Total Maximum Daily Loads for the Upper Raccoon Creek

Final Report

prepared by

Ohio Environmental Protection Agency
Division of Surface Water

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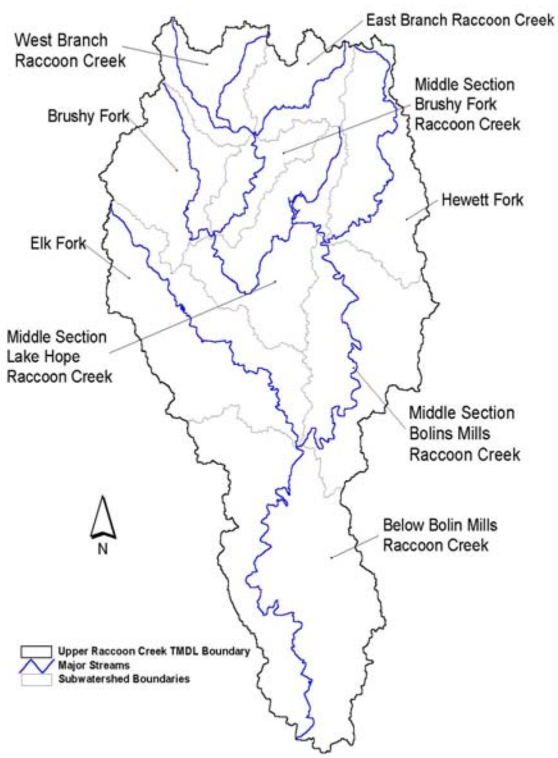
TMDL in Brief:



Basin:	Upper Raccoon Creek is in the Ohio River Basin
Study Area:	From the head waters of East and West Branches of Raccoon Creek to the confluence of Little Raccoon Creek; see pictorial
Goal:	Attainment of Warm Water Habitat Use Designation
Major Causes:	Metals and pH
Major Source:	Bituminous coal mining
Measure:	Metals, pH and biological indices

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ACKNOWLEDGMENTS

The following Ohio EPA staff contributed to this project:

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Many full- and part-time staff participated in field monitoring; chemistry analyses were provided by the Ohio EPA Division of Environmental Services.

Ohio EPA acknowledges the property owners that allowed Ohio EPA personnel access to the Upper Raccoon Creek and its tributaries.

Special thanks to Institute for Local Government Administration and Rural Development (ILGARD) for facilitating the group meetings and development of the Acid Mine Drainage Abatement and Treatment (AMDAT) Plan, in particular Rachel Hoy and Chip Rice.

EXECUTIVE SUMMARY

The upper Raccoon Creek watershed is a sparsely populated, rural watershed, heavily impacted by coal mining. The following characteristics describe the watershed:

- located in south central Ohio
- tributary to Ohio River
- largest village is McArthur, population 1,888
- 386 square miles drainage area
- mainstem 74 miles long with an average slope of 1.9 feet/mile
- elevation changes from 1100 feet above sea level on headwater ridges to 600 feet above sea level at mainstem downstream terminus of study area
- unglaciated, Western Allegheny Plateau Ecoregion
- sandstone - shale soils
- 96% wooded
- 28,964 acres mined for coal

Data for this report were drawn from Ohio EPA and from the Acid Mine Drainage Treatment and Abatement (AMDAT) Plan for the Headwaters of Raccoon Creek from the Institute for Local Government Administration and Rural Development (ILGARD), at Ohio University. Ohio EPA assessed Raccoon Creek in 1995 and 2000 examining biological, habitat, physical and chemical parameters. The AMDAT primarily examined physical and chemical parameters from historical data and from extensive field work in 2000.

The 1998 303(d) list included 12 stream segments in three watersheds (as defined by 11-digit hydrologic unit code (HUC) boundaries) in non attainment of water quality standards. The 2002 303(d) list (as submitted to U.S. EPA for approval) includes all three watersheds based on data from 33 segments. The increase in the number of segments reflects more extensive assessment rather than degradation of the resource.

The primary causes of non attainment are pH and metals. However, pH cannot be modeled. Net alkalinity was selected as a surrogate for pH. Metal concentrations are inversely proportional to net alkalinity. An instream minimum target value of 20 mg/l net alkalinity was developed. Achieving this target will result in pH values within water quality standards and pH and metal concentrations will not be limiting the stream from achieving attainment of the Warm Water Habitat use designation.

Meeting the instream alkalinity target can largely be achieved through reclamation of abandoned coal mined lands. Details of necessary reclamation projects are detailed in the AMDAT Plan. Because of the numerous partners working to improve Raccoon Creek it is reasonable to expect that financial resources will be allocated for this restoration effort.

The production of this TMDL report would not have been possible without the AMDAT Plan provided by ILGARD.

1.0 INTRODUCTION

The Clean Water Act (CWA) Section 303(d) requires States, Territories, and authorized Tribes to list and prioritize waters for which technology-based limits alone do not ensure attainment of water quality standards. Lists of these waters (the section 303(d) lists) are made available to the public and submitted to the U.S. Environmental Protection Agency (U.S. EPA) in even-numbered years (40 CFR 130.7(d) did not require a 303(d) list submittal in the year 2000). The Ohio Environmental Protection Agency (Ohio EPA) identified the upper Raccoon Creek watershed as a priority impaired water on the 1998 303(d) list. A summary of the upper Raccoon Creek watershed portion of the 1998 303(d) list is included in Table 1. A general overview of Ohio's water quality standards is included in Table 3.

The Clean Water Act and U.S. EPA regulations require that Total Maximum Daily Loads (TMDLs) be developed for all waters on the section 303(d) lists. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. The process of formulating TMDLs for specific pollutants is, therefore, a method by which impaired water body segments are identified and restoration solutions are developed. Ultimately, the goal of Ohio's TMDL process is full attainment of biological and chemical Water Quality Standards (WQS) and, subsequently, removal of water bodies from the 303(d) list. The Ohio EPA believes that developing TMDLs on a watershed basis (as opposed to solely focusing on impaired segments within a watershed) is an effective approach towards this goal.

This report documents the upper Raccoon Creek TMDL process and provides tangible actions to restore and maintain this water body. The main objectives of the report are to describe the water quality and habitat condition of the upper Raccoon Creek and to quantitatively assess the factors affecting non or partial attainment of WQS. A draft implementation plan is also included. This plan identifies actions to address these factors and specifies monitoring to measure the success of the actions prescribed. The report organization follows the progression of the TMDL process.

The primary causes of non attainment are pH and metals. Other less significant causes not addressed in this report include siltation and organic enrichment/D.O. pH and metals are the limiting factors in this watershed. An adaptive management approach suggests that focusing on these limiting causes first, combined with follow-up monitoring to determine subsequent stream condition and response, is reasonable especially given the clear indication of the current problems and the readiness to proceed with restoration. Table 1 identifies 303(d) listed waters and the causes of impairment.

