table 19.

A 1988 U.S. EPA sediment sample collected in the mixing zone of the Wellston WWTP (located at RM 1.20 in 1988) showed a dioxin level of 2,529 ppt Total Toxicity Equivalents (TTE). A portion of Meadow Run from the SR 327 bridge (RM 2.05) to approximately 200 feet below Wellston's current outfall (RM 1.17) was dredged in 1989 by the city. Dredged material was placed adjacent to the stream. Sediment sampling from 1989 showed a low level of dioxin upstream at 14th Street (3.2 ppt TTE) compared to high levels downstream at Chaetwood Road (246 ppt TTE), near the mine overflow (338 ppt TTE) and near the mouth (155 ppt TTE).

The 1995 survey showed similar concentrations of dioxin as the 1989 data did at 14th Street (3.9 ppt TTE) and Chaetwood Road (246 ppt TTE). Data showed a reduction from 2,529 ppt TTE in 1988 to 362 ppt TTE in 1995 in the Wellston WWTP mix zone (located at RM 1.17 in 1995). This may be in response to the section of Meadow Run dredged from RM 2.05 to RM 1.16 in 1989, or the difference in outfall/sediment sampling locations from RM 1.20 in 1988 to RM 1.16 in 1995.

Table 18. Dry weight concentrations of heavy metals (mg/kg or ppm) in sediments of Meadow Run study area during l995. All parameter concentrations were ranked based on stream sediment classification system[1] described in the *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* (Persaud, *et.al.*,1994.)

	Sediment Concentration (mg/kg, dry weight)							
	As	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Ni***	**Zn**
LEL[2]	6	0.6	26	16	20000	31	16	120
SEL[3]	33	10	110	110	40000	250	75	820
River Mile (year)								
Meadow Run								
3.1 (1990)	5.06	*4.20*[2]	12.4	11.8	*36600*[2]	12.4	*17.5*[2]	69.5
3.1 (1995)	*13.1*[2]	0.12	*29.6*[2]	10	*24400*[2]	<17.7	<23.6*	85.7
1.4 (1990)	*11.2*[2]	0.76[2]	15.6	*31.8*[2]	*29000*[2]	*52.8*[2]	*36.1*[2]	*193*[2]
1.47 (1995)	*12.6*[2]	<0.14	<20.9	9.75	*28900*[2]	<20.9	<27.8*	86.3
1.1 (1990)	*11.0*[2]	*0.869*[2]	17.8	*71.0*[2]	*22700*[2]	*73.4*[2]	*25.9*[2]	*232*[2]
0.72 (1995)	*12.4*[2]	0.53	*38.8*[2]	*50.5*[2]	*26400*[2]	*88.5*[2]	<36.1*	*244*[2]

[1]Below Lowest Effect Level-no notation after reported value.
[2]*Exceeds Lowest Effect Level*
[3]**Exceeds Severe Effect Level**
*The 1995 values for nickel could not be accurately screened since the detection limit was greater than the LEL.

Table 19. Dioxin and dibenzofuran levels in sediment collected from Meadow Run, 1989 and 1995 by the Ohio EPA, 1988 by USEPA. Concentrations are in ng/kg (ppt).

	Toxicity Equivalence Factor (TEF)	Ust. Wellston WWTP RM 1.45 1989	Ust. Wellston WWTP RM 1.47 1995	Wellston Mix Zone RM 1.20 1988	Wellston Mix Zone RM 1.17 1995	Dst. Wellston WWTP RM 0.7 1989	Dst. Wellston WWTP RM 0.72 1995
Dioxins							
2378-TCDD	1	<21	<0.3	600	33.9	<160	29.7
12378-PeCDD	0.5	<59	<0.5	1800	199	<230	93.4
123478-HxCDD	0.1	<72	<0.5	<90	59.1	<98	24.2
123678-HxCDD	0.1	<72	0.51	1900	379	<160	181
123789-HxCDD	0.1	<130	0.66	2800	536	<120	133
1234678-HpCDD	0.01	<78	38.9	24000	5610	1800	5320
OCDD	0.001	3200	3420	100000	48620	15000	71150
Total TCDD		<28	<0.3	1800	91.1	<160	100
Total PeCDD		<30	<0.5	9900	967	<230	412
Total HxCDD		<68	5.0	33000	6230	<1000	3090
Total HpCDD		<80	99.6	55000	14660	4500	13950
Dibenzofurans							
2378-TCDF	0.1	<8.9	<0.3	37	4.1	<36	7.5
12378-PeCDF	0.05	<30	<0.4	260	10.5	<74	6.5
12478-PeCDF	0.5	<30	<0.4	130	8.9	<70	3.7
123478-HxCDF	0.1	<50	<0.4	140	40.6	<570	26.9
123678-HxCDF	0.1	<47	<0.3	730	64.0	<55	13.8
234678-HxCDF	0.1	<47	0.23	<57	40.1	<55	5.6
123789-HxCDF	0.1	<47	<0.4	ND	1.6	<57	<2.7
1234678-HpCDF	0.01	<78	0.5	2900	463	<100	259
1234789-HpCDF	0.01	<140	<0.4	<380	19.5	<230	10.8(E)
OCDF	0.001	<140	0.78	12000	1480	<450	1100
Total TCDF		<37	<0.3	560	48.3	<200	66.1
Total PeCDF		<30	<0.4	5700	441	<74	235
Total HxCDF		<50	0.59	11000	1690	<120	472
Total HpCDF		<140	0.87	10000	1130	<500	768
2378 TCDD Total Toxicity Equivalent-TTE (includes one half of the not detected limit)		3.2 (61.9)	3.9 (4.9)	2520 (2524)	361 (361)	33 (246)	245 (246)

