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Biological and Water Quality Study of the Muskingum River Tributaries

(Zanesville to Rokeby Lock)

Ted Strickland, Governor
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Biological and Water Quality Survey of the Muskingum River Tributaries (Zanesville to Rokeby Lock)

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TABLE OF CONTENTS

SUMMARY 4
RECOMMENDATIONS 8
INTRODUCTION 10
RESULTS 11
- Water Chemistry 11
- Recreational Use 14
- Effluent Dischargers 16
- Stream Physical Habitat 18
- Fish Community 19
- Macroinvertebrate Community 21

WATERSHED ASSESSMENT UNITS 23
ACKNOWLEDGEMENTS 24
REFERENCES 25

APPENDICES A1

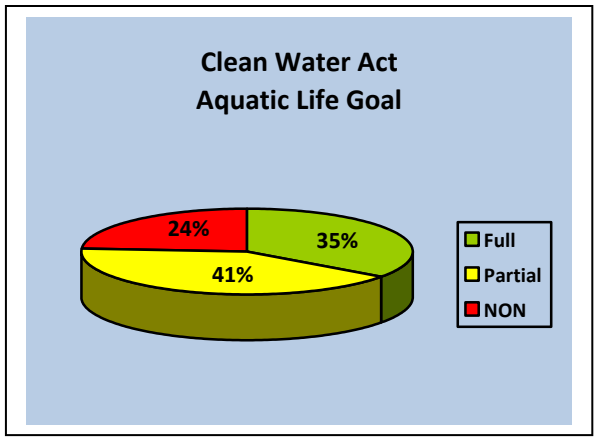
LIST OF FIGURES

Figure	Title	Page
Figure 1	Muskingum River Tributaries sampling locations and biological performance.	6
Figure 2	Muskingum River Tributaries study area.	10
Figure 3	Flow conditions in Salt Creek during 2008.	11
Figure 4	Muskingum River Tributaries pH values collected during 2008.	11
Figure 5	Brush Creek at State Route 555.	18

LIST OF TABLES

Table	Title	Page
Table 1	Muskingum River Tributaries sampling locations from the 2008 survey.	5
Table 2	Aquatic life use attainment status for locations in the Muskingum River Tributaries, 2008.	7
Table 3	Waterbody use designation recommendations for the Muskingum River Tributaries.	9
Table 4	Exceedances of Ohio Water Quality Standards criteria (OAC3745-1) for chemical/physical parameters measured in the Muskingum River Tributaries, 2008.	12
Table 5	Summary statistics for select mining water quality parameters sampled in the Muskingum River Tributaries study area, 2008.	13
Table 6	Summary statistics for select nutrient water quality parameters sampled in the Muskingum River Tributaries study area, 2008.	13
Table 7	A summary of E. coli data for the 13 locations sampled in the Muskingum River Tributaries, June 30th – August 28th, 2008 under the new rule.	15
Table 8	Concentrations of monitored chemicals in effluent discharged from 3 facilities within the Muskingum River Tributaries study area.	17
Table 9	Stream habitat (QHEI) results for the Muskingum River Tributaries study area, 2008.	18
Table 10	Fish community summaries based on pulsed D.C. electrofishing sampling conducted by the Ohio EPA in the Muskingum River Tributaries from June– August, 2008.	20
Table 11	Summary of macroinvertebrate data collected from natural substrates in the Muskingum River Tributaries study area, June – August, 2008.	22
Table 12	Results for the Muskingum River Tributaries watersheds using the HUC12 methodology	23

SUMMARY



Rivers and streams in Ohio support a variety of uses such as recreation, water supply, as well as supporting aquatic life. Ohio EPA evaluates each stream to determine the appropriate use designation and to also determine if the use is meeting the goals of the federal Clean Water Act. Fifteen streams in the Muskingum River Tributaries study area, all confluent with the Muskingum River in the river reach between Zanesville and Rokeby Lock in northern Morgan County, were evaluated for aquatic life and recreational use potential in 2008 (see Figure 1 and Table 1 for sampling locations).

Of the 17 biological samples collected from the 2008 Muskingum River Tributaries study area, only six (35%) were fully meeting the designated or recommended aquatic life use, seven (41%) were in partial attainment, and four (24%) were in non-attainment. The four non-attainment sites were affected by acid mine drainage (AMD) in the Brush Creek subwatershed. Numerous metals, low pH, high conductivity and high acidity caused toxicity to the aquatic life. Excluding the AMD affected Brush Creek subwatershed, the macroinvertebrates met the Clean Water Act goal at all of the sites. Partial attainment was found at seven sites mostly due to the following natural or historic mining influences to fish communities:

- *Back Run* - very small drainage/ Primary Headwater Habitat conditions
- *Duncan Run* - unstable substrates/stream flashiness
- *Big Bottom Run* - limited pool habitat and interstitial flows – Muskingum River floodplain area
- *Brush Creek and Goose Run* - historical mining influences
- *Island Run and South Branch Island Run* - past historical land use changes and waterfall barrier

Streams in the Brush Creek subwatershed were assigned the Limited Warmwater Habitat (LWH) aquatic life use designation based on a cursory evaluation in 1978. The recommended use designation for Brush Creek, Turkey Run, Goose Run and Baughman Run are Warmwater Habitat (WWH) based on the potential for recovery due to good quality habitat. The Coldwater Habitat (CWH) use designation is recommended for Sycamore Hollow Run (currently undesignated), Little Duncan Run and Little Bluerock Creek. The Exceptional Warmwater Habitat/Coldwater Habitat (EWH/CWH) use designation is recommended for Bluerock Creek. Flat Run (currently undesignated), Island Run, S. Br. Island Run, Dry Riffle Run and Duncan Run will remain or are recommended WWH.

The recreational use goal of the Clean Water Act was met at 61.5% (eight) of the sites in the Muskingum River Tributaries basin and was in non-attainment at 38.5% (five) of the sites. The locations not attaining the recreational use were most likely due to unsanitary conditions from household sewage treatment systems (HSTS) and/or agricultural activities such as pasture land runoff and manure land application.

Table 1. Muskingum River Tributary watershed sampling locations from the 2008 survey.

Site Number*	**RIVER**/Location	River Mile	Drainage Area	Latitude	Longitude
1	**Island Run** Helmic Bridge	3.4	10.8	39.72009	-81.94219
2	**S. Br. Island Run** adj. TR 193 - Brown Road	0.1	4.9	39.71946	-81.94995
3	**Big Bottom Run** near mouth	0.2	4.2	39.75218	-81.91874
4	**Blue Rock Creek** off River Rd	0.8	9.5	39.79253	-81.91593
5	**Little Bluerock Creek** Tyman Hill Rd	0.1	2.7	39.78980	-81.92620
6	**Back Run** Adj Back Run Rd.	0.7	3.7	39.80772	-81.90285
7	**Dry Riffle Run** SR 60	0.2	4.2	39.80393	-81.89146
8	**Duncan Run** River Rd.south of Philo	0.3	7.3	39.85333	-81.90615
9	**Little Duncan Run** Duncan Run Rd.	0.1	2.8	39.85049	-81.91693
10	**Brush Cr.** Dst. Goose Run adj. Goose Run Rd	7.3	6.2	39.86728	-81.98658
11	**Brush Creek** Dst. Turkey Run on SR 555	4.8	15.9	39.83439	-81.98730
12	**Brush Creek** Adj. SR 555	1.2	24.0	39.86860	-81.98617
13	**Baughman Run** at mouth	0.1	2.2	39.83720	-81.99100
14	**Turkey Run** SR 555	0.1	2.1	39.83070	-81.98730
15	**Goose Run** Elmville Rd	0.1	2.0	39.80490	-81.99380
16	**Sycamore Hollow Run** River Rd.	0.2	1.5	39.86967	-81.92167
17	**Flat Run Rd.** Adj Chatau Estates MHP	0.3	5.0	39.90404	-81.99771