Table 1 - Summary of 1998 303(d) Listed Waters Included in This TMDL Report[1]

Waterbody Segment Description [Identification Number]	303(d) Status[1]		Major Causes 303(d)	Included in this Report?[2]	Comments
	1998	2002			
05090101-020 Raccoon Creek (hdw to Hewett) [was 05090101-045 on 1998 list]					
OH30-60 Raccoon Creek (East/West Branch to Brushy Fork)		✓	Metals	✓	
	✓	✓	pH	✓	
OH30-63 East Branch Raccoon Creek		✓	Metals	✓	
		✓	pH	✓	
OH30-64 West Branch Raccoon Creek		✓	Metals	✓	
OH30-62 Two Mile Run		✓	Metals	✓	
OH30-59 Brushy Fork	✓	✓	pH	✓	
		✓	Metals		
OH30-59.1 Dunkle Creek		✓	Metals	✓	
		✓	Habitat Alteration	No	
OH30-56 Sandy Run		✓	Metals	✓	
		✓	pH	✓	
		✓	Siltation	No	
OH30-56-390 Lake Hope	✓		Organic Enrichment/D.O.	☺	
	✓	✓	pH	✓	
	✓	✓	Siltation	No	
	✓	✓	Metals	✓	
	✓		Taste and Odor	☺	
OH30-65 Honey Fork		✓	Siltation	No	
05090101-030 Raccoon Creek (Hewett to Elk) [was 05090101-050 on 1998 list]					
OH30-58 Wheelabout Creek		✓	Siltation	No	
OH30-50 Hewett Fork		✓	pH	✓	
OH30-50.1 Carbondale Creek		✓	Metals	✓	
		✓	pH	✓	

Waterbody Segment Description [Identification Number]	303(d) Status[1]		Major Causes 303(d)	Included in this Report?[2]	Comments
	1998	2002			
OH30-51 Rockcamp Creek		✓	Cause Unknown	No	
OH30-54 Grass Run		✓	Metals	✓	
OH30-53 Pine Run		✓	Metals	✓	
		✓	pH	✓	
OH30-52 Coal Run		✓	Metals	✓	
		✓	pH	✓	
OH30-48 Onion Creek		✓	Cause Unknown	No	
OH30-47 Tedroe Run		✓	Metals	✓	
OH30-46 Merrit Run		✓	Cause Unknown	No	
OH30-45 Russell Run		✓	Oil and Grease	No	
OH30-43 Long Run		✓	Salinity / TDS / Chloride	No	
		✓	Oil and Grease	No	
OH30-35 Elk Fork		✓	Cause Unknown	No	
		✓	Metals	✓	
		✓	pH	✓	
		✓	Siltation	No	
OH30-38 Wolf Run		✓	Nutrients	No	
		✓	Organic Enrichment/D.O.	No	
	✓	✓	pH	✓	
	✓	✓	Metals	✓	
OH30-40 Austin Powder Trib.		✓	Metals	✓	
		✓	Ammonia	No	
		✓	Nutrients	No	
		✓	Flow Alteration	No	
OH30-44 Flat Run		✓	Cause Unknown	No	
		✓	Oil and Grease	No	

Waterbody Segment Description [Identification Number]	303(d) Status[1] 1998	303(d) Status[1] 2002	Major Causes 303(d)	Included in this Report?[2]	Comments
05090101-040 Raccoon Creek (Elk to Little Rac) [was 05090101-060 on 1998 list]					
OH30-34 Zinns Run	✓		Flow Alteration	☺	
OH30-33 Pierce Run		✓	Metals	✓	
		✓	pH	✓	
OH30-32 Rockcamp Run		✓	Metals	✓	
OH30-31 Indiancamp Run		✓	pH	✓	
OH30-30 Karr Run		✓	pH	✓	
OH30-28 Raccoon Creek (Elk Fork to Flatlick Run)	✓	✓	Cause Unknown	No	
		✓	Metals	✓	
	✓	✓	Siltation	No	
OH30-27 Opossum Run		✓	Metals	✓	
		✓	pH	✓	
		✓	Siltation	No	
		✓	Oil and Grease	No	
OH30-25 Strongs Run	✓	✓	pH	✓	
	✓	✓	Organic Enrichment/D.O.	No	
	✓	✓	Metals	✓	
	✓	✓	Salinity / TDS / Chloride	No	
	✓	✓	Siltation	No	
		✓	Other Inorganics	No	
OH30-23 Robinson Run	✓		Metals	☺	presently meets WWH
	✓		pH	☺	
	✓		Organic Enrichment/D.O.	☺	
	✓		Salinity / TDS / Chloride	☺	
	✓		Flow Alteration	☺	
			Habitat Alteration	☺	
OH30-24 Sugar Run	✓		Metals	☺	presently meets WWH
	✓		pH	☺	
	✓		Salinity / TDS / Chloride	☺	
	✓		Siltation	☺	
OH30-22 Raccoon Creek (Flatlick Run to Little Raccoon Cr.)	✓		Cause Unknown	No	
		✓	Metals	✓	
		✓	pH	✓	
	✓	✓	Siltation	No	
OH30-26 Williams Run	✓	✓	pH	✓	
	✓	✓	Siltation	No	

[1] Indicates if cause was listed in 1998 303(d) report or, based on current information Ohio EPA expects it to be listed in the 2002 303(d) report.

[2] Indicates: ☺ is not addressed because it is no longer a cause of impairment
no is not addressed in this report but is a cause of impairment
✓ Cause of impairment is addressed in this report. (Monitoring covered all areas indicated. The headwaters to Bolins Mills were modeled; Bolins Mills to the confluence with Little Raccoon Creek are not yet modeled. See Appendix A for explanation.)

2.0 WATERBODY OVERVIEW

2.1 Description of the Study Area

The Upper Raccoon Creek watershed is located in south central Ohio in the Ohio River drainage basin and the Western Allegheny Plateau ecoregion. The portion of the basin covered by this TMDL includes the catchment area on the mainstem of Raccoon Creek upstream from the confluence with Little Raccoon Creek near Village of Vinton. This upper half of the basin covers parts of five counties (Hocking, Athens, Vinton, Meigs and Gallia) and draining 386 square miles. Raccoon Creek mainstem within this study area is 74.4 miles long and has an average fall of 1.9 feet per mile. The topography is unglaciated with land that is quite hilly and elevations vary from 1100 feet along some ridgetops to 600 feet in the river bottoms at the southern part of this sub-watershed. The bedrock is of Pennsylvanian age and is composed mostly of shale, sandstone and coal. The soils are mainly sandstone and shale from the Muskingum-Dekalb-Latham association with lesser amounts of Gilpin-Latham-Dekalb and Monongahela-Allegheny soil. The only impoundment in the watershed is Lake Hope (120 acres), in Lake Hope State Park (3103 acres). Raccoon Creek mainstem has no dams on this segment. Wayne National Forest occupies about 1800 acres and Zaleski State Forest covers approximately 26,400 acres. The watershed is mostly forested or agricultural (Appendix B, Figure 1).

Table 2 - Land Use in Upper Raccoon Creek Basin

Land Use	% of Land Use	Acres	Square Miles
Urban	0.05	1677	2.62
Agricultural/Urban	4.00	9,882	15.44
Shrub/Scrub	0.19	6,874	10.74
Wooded	95.68	236,365	369.32
Open Water	0.02	659	1.03
Non-Forested Wetland	0.01	448	0.70
Barren	0.05	1805	2.82

The McArthur WWTP is in compliance with it's NPDES permit. The WWTP has a positive effect on Puncheon Fork by discharging an average of 211 mg/L alkalinity (Biological and water Quality of The Raccoon Creek Basin (1995) Ohio EPA). All communities are small and unsewered except McArthur, which has a population of 1,888 and a two-stage lagoon sewage treatment plant which discharges to Puncheon Fork. The other numerous small NPDES dischargers within Upper Raccoon Creek Watershed have no impact on the basin streams. These discharges are typically from ridgetops or to small swales and the discharges rarely reach streams. See appendix B, Table 1 for discharges. Because McArthur is the only significant discharger and it discharges net alkalinity rather than net acidity no waste load allocation was developed for acidity for the permitted discharges in the basin.

Coal mining was a major activity that has severely impacted the study area. Mining began in the mid 1800s using shaft and deep mines and by the 1930s strip mining became more common. Presently 11,105 acres of land have been strip mined and 17,859 acres have been deep mined (Appendix B Figures 4, 5 and 6). Prior to the 1970s, little effort was made to reclaim mined land. As a result, thousands of acres of both surface and deep mined lands have been abandoned or unreclaimed.

2.2 Water Quality and Biological Assessment

Under the Clean Water Act, every state must adopt water quality standards to protect, maintain and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the goal of "swimable/fishable" waters. Table 3 provides a brief description of Ohio’s water quality standards. Further information is available in Chapter 3745-1 of the Ohio Administrative Code (OAC) (http://www.epa.state.oh.us/dsw/wqs/criteria.html). In the Upper Raccoon Creek study area, the aquatic life use designations that apply to various segments are Warmwater Habitat (WWH) and Limited Warmwater Habitat (LWH). Waters designated as WWH are capable of supporting and maintaining a balanced integrated community of warmwater aquatic organisms. Waters designated as LWH are incapable of supporting WWH assemblages of aquatic organisms due to their small size (drainage area), severe impacts from mining or channelization and other radical habitat modifications. Attainment of aquatic life uses is measured in two ways. The first is criteria in the WQS for various pollutants are compared to measurements taken from the water to determine attainment for specific pollutants.