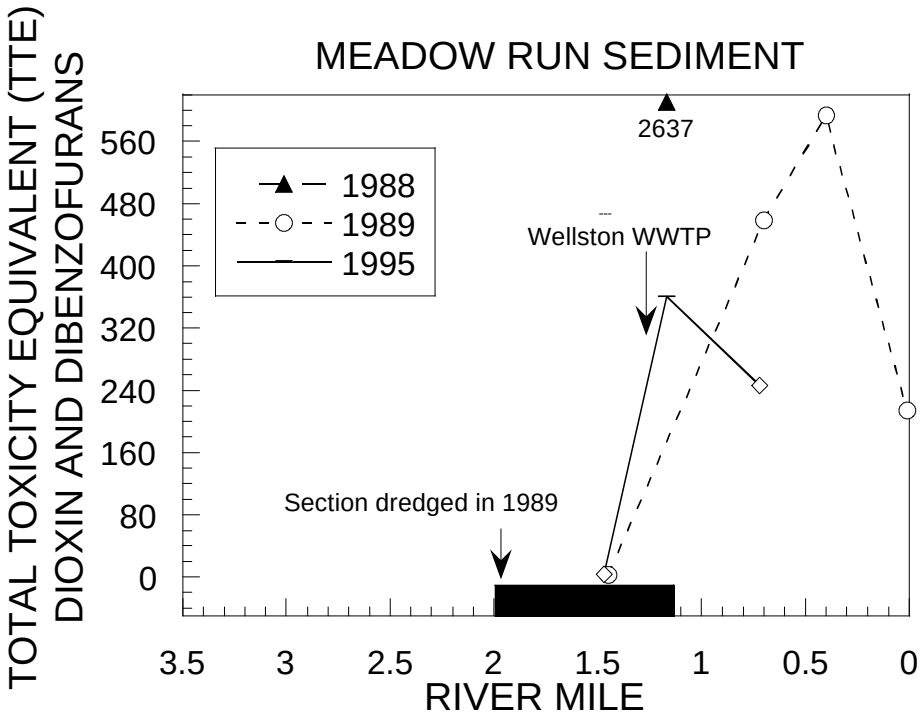


Figure 44. Trend for dioxin/dibenzofuran sediment data (total toxicity equivalent, TTE) in Meadow Run, 1988, 1989, and 1995.

Fish Tissue Trends (Table 20)

Little Raccoon Creek and Meadow Run
Four fish tissue samples were collected from Little Raccoon Creek in 1990 (Table 20). Dioxin and dibenzofuran congeners were analyzed in carp and largemouth bass collected upstream and downstream from Meadow Run. Carp and largemouth bass fillet samples collected downstream from Meadow Run were below the U.S. Food and Drug Administration (FDA) Action Level (50 parts per trillion, ppt), as well as below the FDA reduced consumption level of 25-50 ppt. The carp whole body sample collected upstream reported a value of 33.4 ng/kg 2,3,7,8-TCDD.

Fish were collected in Meadow Run in 1995 and included yellow bullhead and black bullhead composite samples collected upstream and downstream from the Wellston WWTP at RM 1.6 and RM 0.8. None of the 1995 results exceeded the FDA Action Levels.

The two 1990 samples collected in Little Raccoon Creek upstream from Meadow Run reported 34.6 and 57.7 TTEs, the four samples collected in Meadow Run in 1995 reported a range of 15.3 to 21.6 TTEs, and the two 1990 samples collected in Little Racoon Creek downstream from Meadow Run reported 0.7 and 1.6 TTEs.

Table 20. Dioxin and dibenzofuran levels in fish tissue samples collected from Little Raccoon Creek, November 1989. Concentrations are in ng/kg (ppt).

		Upstream Meadow Run		Downstream Meadow Run	
	Toxicity Equivalence Factor (TEF)	Fillet Lm. Bass	Whole Body Carp	Fillet Lm. Bass	Whole Body Carp
Dioxins					
2378-TCDD	1	22.1	33.4	1.1	<0.5
12378-PeCDD	0.5	20.2	37.8	(E) 0.5	<0.4
123478-HxCDD	0.1	1.4	2.9	<0.4	<0.6
123678-HxCDD	0.1	7.8	16.5	<0.3	<0.5
123789-HxCDD	0.1	4.3	12.5	<0.4	<0.6
1234678-HpCDD	0.01	7.6	34.9	<0.4	<0.8
OCDD	0.001	8.1	192	(B) 2.7	(B) 2.8
Total TCDD		22.1	34.0	1.1	<0.5
Total PeCDD		21.0	38.8	(E) 0.5	<0.4
Total HxCDD		15.3	43.5	<0.4	<0.5
Total HpCDD		7.9	60.7	<0.4	<0.8
Dibenzofurans					
2378-TCDF	0.1	1.1	1.0	<0.2	<0.3
12378-PeCDF	0.05	1.1	2.4	<0.2	<0.3
23478-PeCDF	0.5	1.2	2.0	<0.3	<0.4
123478-HxCDF	0.1	(E) 0.37	0.94	<0.3	<0.4
123678-HxCDF	0.1	0.66	2.1	<0.2	<0.3
234678-HxCDF	0.1	0.48	0.98	<0.3	<0.5
123789-HxCDF	0.1	<0.2	<0.4	<0.5	<0.8
1234678-HpCDF	0.01	0.54	1.9	<0.2	<0.5
1234789-HpCDF	0.01	<0.2	0.32	<0.5	<1.2
OCDF	0.001	<0.2	1.6	<0.5	<0.9
Total TCDF		1.1	1.0	<0.2	<0.3
Total PeCDF		5.6	10.7	<0.2	<0.4
Total HxCDF		2.9	8.6	<0.3	<0.5
Total HpCDF		0.73	4.1	<0.3	<0.7
2378 TCDD Total Toxicity Equivalent - TTE (includes one half of the not detected limit)		34.5 (34.6)	57.7 (57.7)	1.1 (1.6)	0.0 (0.7)