***The color of the site number corresponds to the narrative biological score (blue is exceptional to very good (meets EWH goals), green is good to marginally good (meets WWH goals), yellow is fair, orange is poor, and red is very poor (fair, poor, and very poor do not meet the goals of WWH).**

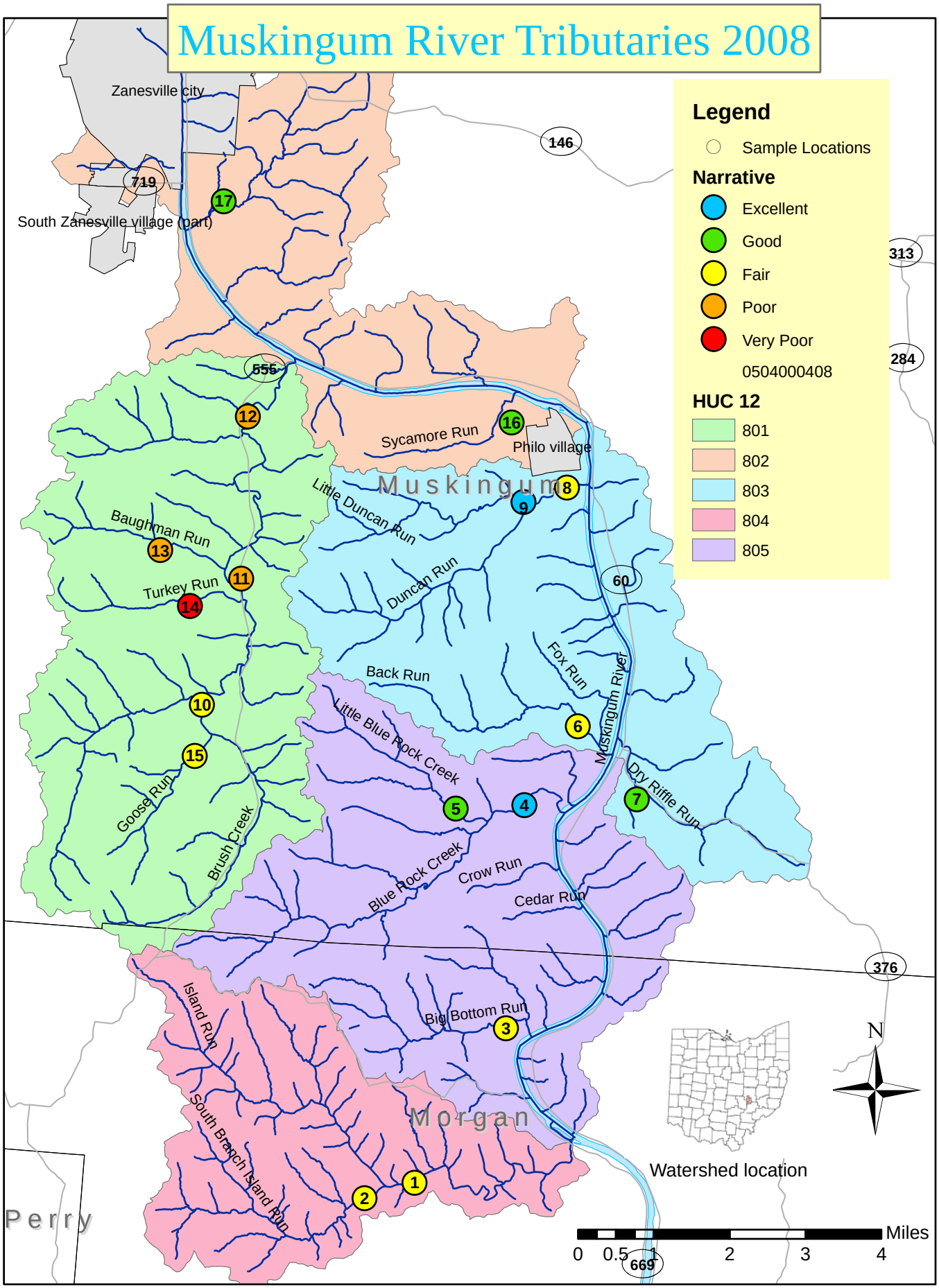


Figure 1. Muskingum River Tributaries sampling locations and biological community performance. Site numbers corespond to Table 1.

Table 2. Aquatic life use attainment status for sampling locations in the Muskingum River Tributaries study area, 2008. The Index of Biotic Integrity (IBI), Modified Index of Well-being (MIwb), and Invertebrate Community Index (ICI) scores are based on the performance of the biological community. Stream habitat reflects the ability to support a biological community. The Muskingum River tributaries study area is located in the Western Alleghany Plateau (WAP) ecoregion. If biological impairment has occurred, the cause(s) and source(s) of the impairment are noted. NA = not applicable. For the Aquatic Life Use Designation, R denotes a recommendation that differs from the current use designation.

Stream	Sample Location River Mile	Sampling Type	Ecoregion	Aquatic Life Use Designation	Aquatic Life Attainment Status	IBI	MIwb	ICI[a]	Stream Habitat[b]	Aquatic Life Use Impairment Cause/Source[b]
Island Run	3.4	Headwater	WAP	WWH	PARTIAL	30*	NA	G	72.0	Agriculture, Natural/Past historical land use, Waterfall Barrier
South Branch Island Run	0.1	Headwater	WAP	WWH	PARTIAL	36*	NA	VG	69.0	Agriculture, Natural/Past historical land use, Waterfall Barrier
Big Bottom Run	0.2	Headwater	WAP	CWH-R	PARTIAL	28*	NA	G	59.5	Natural / Natural sources (interstitial flow)
Bluerock Creek	0.8	Headwater	WAP	EWH/CWH-R	FULL	48[ns]	NA	E	72.5	
Little Bluerock Creek	0.1	Headwater	WAP	CWH-R	FULL	50	NA	G	69.0	
Back Run	0.7	Headwater	WAP	WWH	PARTIAL	34*	NA	G	69.5	Natural (small drainage)/ Natural
Dry Riffle Run	0.2	Headwater	WAP	WWH	FULL	40[ns]	NA	MG[ns]	73.0	
Duncan Run	0.3	Headwater	WAP	WWH	PARTIAL	36*	NA	G	65.0	Flow & Habitat Alteration/ Unknown
Little Duncan Run	0.1	Headwater	WAP	CWH-R	FULL	48	NA	VG	59.0	
Brush Creek	7.3	Headwater	WAP	WWH-R	PARTIAL	28*	NA	G	73.5	Metals, Conductivity, TDS / AMD
Brush Creek	4.8	Headwater	WAP	WWH-R	NON	22*	NA	F*	75.0	Metals, pH,TDS / AMD
Brush Creek	1.2	Wading	WAP	WWH-R	NON	28*	3.9*	MG[ns]	52.5	Metals, Sediment, Conductivity, TDS / AMD
Baughman Run	0.1	Headwater	WAP	WWH-R	NON	20*	NA	F*	73.0	Sediment, TDS/ Reclaimed mine lands
Turkey Run	0.1	Headwater	WAP	WWH-R	NON	18*	NA	P*	56.5	Metals, conductance, TDS,pH/ Abandoned coal mines
Goose Run	0.1	Headwater	WAP	WWH-R	PARTIAL	36*	NA	G	68.0	Fish passage barrier/ Historic mining downstream limits fish migration to headwaters
Sycamore Hollow Run	0.2	Headwater	WAP	CWH-R	FULL	32	NA	VG	53.5	
Flat Run	0.3	Headwater	WAP	WWH-R	FULL	52	NA	G	61.0	