Table 3 - Summary of the Components and Examples of Ohio’s Water Quality Standards

WQS Components	Examples of:	Description
Beneficial Use Designation	Aquatic life habitats (partial list): • Exceptional Warmwater (EWH) • Warmwater (WWH) • Modified Warmwater (MWH) • Limited Resource Water (LRW)	Each use designation has an individual set of numeric criteria associated with it, which are necessary to protect the use designation. For example, a water that was designated as a drinking water supply and could support exceptional biology would have more stringent (lower) allowable concentrations of pollutants than would the average stream.
Numeric Criteria	1. Chemical	Represents the concentration of a pollutant that can be in the water and still protect the designated use of the waterbody. Laboratory studies of organism’s sensitivity to concentrations of chemicals exposed over varying time periods form the basis for these.
	2. Biological *Measure of fish health:* • Index of Biotic Integrity *Measure of bug (macroinvertebrate) health:* • Invertebrate Community Index	Indicates the health of the instream biological community. The numeric biological criteria (biocriteria) were developed using a large database of reference sites.

Refer to http://www.epa.state.oh.us/dsw/wqs/wqs.html for more information on all of Ohio’s WQS.

The second way attainment is determined is by directly measuring fish and aquatic insect populations to see if they are comparable to those seen in least impacted areas of the same ecological region and aquatic life use. Attainment benchmarks from these least impacted areas are established in the WQS in the form of "biocriteria," which are then compared to the measurements obtained from the study area. If measurements of a stream do not achieve the two biocriteria (fish: Index of Biotic Integrity (IBI) and aquatic insects: Invertebrate Community Index (ICI)) the stream is considered in "non attainment." If the stream measurements achieve some of the biological criteria, but not others, the stream is said to be in "partial-attainment." A

stream that is in "partial attainment" is not achieving its designated aquatic life use, whereas a stream that meets all of the biocriteria benchmarks, it is said to be in full attainment.

2.3 Causes and Sources of Impairment

Acidity and metals were identified as major causes of impairment. Streams within the Upper Raccoon Creek Watershed have always been slightly acidic, a natural condition in sandstone geology, and when acid discharges from mining activities add more acidity to these streams, the fish and aquatic insects are adversely affected. For more detail on how acidity effects biology see Appendix J (AMDAT), pg. 21, Biological Health. This reference discusses the impacts of AMD on aquatic life (figure 12) with mention of the biological responses to AMD. It also discusses measures of biological health, numeric biocriteria for QHEI, ICI, IBI (figure 13) and shows attainment status and biological community performance (Figure 14) in the AMD effected region.

In the mid-1800s, Ohio was changing from an agrarian economy to an industrial economy and coal mining and coal consumption played a major role in that transition. Mining began within the watershed during this period. Coal mining has severely impacted the study area. While underground mining was the preferred method of coal mining throughout the region, steam shovels were being used in the late 1800s for surface mining. By 1950s strip mining became more common with the development of efficient very large earth-moving equipment (Crowell 1995). Prior to the 1977 Surface Mining Control and Reclamation Act (SMCRA), little effort was made to reclaim land that was mined, resulting in thousands of acres of both surface and deep mined lands being abandoned or unreclaimed. These unreclaimed areas resulted in vast areas of highly erodible, toxic soils and exposed coal refuse piles (gob piles). Unreclaimed underground mine shafts were left unsealed and discharging mine water.

The unreclaimed areas mined before the SMCRA laws came into effect contribute large volumes of sediments, metals (primarily iron and aluminum) and acidic water into Raccoon Creek and its tributaries. The acidic water has metals dissolved in it and is known as acid mine drainage (AMD). Pre-law mining in the watershed has devastated the biological diversity and integrity of many streams. Figure 1 shows a typical stream in the study area.

Southeast Ohio is part of the Eastern Coal Province which stretches from northwestern Pennsylvania to northern Alabama (Stoertz 1998). The sandstone and coal components have a high concentrations sulfides in the form of pyrite.

Figure 1 - AMD Stream Within Upper Raccoon Creek TMDL Study Area

When the pyrite (FeS_2) is exposed to water and air the end products are an iron hydroxide ("yellowboy") and sulfuric acid (PDEP).

$$4FeS_2 + 15O_2 + 14H_2O \Leftrightarrow 4Fe(OH)_3^- + 8H_2SO_4$$

Pyrite + Oxygen + Water ↔ Ferric Hydroxide + Sulfuric Acid

The acid produced dissolves other metals such as zinc, aluminum and manganese, from the coal refuse.

In Table 4, the many streams that are not meeting the WWH use designation are listed and a cause for their non-attainment is also noted. Figure 2 shows stream segments meeting and not meeting use attainment within the TMDL watershed. Table 1 and Table 4 have use discrepancies due to data collection.

Table 4 - Aquatic Life Use Attainment Status for Impaired Streams in the Upper Raccoon Creek Basin 1996-2000

The Index of Biotic Integrity (IBI) and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community in the *Western Allegheny Plateau WAP* ecoregion. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community.

Stream (stream code) Designation / Recommended Designation					
River Mile	**IBI**	**ICI**[1]	**QHEI**	**Attainment Status**	**Causes**
Raccoon Creek (09-500) LRW-AMD (existing) / WWH (recommended)					
89.5-111.9	18	16	60	NON	metals, pH
East Br. Raccoon Creek (09-574) LRW-AMD (existing) / WWH (recommended)					
0.1-6.6	12	9	68.	NON	metals, pH
Honey Fork (09-576)WWH (existing) / (recommended)					
0.5/1.5	30	Fair	76	PARTIAL	habitat/sed.
West Br. Raccoon Creek (09-575) WWH (existing) / (recommended)					
0.2-5.7	24	38/Fair	58	NON	metals
Two Mile Run (09-573) WWH (existing) / (recommended)					
0.2	28	good	63	PARTIAL	metals
Brushy Fork (09-571) EWH (existing) / WWH / (recommended)					
0.4-9.1	16	V. Poor	47/64	NON	pH
Dunkle Creek (09-590) undesignated (existing) / WWH (recommended)					
0.7-0.9	34	M. Good	64	PARTIAL	metals
Wheelabout Creek (09-570) EWH (existing) / WWH (recommended)					
0.6/0.6	28	Good	67	PARTIAL	sediment
Sandy Run (09-568) WWH (existing) / (recommended)					
2.7-5.2	18	NA	56.5	NON	metals, pH

Table 4 - Aquatic Life Use Attainment Status for Impaired Streams in the Upper Raccoon Creek Basin 1996-2000

Stream (stream code) Designation / Recommended Designation **River Mile**	**IBI**	**ICI**[1]	**QHEI**	**Attainment Status**	**Causes**
Lake Hope (09-568) EWH (existing)/(recommended)					
--	--	--	--	PARTIAL	metals, pH
Hewett Fork (09-563) LRW-AMD (existing) / WWH (recommended)					
8.3-13.4	17	V. Poor	74	NON	pH
Carbondale Creek (09-586) undesignated (existing) / WWH (recommended)					
0.5	12	V. Poor	51.5	NON	pH
Rockcamp Creek (09-564) WWH (existing) / (recommended)					
1.8	44	Fair	55	PARTIAL	unknown
Grass Run (09-567) WWH (existing) / (recommended)					
0.1	30	Fair	55	PARTIAL	metals
Pine Run (09-566) WWH (existing) / (recommended)					
0.1	--	Poor	--	NON	metals, pH
Coal Run (09-565) WWH (existing) / (recommended)					
0.1	30	Fair	58	PARTIAL	metals, pH
Onion Creek (09-561) WWH (existing) / (recommended)					
1.4	30	V. Good	76.5	PARTIAL	habitat/sed.
Tedrow Run (09-560) WWH (existing) / (recommended)					
0.1	28	Fair	54	PARTIAL	metals
Merrit Run (09-559) WWH (existing) / (recommended)					
0.1	34	Poor	63	NON	unknown
Russell Run (09-558) WWH (existing) / (recommended)					
0.6	36	Good	48	PARTIAL	oil & gas
Long Run (09-556) WWH (existing) / (recommended)					
1.4	38	Fair	69	PARTIAL	oil/salinity
Elk Fork (09-530) WWH (existing) / (recommended)					
0.1-18.6	36-44	36-54	54-75	PARTIAL	metals, pH
Wolf Run (09-533) LRW-AMD (existing) / WWH (recommended)					
2.5	--	Poor	--	NON	metals, pH
Austin Powder Trib. (09-578) WWH (existing) / (recommended)					
0.1-2.95	--	Fair	--	PARTIAL	metals
Flat Run (09-557) WWH (existing) / (recommended)					
1.3/1.6	36	Good	51	PARTIAL	unknown
Pierce Run (09-553) LRW-AMD (existing) / WWH (recommended)					
0.7	34	Poor	52	NON	metals, pH