Biological Trends: Macroinvertebrates (Figures 45, 47, and 48)

Raccoon Creek

Macroinvertebrates were surveyed in the Raccoon Creek mainstem from upstream Radcliff (RM 63.8/63.0) to Northup (RM 10.2) in the years 1990, 1993, 1994, and 1995. Sampling in 1993 and 1994 was in response to the Meigs Mine discharge of mine waters during July-September 1993.

In 1990, all stations sampled in the river segment from Radcliff to Northup had Invertebrate Community Index scores (ICI = 42-46) in the very good to exceptional range.

Macroinvertebrate communities in the Raccoon Creek mainstem in 1993 were affected by the discharge of untreated and partially treated mine waters from the Meigs #31 Mine via Strongs Run (RM 43.71) and Robinson Run (RM 42.0). The site upstream from these tributaries at Humpback Bridge (RM 50.1) attained the WWH criterion with an ICI score of 42. The benthic community shifted from a predominance of tanytarsini midges upstream from the impacted tributaries to a predominance of other dipterans and noninsects and a higher percentage of tolerant organisms at downstream sites. The 1993 ICI scores at Vinton (RM 39.9) and Adamsville (RM 29.1) were in the fair range, 26 and 30, respectively.

In 1994, the sites at Humpback (RM 50.1), Vinton (RM 39.9), and Adamsville (RM 29.1) all scored ICI values (22-26) in the fair range. Flow recorded at the U.S.G.S. gauging station at Adamsville was higher than normal (644 cfs) in 1994 (836 cfs) and the biological sampling occurred after a major high water event. There are mine affected tributaries between Radcliff and Humpback Bridge, particularly Pierce Run (RM 60.46) and Karr Run (RM 53.84), that may have contributed an acid mine load during the high water event. Noticeable precipitates at the Humpback Bridge sampling location were evidence of this occurrence.

Results from the 1995 survey showed ICI values ranging from marginally good to exceptional from upstream Radcliff to Northup. The ICI did decline from 48 upstream from Radcliff (RM 63.8) to 32 at Humpback Bridge (RM 50.1). This may have been indicative of the lingering mining impact from the high flows from the previous year or a recurring annual problem. The macroinvertebrate communities collected at Vinton (ICI = 38) and Adamsville (ICI = 46) in 1995 appeared to have recovered from the impact of the Meigs Mine discharge in 1993.

Elk Fork

Although quantitative and qualitative sampling was conducted in 1995 at RMs 16.2, 14.1, 13.3, 10.9, and 0.1, only qualitative samples from the natural substrates were collected in 1981 at the same comparable sites.

The upstream station at RM 16.2 supported macroinvertebrate communities consistent with the WWH aquatic life use both in 1981 and 1995. The next downstream station, RM 14.1/13.9, showed the most improvement in1995, compared to 1981, than any other site in the Elk Fork basin. In 1981, the McArthur WWTP discharged to RM 15.2, and the macroinvertebrate community collected from the natural substrates at RM 13.9 was considered fair with only 5 EPT taxa and a QCTV score of 31.0 (a reflection of the number of pollution sensitive taxa at the site). By the 1995, survey the WWTP had moved its location to Puncheon Fork, and, at RM 14.1, the macroinvertebrate community was

considered exceptional with 16 EPT taxa and a QCTV score of 39.2.

Communities collected from the natural substrates were similar during both survey years for RMs 13.3, 10.9, and 0.1 based on the qualitative EPT taxa (5-8). QCTV scores increased from 1981 (30.1 to 33.2) to 1995 (37.7 to 39.1) at these sites. Macroinvertebrates collected on artificial substrates at RM 10.9 and 0.1 indicated very good water quality (ICI scores of 42 and 44, respectively). These results suggested improved water quality in the lower Elk Fork mainstem but more persistent problems with sedimentation from nonpoint sources.

In 1981, impairment of macroinvertebrate communities was, in part, attributed to sedimentation from rivulets draining ridges adjacent to Elk Fork between RM 13.3 and RM 11.2. In 1995, field staff observed a tributary at RM 13.3 that appeared to be contributing sediment to the Elk Fork mainstem. In fact, two of the artificial substrate samplers had been completed buried by sediment and another two were 95 % covered with sediment during the six week colonization period in Elk Fork at RM 13.3 in 1995.