BIOCRITERIA – WAP ECOREGION		
INDEX - Site Type	WWH	EWH
IBI: Headwater/Wading	44	50
MIwb: Wading	8.4	9.4
ICI	36	46

[ns] Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).
* Significant departure from biocriterion (>4 IBI or ICI units; >0.5 MIwb units). Poor and very poor results are underlined.
[a] Narrative evaluation used in lieu of ICI (E=Exceptional; VG=Very Good; G=Good; MG=Marginally Good; F=Fair; P=Poor; VP=Very Poor).
[b] Narrative habitat evaluations are based on QHEI scores as follows: Excellent =70-100, Good = 55-69, Fair = 43-54, Poor = 30-42 and Very Poor <30

RECOMMENDATIONS

The streams in the Muskingum River Tributaries study area currently listed in the Ohio Water Quality Standards are assigned one or more of the following aquatic life use designations: Warmwater Habitat (WWH) or Limited Warmwater Habitat (LWH) – acid mine drainage. Two of the streams in the study area (Flat Run and Sycamore Hollow Run) are not listed in the Ohio Water Quality Standards. All the other Muskingum River Tributaries streams were originally designated for aquatic life uses in the 1978 Ohio WQS. The techniques used then did not include standardized approaches to the collection of instream biological data or numerical biological criteria. This study used biological data to evaluate and establish aquatic life uses for a number of streams in the Muskingum River Tributaries study area.

Limited warmwater habitat streams were temporarily designated in the 1978 water quality standards as not meeting specific warmwater habitat criteria. Criteria for the support of the LWH use designation are the same as the criteria for the support of the use designation warmwater habitat. However, individual criteria are varied on a case-by-case basis and supersede the criteria for warmwater habitat where applicable. For streams assigned the LWH use in the Muskingum River Tributaries study area, the following WWH criteria are exempt: total dissolved solids, pH, iron and zinc. No additional stream segments will be designated limited warmwater habitats and those currently designated LWH are to be evaluated and assigned a new use since the LWH use designation is being phased out.

The Ohio Department of Natural Resources Mineral Resources Management (ODNR-MRM) is currently evaluating the Brush Creek subwatershed for the potential of conducting an Acid Mine Drainage Abatement and Treatment (AMDAT) Plan. Because the Brush Creek subwatershed has the habitat to support a WWH community, it is recommended that this plan be completed and implemented. Once reclamation projects have been completed in this watershed, a future study should be conducted to determine if biological recovery has occurred.

Fifteen streams in the Muskingum River Tributaries study area were evaluated for aquatic life and recreational use potential in 2008 (Table 3). Significant findings include the following:

- Brush Creek and Goose Run are currently listed as LWH streams. Biological monitoring during this study confirmed that these streams should be designated WWH.

- Turkey Run and Baughman Run are currently listed as LWH streams. These streams are tributary to Brush Creek. Habitat conditions in both streams are adequate for supporting warmwater biological communities. With proper AMD controls, both streams would achieve the WWH use.

- Five streams with an existing WWH use designation should be maintained. These streams include Duncan Run, Back Run, Island Run, South Branch Island Run, and Dry Riffle Run.

- Two streams evaluated in this study are not currently listed in the Ohio WQS. These streams include Flat Run and Sycamore Hollow Run. Their recommended use designations are noted in Table 14.

- The Coldwater Habitat (CWH) aquatic life use designation is recommended for Sycamore Hollow Run, Little Duncan Run, Little Bluerock Creek, and Big Bottom Run based on abundant populations of coldwater fish species and/or coldwater macroinvertebrate taxa.

- Bluerock Creek has a dual aquatic life use designation recommendation of CWH and Exceptional Warmwater Habitat (EWH). Biological monitoring results support this higher level of protection.

All 15 streams in this study should retain the Primary Contact Recreation use, along with the Agricultural Water Supply and Industrial Water Supply uses.

Table 3. *Waterbody use designation recommendations for the Muskingum River Tributaries.* *Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). A plus sign (+) indicates a new recommendation or confirmation of an existing use based on the findings of this report.*

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Island Run		+							+	+		+		
South Branch Island Run		+							+	+		+		
Big Bottom Run						+			+	+		+		
Cedar Run		*							*	*		*		
Crow Run		*							*	*		*		
Bluerock Creek			+			+			+	+		+		
Little Bluerock Creek						+			+	+		+		
Back Run		+							+	+		+		
Fox Run		*							*	*		*		
Dry Riffle Run		+							+	+		+		
Duncan Run		+							+	+		+		
Little Duncan Run						+			+	+		+		
Salt Creek and tributaries														
Sycamore Hollow Run						+			+	+		+		
Brush Creek		+							+	+		+		
Baughman Run		+							+	+		+		
Turkey Run		+							+	+		+		
Goose Run		+							+	+		+		
Flat Run		+							+	+		+		

INTRODUCTION

Fifteen tributaries to the Muskingum River between Zanesville and Rokeby Lock were sampled in Muskingum and Morgan Counties. These tributaries include Flat Run, Duncan Run, Little Duncan Run, Sycamore Hollow Run, Bluerock Creek, Little Bluerock Creek, Island Run, South Branch Island Run, Big Bottom Run, Back Run, Dry Riffle Run, Brush Creek, Goose Run, Turkey Run and Baughman Run (Figure 2). Three facilities along Flat Run have municipal or industrial National Pollutant Discharge Elimination System (NPDES) permits. None of the other tributaries have NPDES permitted point source discharges.

Figure 2. Muskingum River Tribs. Study Area

During 2008, Ohio EPA conducted a water resource assessment of fifteen tributaries to the Muskingum River using standard Ohio EPA protocols as described in Appendix Table 7. Included in this study were assessments of the biological, surface water and recreational (bacterial) condition. A total of 17 biological, 13 water chemistry, and 13 bacterial stations were sampled in the selected tributaries to the Muskingum River. All of the biological, chemical and bacteria results can be downloaded from the Ohio EPA GIS interactive maps at the following link: http://www.epa.state.oh.us/dsw/gis/index.aspx.

Specific objectives of the evaluation were to:

- establish the present biological conditions in the selected Muskingum River Tributaries by evaluating fish and macroinvertebrate communities,
- assess physical habitat influences on stream biotic integrity,
- determine recreational water quality, and
- determine the attainment status and recommend changes if appropriate.

The majority of the streams listed in the Ohio Water Quality Standards for the study area are assigned the Warmwater Habitat (WWH) aquatic life use designation with the exception of the Brush Creek subwatershed. These streams were originally designated for aquatic life uses in the 1978 Ohio WQS. The techniques used then did not include standardized approaches to the collection of instream biological data or numerical biological criteria. This study used biological data to evaluate and establish aquatic life uses for a number of streams in the study area.

The selected Muskingum River Tributaries are located in the Western Allegheny Plateau (WAP) ecoregion. Streams in the Brush Creek subwatershed (including Brush Creek, Goose Run, Turkey Run and Baughman Run) are currently assigned the Limited Warmwater Habitat (LWH) aquatic life use designation due to acid mine drainage in the Ohio Water Quality Standards (WQS) based on a desktop review, as well as Primary Contact Recreation (PCR), Agricultural Water Supply (AWS) and Industrial Water Supply (IWS). Island Run, South Branch Island Run, Big Bottom Run, Bluerock Creek, Little Bluerock Creek, Back Run, Dry Riffle Run, Duncan Run and Little Duncan Run are currently assigned the Warm Warmwater Habitat (WWH) aquatic life use designation in the Ohio WQS based on a desktop review, as well as PCR, AWS and IWS. Sycamore Hollow Run and Flat Run are currently undesignated in the Ohio WQS.