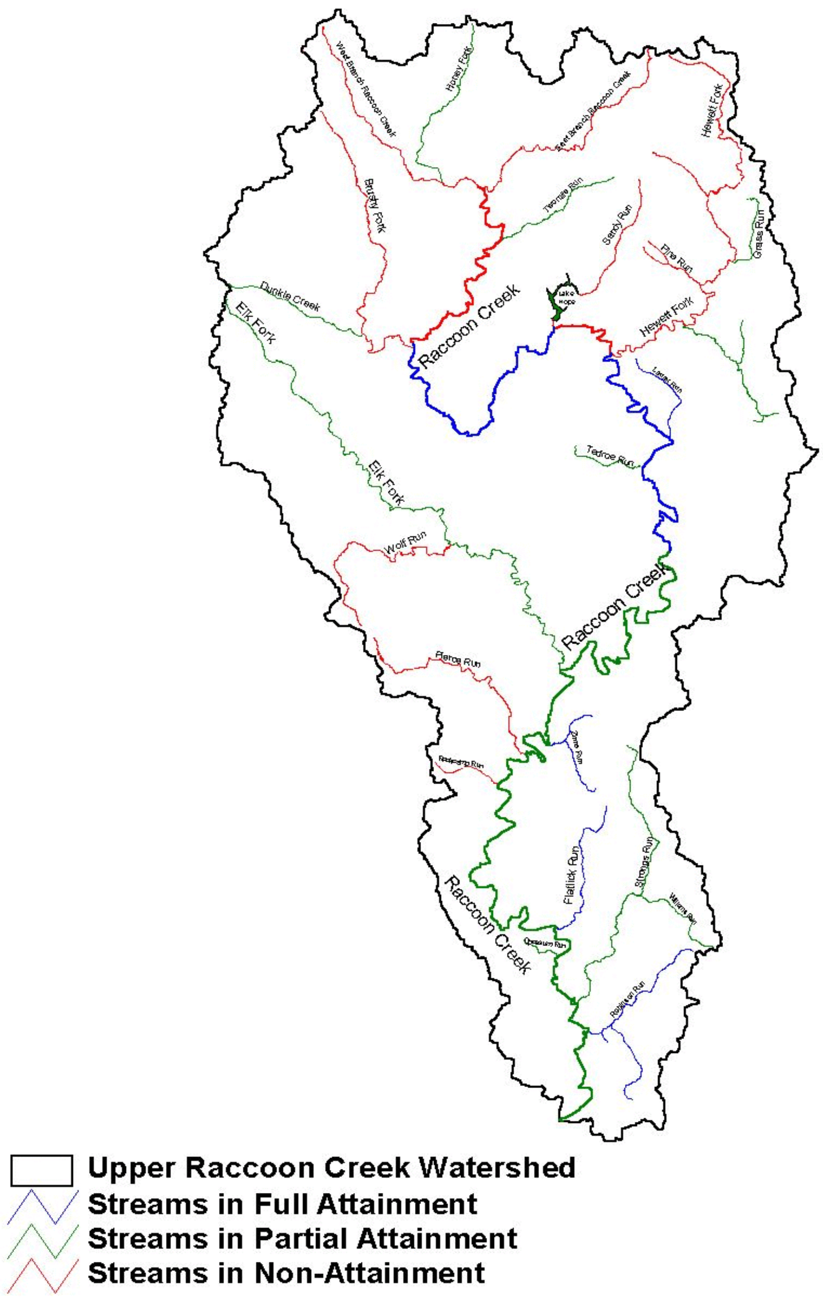
Table 4 - Aquatic Life Use Attainment Status for Impaired Streams in the Upper Raccoon Creek Basin 1996-2000

Stream (stream code) Designation / Recommended Designation **River Mile**	**IBI**	**ICI**[1]	**QHEI**	**Attainment Status**	**Causes**
Rockcamp Run (09-552) LRW-AMD (existing) / WWH (recommended)					
1.7	12	Poor	55	NON	metals
Indiancamp Run (09-551) LRW (existing) / WWH (recommended)					
0.3	28	Fair	82	PARTIAL	pH
Karr Run (09-550) LRW (existing) / WWH (recommended)					
0.2	32	Poor	57	NON	pH
Opossum Run (09-548) WWH (existing) / (recommended)					
0.1	42	Fair	64	PARTIAL	metals, pH
Strongs Run (09-546) EWH (existing) / WWH (recommended)					
0.6	28	--	--	PARTIAL	metals
Williams Run (09-547) EWH (existing) / WWH (recommended)					
0.1	--	--	--	PARTIAL	pH
Raccoon Creek (09-500) WWH (existing) / (recommended)					
37.55-47.67	41	38	47	PARTIAL	metals, pH

[1]ICI based on Qualitative sample, which yields a narrative evaluation

Inconsistencies between Table 1 and Table 4 are due to differences in year of data collection.

Figure 2 - Aquatic Life Use Attainment Status of Upper Raccoon Creek Watershed



3.0 PROBLEM STATEMENT

The goal of the TMDL process is full attainment of the Water Quality Standards (see Table 3). As described in Section 2, the water quality and biological assessments of the Upper Raccoon Creek Watershed indicate that the primary causes of non attainment are pH and metals. This TMDL will attempt to determine what changes must occur in the watershed so that pH and metals do not prevent the stream from meeting the Warm Water Habitat aquatic life use designation.

Ohio has Water Quality Standards for pH. However, pH cannot be modeled. As a surrogate, we have selected acidity and alkalinity for load calculations and modeling. Metals are listed in the 305(b) report as causes of impairment. Ohio has no water quality standards for iron, aluminum and manganese.

3.1 Target Identification

The establishment of instream numeric targets is a significant component of the TMDL process. The numeric targets serve as a measure of comparison between observed instream conditions and conditions that are expected to restore the stream to its designated uses. The TMDL identifies the load reductions and other actions that are necessary to meet the target, thus resulting in the attainment of applicable water quality standards.

Due to the overwhelming prevalence of Acid Mine Drainage (AMD) in the Upper Raccoon Creek Basin, capturing and treating all the affected water would be very difficult and cost prohibitive. Therefore, for the purposes of this report, the entire modeled segment will be considered to be meeting the applicable WQS or target when the alkalinity goal of 20 mg/l at the segment end is met. However, it should be noted that in order to meet targets at the model segment ends, many of the upstream sites must meet the target.

3.1.1 pH

Ohio's statewide pH water quality criteria for the protection of aquatic life outside mixing zone average of 6.5 - 9.0, was used for the target. This is also the federal recommended nearly maximum level of protection, with 6.0 - 9.0 being the federal recommended high level of protection (U.S. EPA, 1973).

3.1.2 Metals

Ohio EPA currently does not have statewide numeric criteria for the metals of concern: iron, manganese and aluminum. Therefore, the U.S. EPA criterion listed below, were used (Table 5). The targets are: pH 6.5-9.0, net alkalinity 20 mg/l, iron 1000 ug/l, aluminum 750 ug/l, manganese 2000 ug/l and total dissolved solids 1,500,000 ug/l. When available, Ohio EPA outside mixing zone maximum standards were selected. Note that all available criteria are listed in Table 5.