Little Raccoon Creek

In 1984, macroinvertebrate sampling at RM 28.4 upstream from Meadow Run indicated some stress from upstream sources of acid mine drainage. An upstream site at RM 31.2 was located 0.5 miles downstream from Sugar Run (RM 31.7), a known acid mine tributary. Iron stained sand, coal fines and ferrous hydroxide precipitates were the primary substrate components at RM 31.2. The ICI score was poor at both these sites in 1984. Substantial improvement in the ICI scores were observed in 1990 (ICI = 42) and 1995 (ICI = 36) at RM 28.4; both achieved the WWH biocriterion.

The ICI score increased from 1984 (16), to 1990 (24), and to 1995(28) at the Little Raccoon Creek site (RM 24.6) downstream from Meadow Run. These scores were all in nonattainment of the WWH biocriterion and represented only fair water quality all three years. This site has been affected by the poorly treated wastes from dischargers on Meadow Run.

Between RM 24.6 and RM 11.8 there are several tributaries that are mine affected. Benthic communities showed some improvement in 1995 at RM 11.8 (ICI=18) compared to 1984 at RM 11.0 (ICI=6); however, there were still remnants of mine drainage impacts in 1995. This was the only site on Little Raccoon Creek that had orange stained margins and debris in 1995.

Meadow Run

Upstream from the Pillsbury Plant at RM 3.1/3.2, macroinvertebrate communities have historically been impacted by severe acid mine drainage. In 1984, only 9 taxa were collected in very low densities. In 1990, although total taxa richness remained low (13), a tanytarsini midge taxon accounted for 16 % of the organisms in the quantitative sample. The 1994 sampling yielded 5 tanytarsini midge taxa, 4 EPT taxa, and 24 total taxa. The ICI increased from 2 in 1984, to 14 in 1990, and to 20 in 1995. Acid mine impacts appear to have been reduced.

Macroinvertebrates were collected at 14th Street (RM 1.5) in 1990 and 1995. The ICI score remained fair both years but showed an increase from 20 in 1990 to 28 in 1995, due to increases in the number of mayfly, caddisfly, dipteran, and total taxa.

Downstream from the Wellston WWTP at RM 0.8/0.9, the macroinvertebrate community has been consistently very poor (ICI= 0 in 1984, 1990, and 1995). No mayflies, caddisflies, or tanytarsini midges have been collected at this site by the Ohio EPA during any of these survey years. Tolerant organisms have comprised between 79.7 % and 99.0 % of the organisms collected from the artificial substrates. This prevailing biological condition represents the cumulation of poorly treated waste from relatively high volume discharges into a much lower volume stream creating a segment of very poor water quality in the lower segment of Meadow Run.

Biological Trends: Fish Community (Figures 45-48)

Raccoon Creek

Fish community data were collected from Raccoon Creek in 1990, 1993, 1994, and 1995. Collections made prior to the 1995 intensive survey were limited to middle and lower segments of the mainstem. The 1990 survey included two stations located at RM 40.2 (within the Vinton dam pool) and RM 10.0 (downstream from the Northup dam), which bracketed the Little Raccoon Creek confluence. Collections were made in 1993 and 1994 in support of a long-term monitoring effort established following the discharge of untreated and partially treated water from the Meigs # 31 Mine to Strongs Run and Robinson Run during July - September 1993 (Ohio EPA 1994). In 1993, one community sample was collected at RM 39.9, downstream from the Vinton dam and the confluences of Strongs Run and Robinson Run. Three stations were sampled in 1994, located at RM(s) 50.2 (Humpback Bridge), 39.9 (downstream from the Vinton dam and Strongs Run and Robinson Run), and 29.3 (Adamsville). The 1995 survey was by far more robust than previous efforts, as samples were collected through the entire length of the mainstem (RM 109.1, SR 328 to RM 5.4, SR 218).

Environmental conditions in Raccoon Creek, as reflected by the fish community, have generally improved since the initial survey in 1990 (Figure 45). At that time, community performance ranged between fair (IBI=35 and MIwb=7.5) to fair-good (IBI=35 and MIwb=8.8) at RM(s) 40.2 and 10.0, respectively. The identical stations sampled in 1995 yielded good-fair (IBI=41 and MIwb=7.9) to good-very good (IBI=40 and MIwb=9.5) results. Improved biological index scores were reflective of changes in the composition and condition of the assemblages. These changes were most influential on IBI scores, as the MIwb indicated similar structural evenness between survey years. In 1995, the number of sucker species, sunfish species and percent insectivorous species were increased, while the incidence of Deformities, Eroded fins, Lesions, and Tumors (DELT) anomalies were reduced.

The result of the 1993 and 1994 Meigs #31 Mine monitoring efforts indicated stable or improved conditions in comparison with the 1995 survey. No distinct impact in 1995 was evident from mine water discharged through Strongs Run and Robinson Run to Raccoon Creek between 1993 and 1994. Samples collected near Vinton (RM 39.9) during this interval would seem to indicate diminished biological performance in 1995. However, the sampling station near Vinton in 1995 (as well as 1990) was located within the Vinton dam pool at RM 40.2. The 1993 and 1994 station was situated immediately downstream from the Vinton dam in a free flowing portion of Raccoon Creek. Both stations, dam pool and free flowing, offered vastly contrasting habitats over a very short stretch of river. The detrimental effects of impoundments to riverine habitats are well documented (Hynes 1970). As such, the free flowing station sampled in 1993 and 1994 consistently supported a richer fish fauna (yielding higher IBI scores) than did the impounded station. The discrepancies observed between the 1990/1995 and 1993-94 data sets were not attributed to broad environmental changes in Raccoon Creek, rather, the data simply and clearly reflected the difference in macrohabitat quality of each station.