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 may eventually be incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, Total Maximum Daily Loads (TMDLs) and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] report).

RESULTS

Water Chemistry

Surface water chemistry samples were collected three to five times from the Muskingum River Tributaries at 13 locations (Figure 1, Table 1) between June 24 and September 24, 2008. Stations were established in free-flowing sections of the stream and were primarily collected from bridge crossings. Surface water samples were collected directly into appropriate containers, preserved and delivered to Ohio EPA's Environmental Services laboratory. Collected water was preserved using appropriate methods, as outlined in Part II and III of the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA 2006d). Interactive maps of surface water chemical data, downloadable to excel files, are available at the following link: http://www.epa.state.oh.us/dsw/gis/index.aspx.

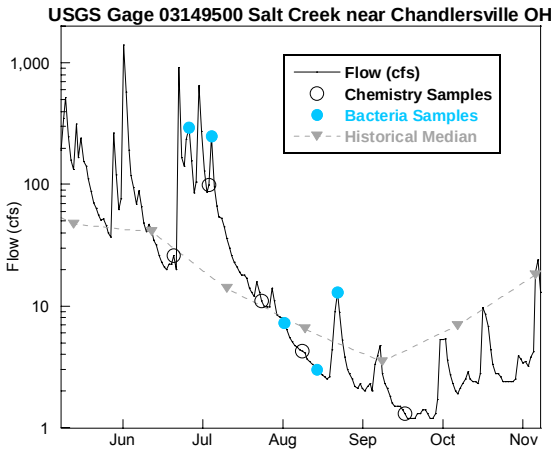


Figure 3. Flow conditions in Salt Creek near Chandlersville during the 2008 Ohio EPA survey.

The Muskingum River Tributaries study area streams do not have United States Geological Survey (USGS) gage stations, therefore the USGS gage data from Salt Creek (Muskingum River) near Chandlersville was used to show flow trends in the Muskingum Tributary streams in 2008 (Figure 3.) Dates when water samples and bacteria samples were collected in the study area are noted on the graph. Flow conditions during the summer field season started out above the historic median and ended below the historic median at the end of the field season. Both water and bacteria samples captured a variety of flow conditions in the study area during the field season.

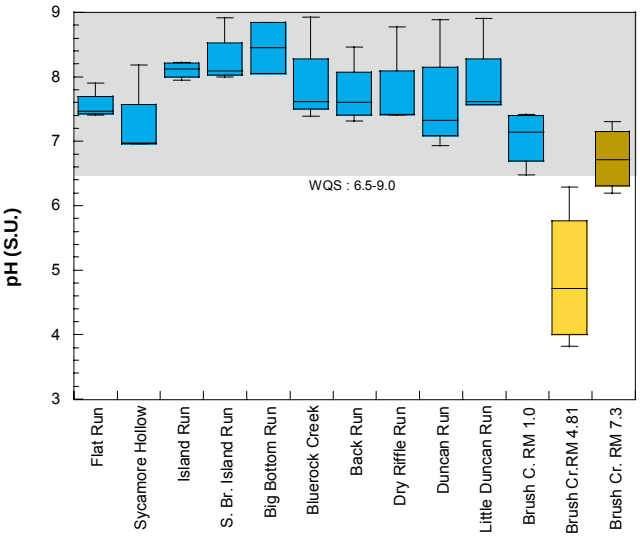


Figure 4. Muskingum River Tributaries pH values measured during the 2008 field season.

Surface water samples were analyzed for metals, nutrients, bacteria, pH, temperature, conductivity, dissolved oxygen, percent saturation, and suspended and dissolved solids (Appendix Tables 1 - 2). Parameters which were in exceedance of the Ohio WQS criteria are reported in Table 4. Bacteriological samples were collected from all 13 locations, and the results are reported in the Recreational Use section.

Water Quality
Brush Creek water quality is affected by AMD. Aside from Turkey Run and Baughman Run, which were not tested, all other streams had good water quality.

Metals were measured at 13 locations with 17 parameters tested (Appendix Table 1). Areas within the Brush Creek watershed were mined for coal before reclamation laws were instituted. Coal mining prior to 1977 did not have to return the ground to its original grade, but instead left large piles of coal waste (gob), highwalls, mine pits of toxic water and underground mine discharges to surface waters. These remaining mining wastes and discharges can contribute large amounts of acid mine drainage (AMD) which is comprised of high acidity, iron, aluminum, manganese, nickel, zinc, total dissolved solids, and low pHs. None of the metals measured during this study exceeded Ohio WQS criteria in any of the streams tested (Table 4). However, AMD chemical effects were observed in Brush Creek at RM 4.81, where

low pH values were recorded (Figure 4), and mine drainage parameters were substantially elevated above reference conditions (Table 5). The highest concentrations of aluminum, manganese, conductivity, sodium, sulfate and acidity occurred in Brush Creek at RM 4.81. The Brush Creek sampling station at RM 4.81 was located immediately downstream from the confluence with Turkey Run. Although Turkey Run water samples were not chemically tested, field observations noted the presence of iron floc throughout the stream.

Surface water monitoring results for all streams within the study area, excluding Brush Creek, revealed good chemical water quality. Exceedances of Ohio WQS criteria were not recorded in these streams, and nutrient levels were within reference conditions (Table 6).

Table 4. Exceedances of Ohio Water Quality Standards criteria (OAC3745-1) for chemical/physical parameters measured in the Muskingum River Tributaries study area, 2008. Bacteria exceedances are presented in the Recreational Use Section.

Stream/RM	**Location**	**Parameter (value – ug/l unless noted)**
Flat Run		
0.3	SR 60 @ Trailer Park	None
Sycamore Hollow Run		
0.23	River Road	None
Island Run		
3.4	Helmic Bridge	None
South Branch Island Run		
0.1	Adjacent TR 193 – Brown Road	None
Big Bottom Run		
0.2	TR 313, near mouth	None
Bluerock Creek		
0.8	Blue Rock Road	None
Back Run		
0.6	Adjacent Back Run Road	None
Dry Riffle Run		
0.2	SR 60 near Gaysport	None
Duncan Run		
0.29	River Road south of Philo	None
Little Duncan Run		
0.06	Duncan Run Road	None
Brush Creek		
7.3	Dst. Goose Run, adj. Goose Cr. Rd.	pH (SU) (6.43, 6.2)[a]
4.81	Dst. Turkey Run confluence	pH (SU) (6.29, 5.24, 4.19, 3.82)[a]
1.0	Adj. SR 555, upstream Brush Cr. Cemetary	None

[a] Exceedance of the aquatic life Outside Mixing Zone Average water quality criterion .

Table 5. Summary statistics for select AMD inorganic water quality parameters sampled in the Muskingum River Tributaries study area, 2008. The 90th percentile value from reference sites from the Western Allegheny Plateau ecoregion is shown for comparison. Values above reference conditions or developed values are shaded.