Table 5 - Raccoon Creek TMDL Targets

Parameter	Criteria Available Units	Sources		Target	Source Used	Comments
		OEPA	USEPA			
pH	S.U.	yes	yes	6.5-9.0	OEPA	6.5-9.0 & 6.0-9.0 USEPA's nearly maximum level of protection and high level of protection
Net Alkalinity	mg/l	N/A	N/A	20	pH driven	When instream net alkalinity conc's. equal 20 mg/l, pH is usually greater than 6.5.
Iron	ug/l	no	yes	1000 ccc[A], no cmc[B]	USEPA	National Recommended Criteria
Aluminum	ug/l	no	yes	87 ccc, 750 cmc	USEPA	National Recommended Criteria
Manganese	ug/l	[G]	[G]	2000[F]	USEPA (see comment)	40 CFR Ch. 1 (7-1-92 edition) Subpart 434.32[C]
TDS	ug/l	yes	no	1500000 omza[D], no omzm[E]	OEPA	

[A] Criterion continuous concentration, USEPA's criterion which is equivalent to OEPA's avg. aquatic life criterion.
[B] Criteria maximum concentration, USEPA's criterion which is equivalent to OEPA's max. aquatic life criterion
[C] National BPT effluent limitations for acid and ferruginous mine drainage
[D] omza = outside mixing zone average
[E] omzm = outside mixing zone maximum
[F] average of 30 consecutive days
[G] The only WQS which exists is for drinking water and since this stream section is not designated for drinking water it will not be used.

3.1.3 TDS

Ohio only has one non drinking water level of protection listed for TDS, it is the outside mixing zone average Aquatic Life Standard of 1,500,000 ug/l.

3.1.4 Net Alkalinity

Acidic water in Raccoon Creek contains metals, sometimes in very high concentrations, in the dissolved state. Buffering[1] causes metals to become colloidal and drop out which decreases the acidity, therefore it makes sense to target acidity. In streams where AMD and metals are prevalent, pH is not a reliable measurement of acidity due to latent acidity from metals. Net alkalinity is, however.

When net alkalinity was chosen as the surrogate for pH and metals, a target that resulted in both pH and metals meeting their targets had to be developed. Due to the high cost of AMD remediation, the net alkalinity target had to be a minimum so as to not unnecessarily burden the existing and future remediation resources. Comparisons were made between increasing net alkalinity and pH and metals to understand the relationships. The results showed that as net alkalinity increased, pH increased and metal concentrations decreased (Figures C1 and C3 in Appendix C). The minimum instream net alkalinity concentration that would allow all the

[1] Buffering occurs when a substance in a solution tends to stabilize the hydrogen ion concentration by neutralizing an added acid.

parameters of concern to meet respective water quality standards was 20 mg/l.

The data for those parameters were assessed at all the sites that meet the warmwater habitat biological criteria (Table 8). Depending on the parameter there were 9 to 115 samples available at these sites. Ideally the minimum value for pH and maximum values for metals at these sites will be reasonably close to our targets in order to protect biological communities without burdening remediation resources. For net alkalinity, the 4th percentile value was 23 mg/l below that were extreme negative net alkalinity values. Using the results from Table 8 and the comparisons of net alkalinity to metals (Figure C3 in Appendix C), the net alkalinity target of 20 mg/l was chosen.

Figure C2 in Appendix C shows a comparison between two separate groups of data. Included are data from sites that have net alkalinity values greater than 20 mg/l and data from sites that meet Ohio EPA's warmwater use designation. There are 157 data points for the net alkalinity sites and 135 for the warmwater habitat sites. Many of the sites overlap but not all. The figure shows that the sites that meet 20 mg/l are similar in chemical content to those that meet the warmwater habitat use designation, thereby validating the use of the net alkalinity target of 20 mg/l.

3.1.5 Biocriteria

The biocriteria are the final arbiter of attainment of a use designation. After the control strategies have been implemented, biological measures including the IBI, ICI, and MIwb will be used to validate biological improvement and biocriteria attainment. The current attainment of the biocriteria along with the applicable standards is listed in Section 2.0, Table 4.

3.2 Current Deviation from Target

Existing instream conditions of the upper Raccoon Creek region are highly acidic. The high acidity, with pH as low as 1.8, is caused in part by the dissolved metals. The high metals in turn can cause elevated TDS values. Table 6 shows for each parameter of concern the variation in values, minimum and maximum values, and the percentage of samples meeting the target. The table was created from data for which there were both acidity and alkalinity values. The upper portion of the table shows the statistics for all useable data. The lower portion shows the statistics from sites that had a net alkalinity of 20 mg/l or greater. Based on the findings it is our conclusion that these conditions reflect what the instream conditions will be in segments with low net alkalinity after remediation brings net alkalinity to 20 mg/l or greater. To determine the net deviation for each parameter compare the "% of samples meeting target" in the upper portion of the table to the "% of samples meeting target" in the lower portion of the table. For example, if the target for pH is 6.5, under existing conditions 10% of the sites meet the target. After remediation, 57% of the sites will meet the target, therefore the deviation for pH is 47% of the sites.

Table 6 - Statistics for Targeted Parameters

Statistics	pH		Iron	Aluminum	Manganese	TDS
Target values are:	6.0	6.5	1000 ug/l	750 ug/l	2000 ug/l	1500000 ug/l
All Samples			**All Samples**			
Minimum	1.80	1.80	0	100	40	170
Maximum	7.51	7.51	567000	103000	79000	6570
Total Samples	212	212	363	364	363	149
# of samples not meeting target	160	191	199	184	213	41
% of samples not meeting target	75	90	55	51	59	28
% of samples meeting target	25	10	45	49	41	72
Samples for which Net Alkalinity is > 20			Samples for which Net Alkalinity is > 20			
Total Samples	23	23	154	154	154	129
No. of samples not meeting target	1	10	66	13	46	32
% of samples not meeting target	4	43	43	8	30	25
% of samples meeting target	96	57	57	92	70	72

3.2.1 Net Alkalinity

A good quantifiable measure of deviation can be accomplished using net alkalinity. As mentioned before, net alkalinity is the load based parameter that is modeled in lieu of pH in an acid mine drainage environment. The deviation for net alkalinity, is calculated by subtracting the existing instream net alkalinity from the target of 20 mg/l for each site. Table 7 shows the net alkalinity target deviation at the end of each reach, for a more comprehensive look at the deviation from site to site see Appendix C, Table C2.

Table 7 - Segment End Net Alkalinity Target Deviation Under Existing Conditions

Net Alkalinity				
Existing Conditions				
Stream Segment		**Cumuative Conc. (Mg/l)**	**Target (Mg/l)**	**Deviation from Target (Mg/l)**
East Branch Raccoon Creek	reach end	-59.0	20	-79.0
West Branch Raccoon Creek	reach end	-20.2	20	-40.2
Middle Section Brushy Creek	reach end	-6.1	20	-26.1
Brushy Creek	reach end	-13.2	20	-33.2
Middle Section Lake Hope	reach end	12.0	20	-8.0
Hewett Fork	reach end	-33.0	20	-53.0
Middle Section Bolins Mills	reach end	-9.5	20	-29.5

Figure C4 in Appendix C shows the instream net alkalinity at the end of each modeled reach for both existing conditions and post Acid Mine Drainage Abatement and Treatment (AMDAT) plan remediation conditions. The goal is met in the Raccoon Cr. mainstem proper but falls slightly short in the East and West Branches, though large improvements do occur in the branches.

3.3 Source Identification

The 305(b) report for Raccoon Creek lists the major sources of impairment as pH and metals. These sources can be lumped into the category of AMD. The source of AMD varies from site to site, but it includes gob piles, coal fines, and seeps from surface and subsurface mines. Though a great effort has been put towards discovering all the points of acidity to the study area a good percentage of the total flow was not measured in the field. In the model the unmeasured flow and associated concentration is called the "unknown." If the flow source is unknown then remediation cannot be planned and therefore cannot be corrected in the model. This unknown flow is what drives the water to acidic conditions in the post remediation model. For specifics on the unknown flows for each segment see Appendix A, Calibration. The other issue, which creates a difficult to solve acidic problem, is direct seepage of AMD into the Branches. Acidic water seeps directly into the stream from the banks and bed, making finding the source difficult. After the suggested remediation projects have been completed and further assessment reveals more acid reduction is desired an effort should be made to find the missing sources.