In summary, analysis of recent and historical data suggested a lessening of mine drainage impacts within the middle and lower portions of the mainstem. This is likely a result of several land-use factors within the watershed that may include limited natural remediation of unreclaimed mine areas, a reduction in the number of active mines, and improved implementation of BMPs for active mines.

Elk Fork Subbasin

Fish community data were collected from the Elk Fork subbasin in 1981 and 1995. Collections made prior to the 1995 intensive survey included the mainstem (RM 17.6 to RM 0.2, CR 438), Puncheon Fork (RM 0.3, near mouth), and the Austin Powder tributary (RM 11.2 and RM 0.4, bracketing the Austin Powder 001 outfall). Objectives of the 1981 sampling effort were to evaluate impacts from: the McArthur WWTP (at its former location upstream from Puncheon Fork), the Austin Powder discharge (via the Austin Powder tributary), and pervasive and unabated mine drainage within the upper portion of the watershed.

The 1995 Elk Fork subbasin survey included seven stations on the mainstem (RM 16.2, SR 93 to RM 0.2, CR 438) and two stations on Puncheon Fork (RM 1.5, upstream from the McArthur WWTP and RM 0.3, downstream from McArthur WWTP). Objectives and placement of sampling stations for the mainstem were similar to that of the previous survey. Evaluation of the tributaries differed in that the McArthur 001 discharge has been moved from the mainstem of Elk Fork to Puncheon Fork. Additionally, the Austin Powder Co. has moved the location of its 001 discharge from the Austin Powder tributary (Elk Fork tributary) to a direct tributary of Raccoon Creek. As a result, fish community samples were not collected from this Elk Fork tributary in 1995.

In 1981, community performance as measured by the IBI ranged, longitudinally, from fair to very poor. Elk Fork was clearly suffering the effects of unabated mine drainage (i.e., low pH, metals, and sedimentation), as the upper portion of the watershed contains several abandoned (unreclaimed) and active mines (Ohio DNR 1985). Puncheon Fork, in particular, was burdened by chronic mine drainage as severely degraded fish communities were found within and downstream from this direct tributary (Figure 46). The Austin Powder tributary also was impacted by chronic mine drainage. Sampling conducted at two stations bracketing the Austin Powder 001 outfall found the stream devoid of fish. Mine drainage channeled through these tributaries, as well as other smaller drainage ways within the Elk Fork basin, were considered the predominant factor influencing instream biological performance throughout Elk Fork in 1981. The detrimental effects of both the McArthur WWTP (BOD and NH_3-N) and the Austin Powder Co. (NO_3+NO_2-N) were identified, but considered secondary in comparison with mine drainage impacts (Ohio EPA 1985).

In comparison with the results from the 1981 intensive survey, the structure, composition and organization of the fish community in 1995 were reflective of tremendous improvements in the environmental conditions of Elk Fork. Every community measure was significantly advanced (e.g., species richness, relative abundance, composition/organization, and structural evenness). Community indices were typically very near or fully consistent with the ecoregionally derived WWH biological criteria. Although incomplete, biological recovery was clearly indicated in 1995. Improved chemical water quality appeared the most significant factor responsible for the recovery, as chemical impacts from mine drainage appeared largely ameliorated in 1995. However, pervasive sedimentation and its detrimental effects to substrate quality were still present and now appear the major factor limiting biological performance in the mainstem.

The 1995 sampling effort in Puncheon Fork found greatly improved conditions. Community samples yielded results fully consistent with the WWH biological criterion. IBI scores and the accompanying narrative evaluations ranged between 44 (good) and 40 (marginally good), indicating complete recovery from the degraded state documented in 1981. No biological impact was evident from the recently installed McArthur WWTP 001 outfall. The chemical impacts associated with mine drainage appeared largely eliminated.

Meadow Run

Fish community data were collected from Meadow Run in 1984, 1990, and 1995. The 1984 survey included two stations, assessing the stream reach between RM 3.1 (headwaters, adj. Pillsbury facility) and RM 0.9 (near the mouth, downstream from the Wellston WWTP and Pillsbury 001 discharges). The 1990 sampling effort included three stations centered around the Wellston WWTP and Pillsbury 001 discharges, evaluating the stream reach extending from RM 1.4 to RM 1.1. The 1995 sampling effort included four stations covering the same area evaluated in 1984: RM 3.1 (headwaters) to RM 0.8 (near the mouth). The remaining two stations were located within the intervening segment to better characterize Meadow Run longitudinally.

Despite community performance ranging from fair to poor in 1995, ambient biological conditions have improved considerably in comparison with 1984 survey results (Figure 48). The combined catch from both stations sampled in 1984 comprised only three individual fish of one highly tolerant species (green sunfish). The compelling lack of fish in Meadow Run was attributed to acidified runoff from unreclaimed mining areas within the headwaters (RM 3.1) and the discharge of wastes from Wellston and Pillsbury near the mouth (RM 0.9) (Ohio EPA 1985). The degraded environmental conditions indicated at that time were so pervasive and severe that the effect of marginal habitat quality on ambient biological performance was merely a secondary consideration.