		Iron	Manganese	Conductivity	Sodium	Sulfate	Acidity[1]	Alkalinity[2]	Aluminum[3]
Units		µg/l	µg/l	umhos/cm	mg/l	mg/l	mg/l	mg/l	µg/l
Stream	River Mile	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Flat Run	0.3	292	228	548	21.4	197	<5	43.5	121
Sycamore Hollow Run	0.23	428	1465	302	7.4	87.7	<5	50.1	206
Island Run	3.4	425	25	326	12	30.3	<5	115	239
South Branch Island Run	0.1	140	22	322	11	27	<5	114	100
Big Bottom Run	0.2	262	16	353	10	33.5	<5	144	188
Bluerock Creek	0.8	136	11	308	12	31.2	<5	123	100
Back Run	0.6	43	11	289	8.4	29.6	<5	98	100
Dry Riffle Run	0.2	55	12	592	24	65.6	<5	198	100
Duncan Run	0.29	65	34	312	8.4	36.7	<5	109	100
Little Duncan Run	0.06	46	53	417	11.2	72.9	<5	120	100
Brush Creek	7.3	1058	482	601	33.3	209	<5	85	146
Brush Creek	4.81	1155	2928	855	43.4	425	25.6	6.5	1750
Brush Creek	1.0	227	1228	777	34.4	367	<5	14.2	333
Reference Values		2494	1230	750	21.5	622	-67	67	750

1– A net acidity of -67 mg/l was developed in the Sunday Creek TMDL (OEPA, 2005) to help determine the WWH use designation.
2 - Minimum of 67 mg/l of alkalinity was developed in the Sunday Creek TMDL (OEPA, 2005) to help determine the WWH use designation.
3 – U.S. EPA maximum criteria.

Table 6. Summary statistics for select nutrient water quality parameters sampled in the Muskingum River Tributaries study area, 2008. The 90th percentile value from reference sites from the Western Allegheny Plateau ecoregion is shown for comparison. Values above reference conditions are shaded yellow.

		Ammonia—N	Nitrate+Nitrite-N	Phosphorus-T
Stream	River Mile	Mean	Mean	Mean
Flat Run	0.3	0.044	0.44	0.008
Sycamore Hollow Run	0.23	0.064	0.12	0.007
Island Run	3.4	0.061	0.13	0.009
South Branch Island Run	0.1	0.025	0.06	0.015
Big Bottom Run	0.2	0.025	0.19	0.015
Bluerock Creek	0.8	0.025	0.06	0.012
Back Run	0.6	0.025	0.11	0.006
Dry Riffle Run	0.2	0.025	0.09	0.008
Duncan Run	0.29	0.025	0.14	0.007
Little Duncan Run	0.06	0.025	0.17	0.010
Brush Creek	7.3	0.031	0.09	0.008
Brush Creek	4.81	0.091	0.14	0.005
Brush Creek	1.0	0.030	0.14	0.006
Reference Value		0.06	0.606	0.09

Recreational Use

Water quality criteria for determining attainment of recreational uses are established in the Ohio Water Quality Standards (Table 7-13 in OAC 3745-1-07) based upon the presence or absence of bacteria indicators (*Escherichia coli*) in the water column.

Escherichia coli (*E. coli*) bacteria are microscopic organisms that are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour, 1977), but there is currently no simple way to differentiate between human and animal sources of coliform bacteria in surface waters, although methodologies for this type of analysis are becoming more feasible. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes, or may enter water bodies along with runoff from soils where these wastes have been deposited.

Pathogenic (disease causing) organisms are typically present in the environment in such small amounts that it is impractical to monitor every type of pathogen. Fecal indicator bacteria, including *E. coli*, by themselves are usually not pathogenic. However, some strains of *E. coli* can be pathogenic, capable of causing serious illness. Although not necessarily agents of disease, fecal indicator bacteria such as *E. coli* may indicate the potential presence of pathogenic organisms that enter the environment through the same pathways. When *E. coli* are present in high numbers in a water sample, it invariably means that the water has received fecal matter from one source or another. Swimming or other recreational-based contact with water having a high *E. coli* count may result in ear, nose, and throat infections, as well as stomach upsets, skin rashes, and diarrhea. Young children, the elderly, and those with depressed immune systems are most susceptible to infection.

Bacteria

Elevated bacteria counts were found throughout the watershed. Failing home sewage treatment systems and manure application on farm fields are the most likely sources of bacteria.

The Muskingum River Tributaries are designated as a Primary Contact Recreation (PCR) use in OAC Rule 3745-1-24. Water bodies with a designated recreational use of PCR "...are waters that, during the recreation season, are suitable for one or more full-body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking and SCUBA diving" [OAC 3745-1-07 (B)(4)(b)]. There are three classes of PCR use to reflect differences in the potential frequency and intensity of use. Streams designated PCR Class B support, or potentially support, occasional primary contact recreation activities. The Muskingum River Tributaries in this survey are all designated Class B PCR waters. The *E. coli* criteria that apply to PCR Class B streams include a geometric mean of <161 cfu/100 ml and maximum value ≤523cfu/100 ml. The geometric mean is based on two or more samples and issued as the basis for determining attainment status when more than one sample is collected (Table 7).

Summarized bacteria results are listed in Table 7, and the complete dataset is reported in Appendix Table 2. Downloadable bacteria results are also available from the Ohio EPA GIS interactive maps at the following link: http://www.epa.state.oh.us/dsw/gis/index.aspx. Thirteen locations in the Muskingum River Tributaries were tested for E. coli levels four to five times, from June 30th – August 28th, 2008. Evaluation of *E. coli* results revealed that 8 of the 13 locations attained the applicable geometric mean criterion while five locations did not attain the applicable geometric mean *E. coli* criteria, indicating an impairment of the recreation use at these locations. The locations not attaining the recreational use were most likely due to unsanitary conditions from failing home sewage treatment systems (HSTS) and/or agricultural activities such as pasture land runoff and manure land application.

Island Run and the S. Branch of Island Run were both not attaining the recreational use most likely due to runoff of manure from adjacent farm fields. Pasture land runoff and application of manure to harvested crop fields in late August 2008 were the most likely reason that bacteria levels were so elevated. Island Run had the highest geometric mean and maximum value of E. coli of all the locations sampled.

During low flows, Flat Run, Little Duncan Run and Brush Creek at RM 7.8 were not attaining the recreational use most likely due to unsanitary conditions from poorly treated sanitary waste or from agricultural activities. These streams all flow through residential areas with no centralized sanitary waste treatment. Flat Run is located south of Zanesville and has three NPDES facility discharges as well as

pasture land in the headwaters. Little Duncan Run flows on the south side of Philo, and the upstream Brush Creek site at RM 7.8 flows south of Cannelville.

Table 7. A summary of E. coli data for locations sampled in the Muskingum River Tributaries study area, June 30 – August 28, 2008. Recreation use attainment is based on comparing the geometric mean to the Primary Contact Recreation (PCR) Class B geometric mean water quality criterion of 161 cfu/100 ml (Ohio Administrative Code 3745-1-07). All values are expressed in colony forming units (cfu) per 100 ml of water. Gray shaded values exceed the PCR Class B geometric mean criterion.