Each model segment refer to AMDAT, Appendix J, starting on page 41.

4.0 TOTAL MAXIMUM DAILY LOADS

A TMDL is a means for recommending controls needed to meet water quality standards (U.S. EPA, 1991). 40 CFR 130.2(i) states that a TMDL calculation is the sum of the individual wasteload allocations for point sources and the load allocations for nonpoint sources and natural background in a given watershed, and that TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure. Aquatic organisms are affected by a combination of variables that are not limited to load based pollutants. Therefore, the attainment of WQS in Ohio requires that both pollutant loads and environmental conditions (pollution, or non-load based parameters such as habitat) be addressed when identified as impairing causes.

pH is the most listed cause of impairment in the Upper Raccoon Creek. It is not a load based parameter and due to latent acidity is not conducive to standard statistics and cannot be reliably modeled. Therefore, net alkalinity (alkalinity - acidity), which is a load based parameter and is conducive to modeling, is used as the surrogate.

Metals are also listed as a cause for impairment. Metals are load based parameters, however in AMD streams where pH is in constant flux, metal concentrations stay in flux as well. Modeling metals is dificult in an AMD impacted stream because ph and thus metals solubility, is highly variable both temporally and spatially. It is more reliable and simpler to model the net alkalinity than to model the metals. Dissolved metal concentrations decrease with increasing net alkalinity and pH. Therefore, net alkalinity is used to calculate the TMDL for both pH and metals.

The TMDL calculation must also include either an implicit or explicit margin of safety that accounts for the uncertainty concerning the relationship between pollutant load or the pollution (the non-load causes of impairment) and water quality. The calculations, then, provide a numeric basis for addressing the impairing causes.

4.1 Method of Calculation

Due to the difficulties caused by pH not being conducive to standard statistics, and latent acidity and buffering creating constantly fluctuating metal concentrations, it makes sense to model net alkalinity as a surrogate for pH and metals (net alkalinity 3.1.4). **In addition, an aquatic organism, and therefore the biological community, responds not to load but rather to the concentration of components of the water immediately surrounding it.** A spreadsheet was built to calculate and follow the cumulative net alkalinity load and concentration from site to site from the headwaters downstream to the end of the study area. The cumulative concentration was calculated by dividing the cumulative "load" by the cumulative flow. It was not necessary to define an actual load into standard units such as kg/d or lbs/d since the target was net alkalinity concentration. The "load"for this model, is simply concentration multiplied by discharge. The model loaded with the existing site data then gives us a picture of the net alkalinity concentration under existing conditions. Sites are impaired where cumulative concentrations dip below the target concentrations. Once the model was set up and calibrated the site concentrations could easily be changed to a potential remediation design concentration, as detailed at the end of each section description in the AMDAT plan (ILGARD, 2001), to see the effects of the remediation on the system. See Model Structure in Appendix A, for details on model inputs.

4.2 Critical Conditions and Seasonality

TMDL development should specify the environmental conditions assumed to define allowable loads. Determinations of TMDLs must take into account critical conditions for stream flow, loading, and water quality parameters (40 CFR 130.7(c)(1)). The critical condition is defined as the set of environmental conditions most stressfull to the aquatic biological community and most likely for water quality standards to be exceeded. Thus if controls are designed to be protective at the critical conditions they will be protective at all other conditions as well.. For example, the critical condition for control of a continuous point source discharge is the drought stream flow. Point source pollution controls designed to meet water quality standards for drought flow conditions will ensure compliance with standards for all other conditions. The critical condition for a wet weather-driven source may be a particular rainfall event, coupled with the stream flow associated with that event.

The net alkalinity concentrations were compared to the reference site flow to develop a concentration to flow trend. Based on that comparison an assumption was made that net alkalinity for each site was unaffected by flow volume until a threshold of 300 cfs at the reference flow site was exceeded (Figure A1 Appendix A). Therefore flow of less than 300cfs is considered the critical condition . These conditions are normally associated with the low rainfall months of October and November, however these conditions, being weather dependent, may occur at any time of the year in southeast Ohio. The reference flow site is the bottom most point of the study area on the Raccoon Cr. and lies just upstream of the Little Raccoon Cr. confluence (Figure 3).

4.3 Margin of Safety

The margin of safety is incorporated implicitly into these TMDLs. Setting the pH target at 6.5 creates a margin of safety since biological measures of health can score high in pH's below 6.5. Although there are very few pH measurements (four) in the database at the sites that meet Ohio EPA's healthy stream Warm Water Habitat status, from those sites that do have pH values the minimum value is 6.07. This shows that healthy populations can occur at pH's less than 6.5. The pH target of 6.5 is also U.S. EPA's level of nearly maximum protection, however if the target is not met but higher than 6.0 it still meets U.S. EPA's "high level of protection" status. This is a cushion of 0.5 pH units. Also, iron has an explicit margin of safety in that the ccc standard was used in lieu of a cmc standard since no cmc standard exists for iron.

Table 8 shows the percentiles for the parameters of concern from sites that presently meet Ohio EPA's healthy Warmwater Habitat use designation. The table also shows the percent rank of the targets for the respective parameter. The percent ranks for the metals are as follows: iron at .65, manganese at .87 and aluminum at .90. This shows that the targets for iron were exceeded in 35% of the samples, 13% for manganese and 90% for aluminum. These targets were exceeded in waters that maintain healthy biological community, therefore demonstrating that the targets may be overly stringent and that by meeting them, a level of protection is created.

To summarize, when the net alkalinity target of 20 mg/l is met the targets for metals will usually be met but in some cases may be exceeded. Even though there might be an exceedance of a metal target, since most metals will achieve their target the additive toxic effect from the metals will be reduced thus allowing the biological community to improve and sustain the warmwater use designation.