By 1990, conditions were markedly improved as Meadow Run recovered the ability to, at least, support a simplified assemblage of fishes. Within the vicinity of Wellston, the 1995 survey yielded similar results to those encountered in 1990. However, in 1995 the upper portion of the Meadow Run study area demonstrated considerable recovery, though hardly complete, from the chronic acidic conditions indicated in 1984. The headwater station in 1995 supported a total of 21 species, with a mean relative abundance and biomass of 417/ 0.3 km. and 10.6 kg/0.3 km., respectively. It appeared that the negative influence of the unreclaimed mining areas within the headwaters of Meadow Run was lessened in 1995.

Little Raccoon Creek

Fish community data were collected from Little Raccoon Creek in 1984, 1990, and 1995. The 1984 survey included six stations, assessing the stream reach between RM 36.7 (CR 25 - upstream from Lake Rupert) and RM 1.8 (Koontz-Sailor Rd.). The 1990 sampling effort included two stations bracketing Meadow Run at RM 27.9 (CR 39 - upstream from Meadow Run) and RM 24.5 (SR 32 - downstream from Meadow Run). Three stations were sampled in 1995 located at RM(s) 28.3 (upstream from Meadow Run), 24.6 (downstream from Meadow Run), and 11.0 (Keystone Furnace).

The 1984 results found Little Raccoon Creek impacted by mine drainage to varying degrees throughout its length (Ohio EPA 1985). No station was found to support a fish community fully consistent with the WWH aquatic life use. Impacts derived from chronic mine drainage were most pronounced on the mainstem downstream from Sand Run and Mulga Run (Figure 47). Community statistics (species

richness, abundance, and biomass) and community indices (IBI and MIwb) precipitously declined downstream from these tributaries. Limited recovery was indicated 3.6 miles downstream from Sugar Run. However, the segment of the mainstem affected by Mulga Run (and several smaller mine drainage tributaries) was severely impacted for the remaining 24.4 river miles. Within this reach, very poor conditions were consistently indicated. Nutrient and organic enrichment emanating from Meadow Run (the Wellston WWTP and Pillsbury Co.) was considered a secondary stressor in comparison with the pervasive mine drainage influence.

The 1990 survey indicated conditions somewhat similar or slightly improved to those encountered in 1984. These improvements included an increase in species richness, abundance, and biomass at the stations bracketing Meadow Run. The MIwb scores remained comparable between sampling years suggesting similar structural evenness within the more species rich 1990 community. The IBI indicated modest improvement upstream from Meadow Run and a modest decline downstream. The results would appear to suggest a lessening of mine drainage impacts within the headwaters of Little Raccoon Creek and a worsening impact from Meadow Run.

In comparison with previous surveys, the results from the 1995 sampling effort found considerable improvement throughout the Little Raccoon Creek study area. Community performance, as measured by the IBI and MIwb, indicated marginally good to fair communities at all sampling stations. The IBI consistently met the minimum WWH biological criterion. The MIwb remained within the fair range (6.8 - 7.7). All basic community statistics were advanced in 1995. No biological impact was detected downstream from Meadow Run. More significantly, the segment downstream from Mulga Run (and other mine drainage tributaries) appeared comparable with upstream results. The highly degraded conditions documented in 1984 within this reach appeared largely recovered in 1995. Sedimentation and its detrimental effects to habitat suitability appeared to be the most significant factor limiting instream biological performance in 1995.