Location	River Mile	Recreation Use	# of Samples	Geometric Mean	Maximum Value	Recreational Attainment Status	Source(s) of Bacteria
Flat Run	0.3	PCR Class B	5	550	1200	**NON**	HSTS, Agriculture
Sycamore Hollow Run	0.23	PCR Class B	5	92	450	FULL	
Island Run	3.4	PCR Class B	5	553	5200	**NON**	HSTS, Agriculture
South Br. Island Run	0.1	PCR Class B	5	166	3400	**NON**	HSTS, Agriculture
Big Bottom Run	0.2	PCR Class B	4	123	620	FULL	
Bluerock Creek	0.8	PCR Class B	5	78	580	FULL	
Back Run	0.6	PCR Class B	5	30	420	FULL	
Dry Riffle Run	0.2	PCR Class B	5	89	560	FULL	
Duncan Run	0.29	PCR Class B	5	123	720	FULL	
Little Duncan Run	0.06	PCR Class B	5	179	1700	**NON**	HSTS
Brush Creek	7.3	PCR Class B	5	320	890	**NON**	HSTS
Brush Creek	4.81	PCR Class B	5	106	2100	FULL	
Brush Creek	1.0	PCR Class B	4	98	1300	FULL	

Effluent Dischargers

A total of three National Pollutant Discharge Elimination System (NPDES) permitted facilities discharge either sanitary wastewater or industrial process water to Flat Run which is a direct tributary to the Muskingum River at RM 73.33. The two sanitary waste discharges include AAA Rentals of Zanesville and the Chateau Estates Mobile Home Park. The other permitted discharge is a combined sanitary and industrial process wastewater discharge from the Carl Rittenberger Sr. custom meat processing plant. Each facility is required to monitor their discharges according to sampling and monitoring conditions specified in their NPDES permit and submit Monthly Operating Report (MOR) data to Ohio EPA. Summarized MOR results are listed in Table 8.

Chateau Estates Mobile Home Park (Ohio EPA Permit # 0PV00009 outfall 001)
The Chateau Estates Mobile Home Park located just south of Zanesville at 2200 South River Road consists of a mobile home park with approximately fifty residential units. The sanitary waste from the mobile home park flows to a 25,000 gallon per day extended aeration wastewater treatment plant which discharges to Flat Run. Treatment of the sanitary waste is provided by a trash trap followed by parallel extended aeration basins with clarifiers for the final settling of sludge. The treated effluent receives final disinfection via ultraviolet radiation prior to discharge. The sanitary waste discharges to Flat Run less than a quarter mile from the confluence with the Muskingum River at river mile (RM) 0.2.

AAA Rentals of Zanesville, LTD (Ohio EPA Permit # 0PW00023 outfall 001 and 002)
AAA Rentals of Zanesville consists of an apartment complex containing two main apartment buildings located at Creedmor Drive and Dietz Lane south of Zanesville, Ohio. The sanitary waste from each apartment building is treated at separate 3,000 gallon per day extended aeration wastewater treatment plants. Treatment of the sanitary waste is provided by trash traps, extended aeration basins with clarifiers, surface sand filters, and ultraviolet radiation disinfection. The apartment building located at Creedmor Drive discharges treated sanitary wastewater from outfall 001 which discharges directly to Flat Run at RM 0.45. Treated sanitary wastewater from the Dietz Lane apartment discharges to an unnamed tributary to Flat Run which enters Flat Run at RM 0.38 (outfall 002).

Carl Rittenberger Sr., Inc. (Ohio EPA Permit # 0IH00003 outfall 001)
Carl Rittenberger meats is a family owned meat processing facility which produces custom meat products for individual processing requests and for retail sale in food service establishments. The facility receives animal carcasses for the processing and packaging of selected cuts for retail sale at local and regional groceries and restaurants in addition to custom individual sale. The industrial process wastewater, which consists of wash water from equipment and processing areas, first receives initial settling through a trash trap and then aerobic decomposition in an aerated lagoon followed by a final polishing pond. The process wastewater is also combined with all sanitary waste generated at the facility which all receives treatment from the 15,000 gallon per day wastewater treatment lagoons. Following secondary treatment from the lagoons, all wastewater is disinfected with chlorine prior to being discharged to Flat Run at RM 2.74.

Table 8. Concentrations of monitored chemicals in effluent discharged from 3 facilities within the Muskingum River Tributaries study area. Results are reported for the time period 2005-2009. MDL = below lab method detection limit.

Discharger/ Parameter	50th Percentile	95th Percentile	Permit Limit -Monthly Avg.-	Permit Limit -Maximum-
AAA Rentals of Zanesville (0PW00023) – Outfall 001 to Flat Run (RM 0.45)				
Dissolved Oxygen (mg/l)	5.2	3.13 (5th percentile)	Monitor	5.0 (min.)
CBOD5 (mg/l)	4	8	10	15
Ammonia-N (mg/l): winter	0.193	10.29	4.5	6.8
Ammonia-N (mg/l): summer	0.125	1.95	1.5	2.3
pH (SU)	6.56 (5th percentile)	7.41	Monitor	6.5 (min)-9.0 (max)
Total Suspended Solids (mg/l)	4.5	114.5	12	18
Flow Rate (GPD)	1000	1400	Monitor	Monitor
Chlorine, Total Residual (mg/l)	0.03	0.092	Monitor	0.019
Fecal Coliform (cfu/100ml): Summer	85	449	1000	2000
AAA Rentals of Zanesville (0PW00023) – Outfall 002 to unnamed tributary to Flat Run (confluence RM 0.38)				
Dissolved Oxygen (mg/l)	5.2	4.8 (5th percentile)	Monitor	5.0 (min.)
CBOD5 (mg/l)	4	8.2	10	15
Ammonia-N (mg/l): winter	2	3	4.5	6.8
Ammonia-N (mg/l): summer	0.13	0.76	1.5	2.3
pH (SU)	6.49 (5th percentile)	7.83	Monitor	6.5 (min)-9.0 (max)
Total Suspended Solids (mg/l)	MDL	13.4	12	18
Flow Rate (GPD)	850	1300	Monitor	Monitor
Chlorine, Total Residual (mg/l)	0.03	0.03	Monitor	0.019
Fecal Coliform (cfu/100ml): Summer	2	12	1000	2000
Chateau Estates WWTP (0PV00009) – Flat Run (RM 0.2)				
Water Temperature (°C)	17	24	Monitor	Monitor
Dissolved Oxygen (mg/l)	7.15	6.6 (5th percentile)	Monitor	Monitor
pH (S.U.)	7.24 (5th percentile)	7.8	Monitor	6.5 (min)-9.0 (max)
Total Suspended Solids (mg/l)	7	34.6	30	45
CBOD5 (mg/l)	3	17.5	25	40
Ammonia-N (mg/l)	0.1	13.07	Monitor	Monitor
Fecal Coliform (cfu/100ml): Summer	50	850	1000	2000
Flow Rate (MGD)	0.0053	0.0053	Monitor	Monitor
Carl Rittberger Sr Inc (0IH00003) – Flat Run (RM 2.74)				
Water Temperature (°C)	7	25.6	Monitor	Monitor
Dissolved Oxygen (mg/l)	8.31	5.76	Monitor	6.0 (min.)
pH (S.U.)	7.43 (5th percentile)	9.25	Monitor	6.5 (min)-9.0 (max)
Total Suspended Solids (mg/l)	9	46	Monitor[1]	Monitor[1]
BOD5 (mg/l): summer	1	9	10	15
BOD5 (mg/l): winter	5	12.9	15	23
Ammonia-N (mg/l): summer	0.16	2.97	1.64	2.46
Ammonia-N: winter	0.13	0.71	Monitor	Monitor
Fecal Coliform (cfu/100ml): Summer	MDL	53	Monitor	400
Oil and Grease (mg/l)	MDL	3	Monitor[1]	Monitor[1]
Chlorine, Total Residual (mg/l)	MDL	0.175	Monitor	0.019
Flow Rate (MGD)	0.005	0.019	Monitor	Monitor

1 – permit limits are based on loading, not concentration.