Figure 3 - Schematic representation of the Upper Raccoon Creek Watershed

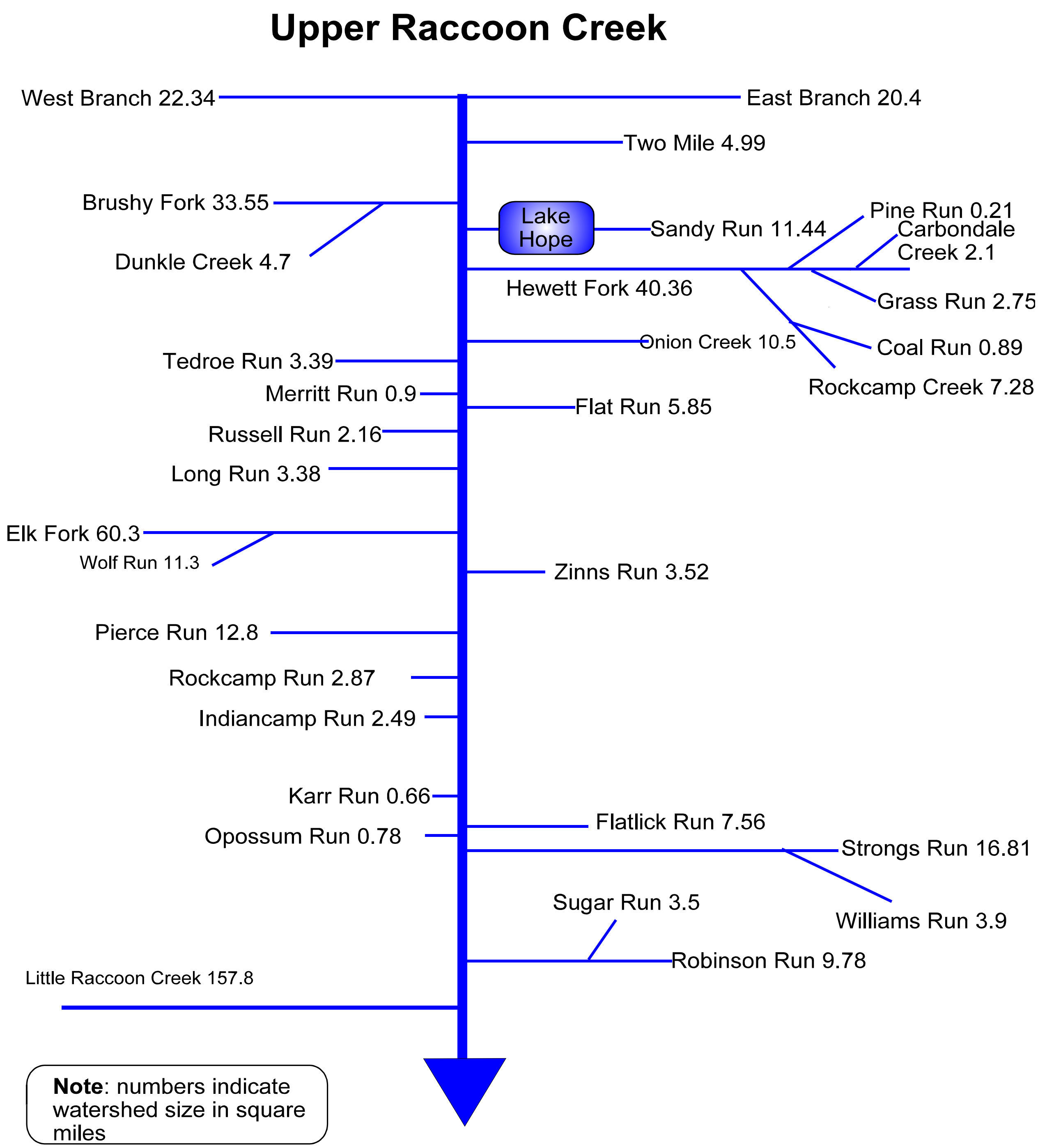


Table 8 - Range of Values for Sites that meet the Warmwater Habitat Use Designation

	pH	*Net Alk (mg/l)*	*Fe (ug/l)*	*Mn (ug/l)*	*Al (ug/l)*	*TDS (ug/l)*
Mainstem only						
Min	6.07	41	220	465	100	150
25th percentile	6.07	43	525	568	100	223
50th percentile	6.35	45	596	653	100	252
75th percentile	6.69	46	818	1120	322	349
99th percentile	6.90	46	5652	4574	3448	512
no. values	*4*	*3*	*29*	*29*	*29*	*26*
Tribs. only						
Min	6.62	-113	197	50	100	132
25th percentile	6.63	62	638	603	100	231
50th percentile	6.69	79	884	860	205	378
75th percentile	6.70	107	1440	1430	337	491
99th percentile	6.70	264	15964	7092	6900	1147
no. values	*5*	*70*	*81*	*81*	*81*	*70*
All 137 sites						
Min	6.07	-113	197	50	100	132
25th percentile	6.62	60	557	581	100	228
50th percentile	6.63	77	821	828	120	343
75th percentile	6.70	105	1320	1370	335	465
99th percentile	6.89	264	14861	6910	5356	1074
percent rank of targets	**(6.5) .22**	**(20) .04**	**(1000) .65**	**(2000) .87**	**(750) .90**	**(1500) all <**
no. values	*9*	*73*	*110*	*110*	*110*	*96*

Note: Sample dates range from 1975 - 2000, mainstem river miles from 72.22 - 29.20. Data is from all available data, it includes only 5 sites from RCP data and 130 from OEPA. The nonRCP sites were unusable in the other data analyses because there are no net alkalinity values. Target values are in ( ).

4.4 TMDL Calculations

Load based reductions for net alkalinity, were estimated by calculating the site cumulative load and reducing it to the site cumulative concentration, then comparing the existing instream net alkalinity concentration to the net alkalinity target of 20 mg/l. Metals are assumed to meet their respective targets when the net alkalinity target is met (Appendix C, Table C1 and Figure C3).

For modeling purposes, the study area was divided into the same 7 segments as the AMDAT plan, they are: West Branch Raccoon Cr. (WB), East Branch Raccoon Cr. (EB), Middle Section Brushy Fork (Brushy Cr. in AMDAT) (MSBC), Brushy Fork (Brushy Cr. in AMDAT) (BC), Middle Section Lake Hope (MSLH), Hewett Fork (HF) and Middle Section Bolins Mills (MSBM). Two

segment in the TMDL study area, Below Bolins Mills and Elk Fork, were not covered in the AMDAT plan and were not modeled (Figure 4).

The model results under existing conditions were compared to the post AMDAT remediation conditions to determine what effect the remediation might have on the study area. The model shows that before remediation the target of 20 mg/l net alkalinity is met in only a few sites. They are: (1) upper headwaters of East Branch, (2) upper headwaters of West Branch and (3) upper the headwaters of Brushy Fork (Brushy Cr. in AMDAT) (Table C2 in Appendix C). For such a large area there are very few sites that achieve the target net alkalinity. The AMDAT remediation efforts are designed to discharge a concentration of zero. When the model concentrations are changed to match the AMDAT remediation plans at the proposed remediation sites the model results are dramatically improved. After remediation, there are sites that meet the target in every segment and where the target is not achieved there is significant improvement. The East Branch does not achieve the target even after remediation, however it changes at the mouth from having a net alkalinity of -59.0 before remediation to -20.3 after remediation. This is a substantial improvement, especially when you consider that before 23 sites had negative net alkalinity concentrations bottoming out at -158, and after the remediation the number of negative net alkalinity sites dropped to 12 bottoming out at -43. Based on the modeling, these kinds of improvements occurred throughout the basin after remediation.

Due to the prevalence of AMD and the overwhelming difficultly of improving every site, the segment ends were the intended target sites of the net alkalinity target of 20 mg/l. The results for the segment ends from the post remediation modeling shows that the two branches, though improved, fall short of the target with the East Br. at -20.3 mg/l and the West Br. at -8.5 mg/l. The mainstem segments exceed the target with the exception of the last site in the last segment, which falls just slightly short of the target with a net alkalinity of 16.3.

The modeling demonstrates that the proposed AMDAT remediation plans, do in fact make great strides in reducing acidity. The AMDAT remediation plan prioritizes sites based on loading, access, and downstream effect. Implementation of the AMDAT remediation plan will cause the segment ends, in most cases, to meet the net alkalinity target and thus meet the pH and metals targets.