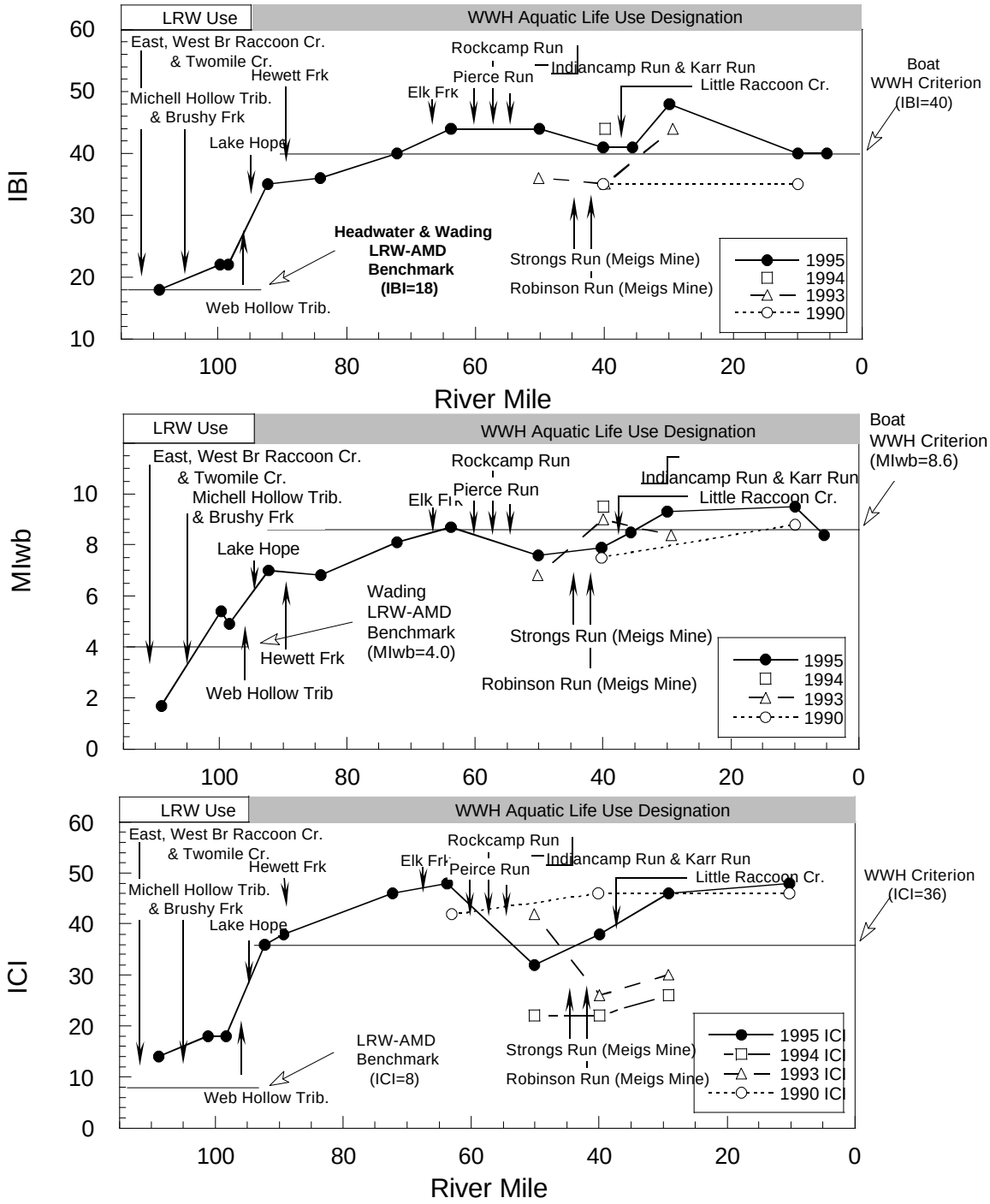


Figure 45. Biological trend data (IBI, MIwb, and ICI) in the Raccoon Creek mainstem, 1990-1995.

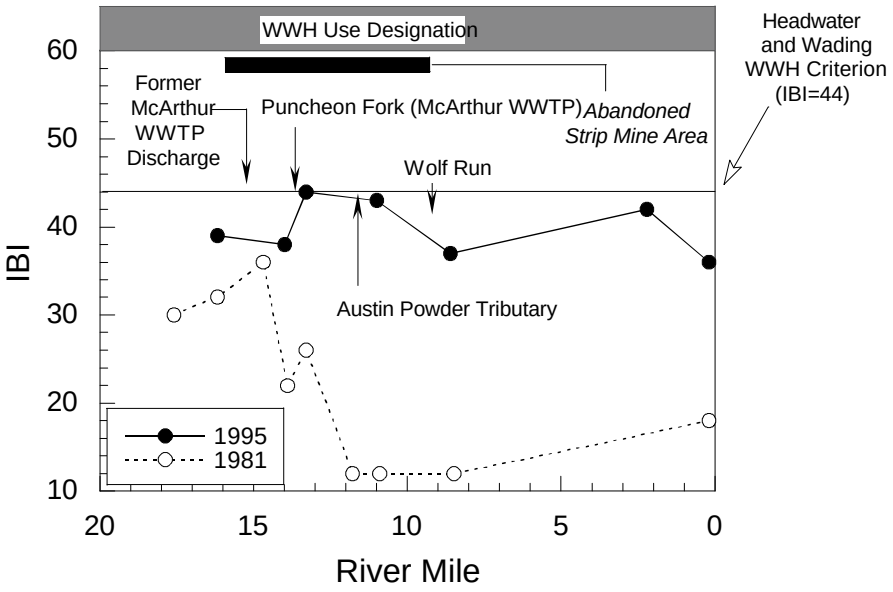


Figure 46. Biological trend data (IBI) in Elk Fork, 1981 and 1995.