Stream Physical Habitat

Stream habitat was evaluated at 17 fish sampling locations (Appendix Table 3). Within the Muskingum River Tributaries study area, good to excellent stream habitat was recorded at 15 sites (88%), and fair habitat was noted at 2 locations (12%)(Table 8). The average QHEI score for all sites combined was 66.0, consistent with good overall habitat quality. Nearly all of the stream sites were predominated by high quality substrates, including gravel, sand, and cobble. Two stream sites (Island Run and South Branch Island Run) were predominated by limestone bedrock substrate. Moderate to extensive embeddedness of the bottom substrates occurred at 5 of the 17 fish sites (29%). Embeddedness is the degree that cobble, gravel, and boulder substrates are surrounded, impacted in, or covered by fine sand and silt, and in the case of AMD streams, metals that precipitate out of solution, especially iron. Extensive amounts are detrimental to bottom spawning fish and impair macroinvertebrate populations.

Figure 5. Brush Creek at State Route 555

Three of the streams sampled in this study exhibited the effects of acid mine drainage associated with unreclaimed coal mines. Iron flocculent precipitates, from unreclaimed mining areas, were observed along the margins at Brush Creek, Turkey Run, and Baughman Run sampling stations. The iron floc gives the stream margins a yellow or orange color. Historical channel modifications occurred at Turkey Run and Flat Run; however, both stream channels are showing signs of recovery. Channel modifications cause reduced habitat diversity for aquatic life.

Table 9. Stream physical habitat (QHEI) summarized results for the Muskingum River Tributaries study area, 2008.

Stream	River Mile	Location	QHEI	Comments
EXCELLENT				
Island Run	3.4	Helmic bridge	72.0	Limestone bedrock predominates
Bluerock Creek	0.8	Blue Rock Road	72.5	
Dry Riffle Run	0.2	SR 60 near Gaysport	73.0	Moderate/extensive embeddedness
Brush Creek	7.3	Adjacent Goose Creek Road	73.5	Iron floc./gob piles along stream
Brush Creek	4.8	Dst. Turkey Run confluence	75.0	AMD affected/moderate embeddedness
Baughman Run	0.1	Near Stovertown @ mouth	73.0	Acid mine drainage
GOOD				
S. Br. Island Run	0.1	Adjacent TR 193 – Brown Road	69.0	Shallow pools
Big Bottom Run	0.2	TR 313	59.5	Extensive embeddedness
Little Bluerock Creek	0.1	Twyman Hill Road	69.0	Shallow pools
Back Run	0.7	Adjacent Back Run Road	69.5	Moderate embeddedness
Duncan Run	0.3	River Road south of Philo	65.0	Shallow riffles
Little Duncan Run	0.1	Duncan Run Road	59.0	Unstable riffles
Turkey Run	0.1	Near Stovertown @ SR 555	56.5	Channel modified, acid mine drainage
Goose Run	0.1	Elmville Road	68.0	Moderate embeddedness
Flat Run	0.3	SR 60 @ Trailer Park	61.0	Channel modified
FAIR				
Brush Creek	1.2	Adj. SR 555	52.5	Acid mine drainage
Sycamore Hollow Run	0.2	River Road near Philo	53.5	Poor-fair channel development

General narrative ranges assigned to QHEI scores.			
Narrative Rating		QHEI Range	
		Headwaters (≤20 sq mi)	Larger Streams
Excellent		≥70	≥75
Good		55 to 69	60 to 74
Fair		43 to 54	45 to 59

Fish Community

A total of 6,323 fish representing 28 species were collected from the Muskingum River Tributaries study area between June and August, 2008. Relative numbers and species collected per location are presented in Appendix Table 4. IBI and MIwb scores are presented in Appendix Table 5. Sampling locations were evaluated using Warmwater Habitat or Exceptional Warmwater Habitat biocriteria based on the current or recommended aquatic life use, along with using Coldwater Habitat narrative benchmarks where applicable. A summary of the fish data are presented in Table 10. Muskingum River Tributaries 2008 biological and habitat data are available on Ohio EPA interactive maps at the following link: http://wwwapp.epa.ohio.gov/dsw/gis/bio/index.php

Fish Biocriteria Full Attainment

Muskingum River Tributaries: 35%

The Muskingum River Tributary sites sampled during 2008 achieved the applicable WWH or EWH fish biocriterion, or CWH narrative benchmarks at 6 of the 17 sites evaluated (35%). Eleven sites were not achieving the CWH narrative or WWH biocriteria, representing 65% of the Muskingum Tributary sites. Of these 11 sites, one site on Brush Creek, and sites in Turkey Run and Baughman Run were represented by poor fish communities. These three poor sites were impacted by acid mine drainage from past mining activities. Fish communities in Goose Creek (headwater tributary to Brush Creek) were fair due to historical mining influences in the watershed that has limited fish migration and recovery.

Streams that maintain cooler summer water temperatures and have a certain number of coldwater taxa can be assigned the CWH use designation. Coldwater fish species collected in the Muskingum Tributaries study area included redside dace and southern redbelly dace. The Coldwater Habitat use designation was recommended for Sycamore Hollow Run, Little Duncan Run, Bluerock Creek, Little Bluerock Creek, and Big Bottom Run based on abundant populations of coldwater fish species and/or coldwater macroinvertebrate taxa. Four of the five coldwater streams were fully meeting the fish biocriterion – only Big Bottom Run had a fish community below expected levels.

Natural causes limit fish communities in several streams including: very small drainage/ Primary Headwater Habitat conditions (Back Run); unstable substrates/stream flashiness (Duncan Run); limited pool habitat and interstitial flows – Muskingum River floodplain area (Big Bottom Run). Additionally past historical land use changes combined with a waterfall prevented full recovery in Island Run and South Branch Island Run.

Fish species collected which are sensitive to water pollution included golden redhorse, northern hog sucker, redside dace, silver shiner, rosyface shiner, sand shiner, rainbow darter, and banded darter. Pollution sensitive fish comprised 6.4 percent of the fish community.

Table 10. Fish community summaries based on pulsed D.C. electrofishing sampling conducted by Ohio EPA in the Muskingum River Tributaries from June – August, 2008. Relative numbers and weight are per 0.3 km for wading and headwater sites. NA= not applicable

Stream	River Mile	Sampling Method	Fish Species (Total)	Relative Number	Relative Weight (kg)	QHEI (Habitat)	IBI	MIwb	Narrative Evaluation
Island Run	3.4	Headwater	9	1414	NA	72.0	**30***	NA	Fair
South Branch Island Run	0.1	Headwater	8	531	NA	69.0	**36***	NA	Fair
Big Bottom Run	0.2	Headwater	8	172	NA	59.5	**28***	NA	Fair
Bluerock Creek	0.8	Headwater	20	1050	NA	72.5	**48**^{ns}	NA	Very Good
Little Bluerock Creek	0.1	Headwater	14	988	NA	69.0	**50**	NA	Exceptional
Back Run	0.7	Headwater	3	918	NA	69.5	**34***	NA	Fair
Dry Riffle Run	0.2	Headwater	14	464	NA	73.0	**40**^{ns}	NA	Marginally Good
Duncan Run	0.3	Headwater	11	374	NA	65.0	**36***	NA	Fair
Little Duncan Run	0.1	Headwater	16	952	NA	59.0	**48**	NA	Very Good
Brush Creek	7.3	Headwater	9	727	NA	73.5	**28***	NA	Fair
Brush Creek	4.8	Headwater	5	154	NA	75.0	**22***	NA	Poor
Brush Creek	1.2	Wading	12	247	2.60	52.5	**28***	**3.9***	Fair/Very Poor
Baughman Run	0.1	Headwater	3	74	NA	73.0	**20***	NA	Poor
Turkey Run	0.1	Headwater	3	35	NA	56.5	**18***	NA	Poor
Goose Run	0.1	Headwater	7	740	NA	68.0	**36***	NA	Fair
Sycamore Hollow Run	0.2	Headwater	6	274	NA	53.5	**32**	NA	Marginally Good
Flat Run	0.3	Headwater	15	2172	NA	61.0	**52**	NA	Exceptional

The color of corresponds to the narrative habitat score (blue is exceptional, green is good and yellow is fair).