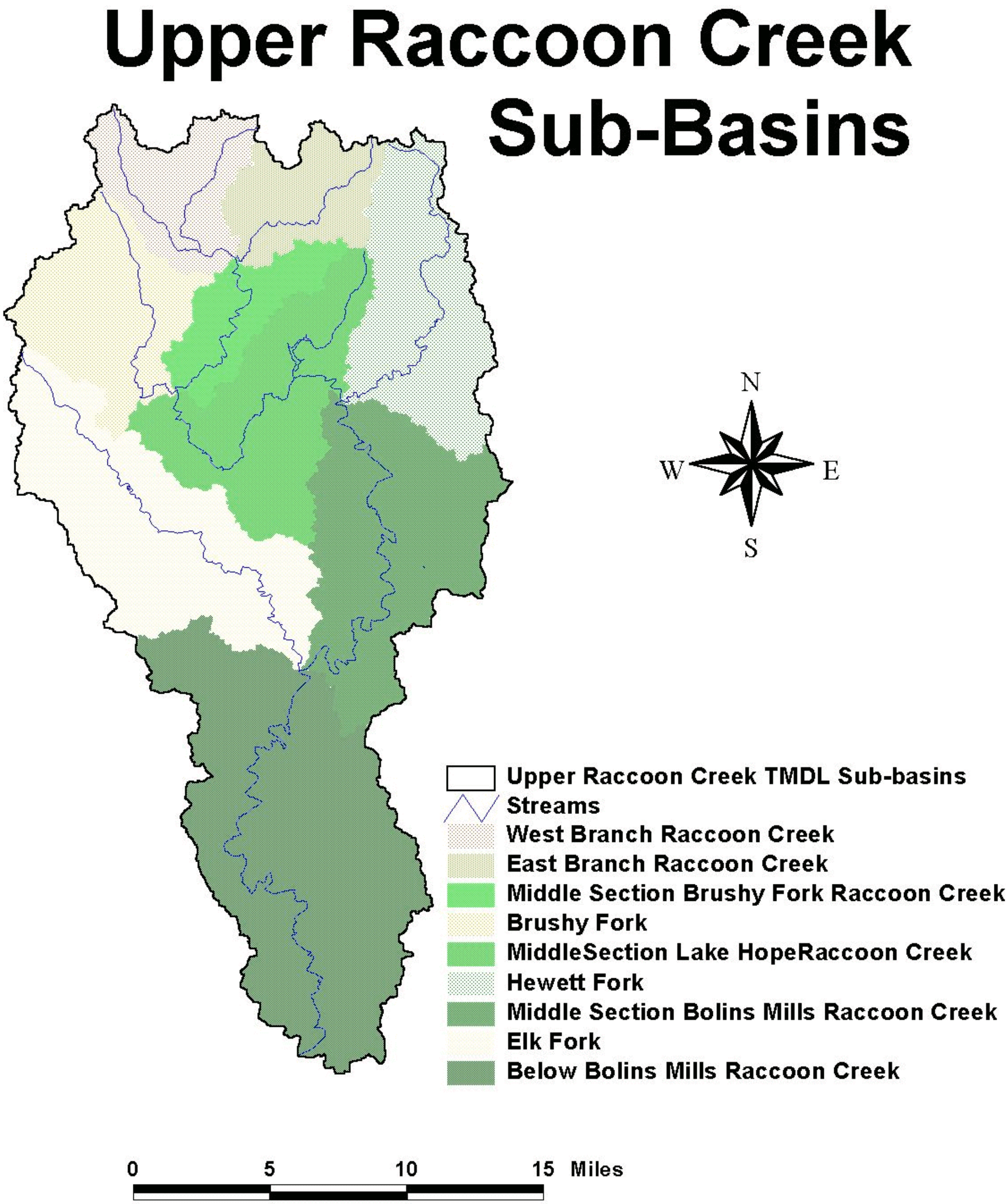


Figure 4 - Upper Raccoon Creek Sub-Basins

5.0 PUBLIC PARTICIPATION

5.1 Statewide

Ohio EPA convened an external advisory group (EAG) in 1998 to assist the Agency with the development of the TMDL program in Ohio. The EAG met multiple times over eighteen months and in July, 2000, issued a report to the Director of the Ohio EPA on their findings and recommendations.

5.2 Upper Raccoon Creek Watershed

In order to understand the extent of public involvement in the TMDL process a history of public concern with Raccoon Creek is in order. In the mid 1980's The Raccoon Creek Improvement Committee (RCIC), a 501(c)(3) non profit organization, was formed by residents of the watershed with the intention of improving Raccoon Creek. The RCIC approached Soil and Water Conservation Districts (SWCD) and the Soil Conservation Service, now the Natural Resources Conservation Service to enlist their help. Based on those discussions the Vinton SWCD applied for and received a FFY 1996, 319 implementation grant from Ohio EPA. Since that time Ohio EPA has supported a full time project coordinator in the Raccoon Creek Watershed. In addition to implementing installation of best management practices and reclamation projects the coordinators have managed a public outreach and education campaign. The Vinton SWCD has since received a FFY1999, 319 grant for reclamation work in the Raccoon Creek headwaters.

Ohio EPA has worked closely with Ohio University, Institute for Local Government Administration and Rural Development (ILGARD) at Ohio University throughout the TMDL process. ILGARD, funded through a 319 grant, is in the midst of producing a watershed management plan which relies heavily on public involvement in the development of public concerns, goal setting and solutions.

ILGARD hosted six public meetings throughout the watershed in 2000 and 2001. The meetings featured displays about the watershed, a presentation about some particular aspect of the watershed, a survey of concerns, ranking of those concerns and a discussion period. Throughout these meetings, reducing acid mine drainage was a top concern.

Eight focus groups were formed around the eight environmental issues that ranked highest in the public surveys. These focus groups were made up of professionals and residents to develop goals, objectives and measurable indicators of success. Acid mine drainage was one of the eight top issues.

The Raccoon Creek Forum is a monthly meeting of resource professionals and citizens to discuss ongoing projects or potential future projects for the improvement of Raccoon Creek. Ohio EPA's TMDL team is regularly represented at the Forum meetings.

The draft TMDL report was available for public comment from October 21 to November, 20, 2002. No comments were received.

6.0 IMPLEMENTATION AND MONITORING RECOMMENDATIONS

Restoration methods to bring an impaired waterbody into attainment with water quality standards generally involve an increase in the waterbody's capacity to assimilate pollutants, a reduction of pollutant loads to the waterbody,or some combination of both. As described in section 2.0, the primary causes of impairment in the Upper Raccoon Creek are pH ,and metals. An effective restoration strategy must quantify the relationship between reclamation of coal mines and their wastes and water quality improvements. This has been done for pH and metals in the AMDAT plan. It is recommended that the implementation plan in the AMDAT be followed.

6.1 Reasonable Assurances

Reclamation of abandoned mine land has proven to be effective in reducing AMD. The reduction of AMD into Raccoon Creek will improve the aquatic resource quality. Many agencies, individuals, non-profit organizations and corporations are working together to improve Raccoon Creek including the Upper Raccoon Creek TMDL area. The following groups bring great resources together to improve the aquatic resource quality:

- Ohio EPA
- Ohio Department of Natural Resources
  - Division of Mineral Resource Management
  - Division of Soil and Water Conservation
  - Division of Forestry
  - Division of Wildlife
- U.S. Department of Interior, Office of Surface Mining
- Natural Resource Conservation Service
- Ohio Valley Resource and Conservation Development Council
- Rural Action
- Raccoon Creek Improvement Committee
- Ohio University
  - Institute for Local Government Administration and Rural Development,
  - Department of Geology
  - Department of Biology
- Vinton Soil and Water Conservation District
- Jackson Soil and Water Conservation District
- Ohio State University Extension

These groups interact informally through the Raccoon Creek Forum, which meets monthly to discuss water quality issues in the Raccoon Creek Watershed. The majority of the issues are centered around reclamation of abandoned mine lands to reduce acid mine drainage but also include tree plantings, forestery best management practice, and water quality education and outreach activities for students and adults.

6.1.1 Draft Implementation Plan

The AMDAT plan discusses implementation. Treatment methods and cost estimates are described in pages 76-83 of that report.

6.1.2 Expected Effectiveness of Example Restoration Scenario

An example restoration scenario and an estimate of its potential to reduce the acidity load by increasing the net alkalinity concentration is included in Appendix F. The existing concentrations for selected sites from the AMDAT were replaced with remediation outputs designed to yield zero net alkalinity. The result is greatly increased net alkalinity concentrations throughout the basin. For a look at the net alkalinity concentration increase at the ends of each model segment see Figure C4 in Appendix C. USGS, 2001

6.2 Process for Monitoring and Revision

The adaptive management approach is recommended for the restoration of Upper Raccoon Creek. Adaptive management suggests that a hypothetical restoration plan be developed and implemented, and then the stream reassessed. If at that time the stream is not meeting use designations another restoration plan will be developed incorporating most recent data.

The causes of impairment in Upper Raccoon Creek include pH, metals, organic enrichment, siltation, and habitat alterations. However pH is the most pervasive and devastating cause of impairment. If all the other listed causes of impairment were corrected pH would still prohibit the stream from meeting biological use designations. Conversely if pH is corrected the other causes may be found to be insignificant and the stream may meet use designations. To direct resources and money at all the problems at once would not be fiscally responsible or even feasible. By working towards neutralizing the primary impairment it may be possible to meet use designations in the most efficient way possible.

The AMDAT plan discusses long term as well as pre and post monitoring of the aquatic resource on page 84. This schedule should be followed with the utilization of adaptive management.

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