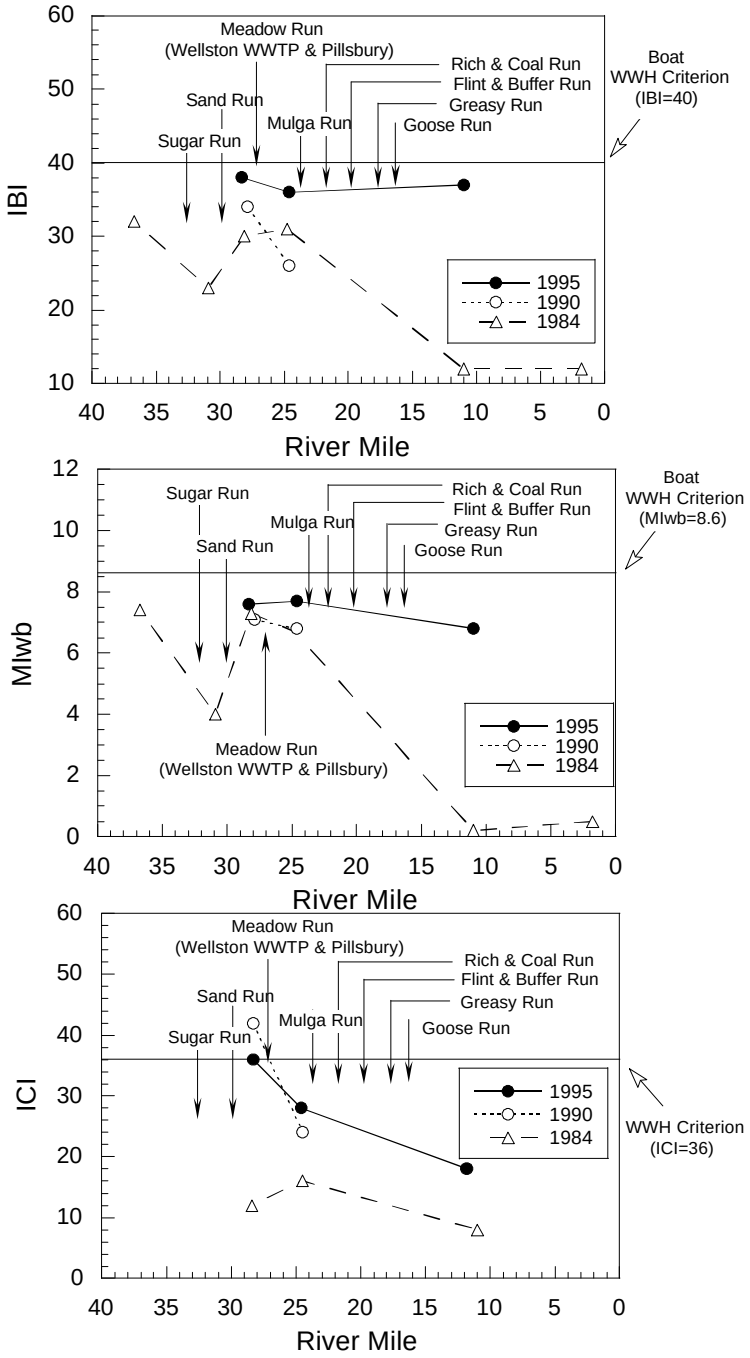


Figure 47. Trend of biological index scores (IBI, MIwb, and ICI) for Little Raccoon Creek, 1984, 1990, and 1995.

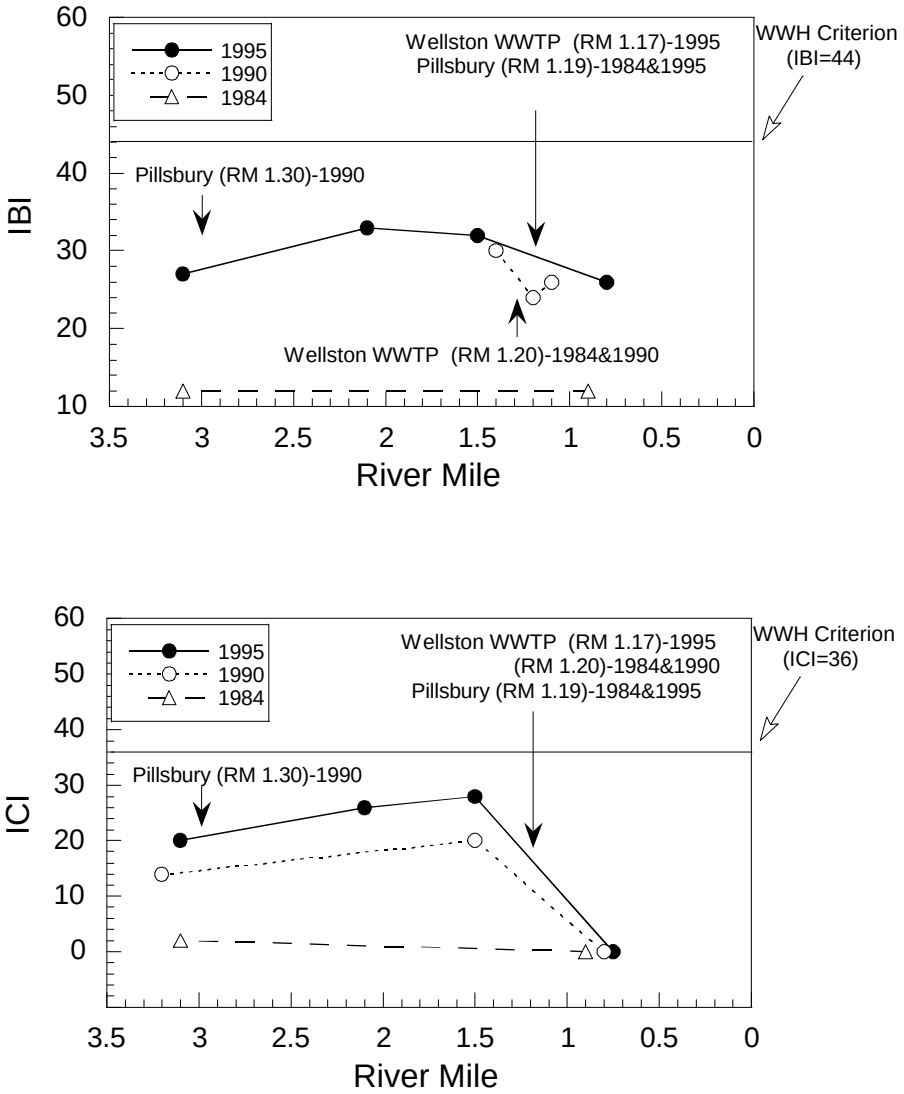


Figure 48. Trend of biological index scores (IBI, MIwb, and ICI) for Meadow Run, 1984, 1990, and 1995.

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