BIOCRITERIA		
INDEX - Site Type	WWH	EWH
IBI: Headwater/Wading	44	50
MIwb: Wading	8.4	9.4

^{ns} Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).
* Significant departure from biocriterion (>4 IBI or ICI units; >0.5 MIwb units). Poor and very poor results are underlined.

Macroinvertebrate Community

The macroinvertebrate communities from 17 locations in the Muskingum River Tributaries study area were sampled in 2008. Qualitative samples were collected from all sampling locations. One quantitative sample was collected from Brush Creek. A summary of the macroinvertebrate data are presented in Table 11. The macroinvertebrate raw data are presented in Appendix Table 6. Sampling locations were evaluated using Warmwater Habitat or Exceptional Warmwater Habitat biocriteria based on current or recommended aquatic life uses along with Coldwater Habitat narrative benchmarks where applicable.

Muskingum River Tributary sites sampled during 2008 achieved the applicable WWH or EWH macroinvertebrate biocriterion or CWH benchmarks at 14 of the 17 sites evaluated (82%). Three sites were not achieving the WWH biocriterion, with narrative ratings of fair to poor. These three sites were all impacted by acid mine drainage (Brush Creek RM 4.9, Baughman Run, and Turkey Run).

Macroinvertebrate Biocriteria Full Attainment

Muskingum River Tributaries: 82%

The three sites with impaired macroinvertebrate communities had the lowest number of pollution sensitive taxa (1-6 taxa), the lowest total number of taxa (12 – 17 taxa), and the lowest number of pollution sensitive mayfly, stonefly, and caddisfly (EPT) taxa (0-4 taxa) among the study area streams. Water chemistry results from Brush Creek at RM 4.9 (water chemistry samples were not collected from Turkey Run or Baughman Run) revealed pH levels as low as 3.82 SU. Field notes from Turkey Run and Baughman Run reported iron floc along the stream margins.

Five streams within the study area exhibited qualities reflective of the Coldwater Habitat aquatic life use. Macroinvertebrate communities from all five streams (Sycamore Hollow Run, Little Duncan Run, Bluerock Creek, Little Bluerock Creek, and Big Bottom Run) were fully meeting the CWH use. Coldwater macroinvertebrates collected from these streams included the following 12 taxa: true flies (*Dicranota sp., Zavrelimyia sp., Corynoneura n.sp.5., Parametriocnemus sp., Rheocricotopus eminellobus, Polypedilum (Polypedilum) albicorne, Polypedilum (Polypedilum) aviceps, and Micropsectra sp.*); stoneflies *(Leuctra sp., and Eccoptura xanthenes)*; caddisflies *(Diplectrona modesta)*; fishflies (Nigronia fasciatus).

Table 11. Summary of macroinvertebrate data collected from natural substrates (qualitative sampling) and one quantitative sample (Brush Creek) in the Muskingum River Tributaries study area, June – August, 2008.

Stream	River Mile	Data Codes	Qual. Taxa	Coldwater Taxa	EPT[a] Taxa	Sensitive Taxa	Density (organisms/ sq. ft.)	**ICI**	Narrative Evaluation
Island Run	3.6		42	4	15	14	Moderate	NA	Good
South Branch Island Run	0.1		36	0	18	16	Mod-Low	NA	Very Good
Big Bottom Run	0.2		25	4	13	14	Mod-Low	NA	Good
Bluerock Creek	0.7		57	5	24	30	Mod-High	NA	Exceptional
Little Bluerock Creek	0.1		26	2	12	10	Low	NA	Good
Back Run	1.0		27	2	14	12	Moderate	NA	Good
Dry Riffle Run	0.1		26	1	10	10	Low	NA	Marginally Good[ns]
Duncan Run	0.3		24	2	10	6	Mod-Low	NA	Good
Little Duncan Run	0.1		42	6	17	18	Low	NA	Very Good
Brush Creek	7.3		36	2	14	12	Low	NA	Good
Brush Creek	4.9		12	1	3	1	Low	NA	Fair*
Brush Creek	1.2	X15	14/43[c]	4	6/7[c]	2/11[c]	67 (Low)	22[b]	Marginally Good[ns]
Baughman Run	0.1		17	2	4	6	Low	NA	Fair*
Turkey Run	0.1		14	2	0	1	Low	NA	<u>Poor</u>*
Goose Run	0.1		28	1	12	9	Mod-Low	NA	Good
Sycamore Hollow Run	0.3		31	6	17	19	Mod-Low	NA	Very Good
Flat Run	0.3		36	4	11	14	Mod-Low	NA	Good

Biocriteria		
INDEX – Site Type	WWH	EWH
ICI	36 (good)	46 (exceptional)

[a] EPT = total Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness.
[b] Narrative evaluation used in lieu of ICI score to assess biological quality. ICI results were influenced by low flow conditions.
[c] Includes both qualitative and quantitative taxa.
[ns] nonsignificant departure from biocriterion or narrative ranges.
* Significant departure from biocriterion (>4 ICI units) or narrative ranges. Poor and very poor results are underlined.
Data codes: X15 = current >0.0 feet per second but < 0.3 fps.

WATERSHED ASSESSMENTS UNITS

The Muskingum River Tributaries study area is comprised of five 12-digit Hydrologic Unit Code (HUC12) watersheds. Data from individual sampling locations in a HUC12 assessment unit are accumulated and analyzed; summary information for each Muskingum River Tributaries watershed assessment unit (WAU) is presented in this section. The sampling site scores calculated for headwater and wading sites were averaged to determine the intermediate score. The intermediate score was averaged with the principle sites score for an overall measure of aquatic life attainment in the HUC 12 watershed. Data used in this analysis were collected in 2008. High magnitude causes and sources of impairment included the following: low pH/ acid mine drainage (Brush Creek), natural causes and sources (Duncan Run, Bluerock Creek and Island Run). Flat Run was the only watershed within the study area that exceeded the statewide goal of 80 percent full attainment of Clean Water Act biological integrity, and met the Federal CWA goal of 100% attainment (Table 12).

Table 12. Results for the Muskingum River Tributaries watersheds using the HUC12 aquatic life assessment methodology.

		Headwater Site Assessment (<20mi^2)			Wading Site Assessment (≥20 to <50mi^2)				Principle Site Assessment (≥50 to <500 mi^2)			HUC 12 Assessment Unit Score[b]
HUC 12 WATERSHED	Drainage Area sq. mi.	Total Sites	#Sites Full Attainment	Score	Total Sites	#Sites Full Attainment	Score	Intermediate Score[a]	Total Sites	#Sites Full Attainment	Score	
050400040801 – Brush Creek	25.0	5	0	0.0	1	0	0.0	0.0	0	NA	NA	0.0
050400040802 – Flat Run	19.3	2	2	100.0	0	NA[c]	NA	100.0	0	NA	NA	100.0
050400040803 – Duncan Run	21.4	4	2	50.0	0	NA	NA	50.0	0	NA	NA	50.0
050400040804 - Island Run	13.5	2	0	0.0	0	NA	NA	0.0	0	NA	NA	0.0
050400040805 – Bluerock Cr.	23.2	3	2	66.7	0	NA	NA	66.7	0	NA	NA	66.7

[a] – Average of headwater and wading scores.
[b] – Average of intermediate and principle sites scores.
[c] – NA = Not applicable. No sampling sites in the noted assessment size.

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*Some of the references not in the report can be found in the Appendix Table 7 which includes Methods, Biosurvey Background Information, and Notice to Users.