Watershed Report for Biological Impairment of the Youghiogheny River Watershed in Garrett County, Maryland Biological Stressor Identification Analysis Results and Interpretation

FINAL

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1650 Arch Street
Philadelphia, PA 19103-2029

March 2014

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List of Abbreviations

AMD	Acid Mine Drainage
ANC	Acid Neutralizing Capacity
AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
CO2	Carbon Dioxide
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
IR	Integrated Report
MBSS	Maryland Biological Stream Survey
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MH	Mantel-Haenzel
mg/L	Milligrams per liter
µS/cm	Micro Siemens per centimeter
NOX	Nitrous Oxides
SSA	Science Services Administration
SOX	Sulfuric Oxides
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

Executive Summary

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met.

The Youghiogheny River watershed (basin code 05020201) is located in Garrett County was identified on the 2012 Integrated Report under various Category listings for the watershed and sub-watersheds. Below is a table identifying the Category listings associated with this watershed.

Table E1. 2012 Integrated Report Listings for the Youghiogheny River Watershed

Watershed	Basin Code	Non-tidal/Tidal	Designated Use	Year Listed	Identified Pollutant	Listing Category
Youghiogheny River	5020201	Non-Tidal	Aquatic Life and Wildlife	2002	Impacts to Biological Communities	5
			Aquatic Life and Wildlife	1996	TSS	4a
			Aquatic Life and Wildlife	1996	Low pH	4a
			Aquatic Life and Wildlife	-	Total Phosphorus	2
			Aquatic Life and Wildlife	-	Total Nitrogen	2
		Sub-watershed	Water Contact Sport	-	Escherichia coli	2
		Sub-watershed	Aquatic Life and Wildlife	-	Low pH	2
	Cherry Creek	Sub-watershed	Water Contact Sport	2008	Escherichia coli	4a
	Lake Louise	Impoundment	Aquatic Life and Wildlife	-	-	3
	Youghiogheny River Lake	Impoundment	Fishing	-	PCBs in Fish Tissue	2
	Youghiogheny River Lake	Impoundment	Fishing	2010	Mercury in Fish Tissue	5

In 2002, the State began listing biological impairments on the Integrated Report. The current Maryland Department of the Environment (MDE) biological assessment methodology assesses and lists only at the Maryland 8-digit watershed scale, which maintains consistency with how other listings on the Integrated Report are made, TMDLs are developed, and implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds by measuring the percentage of stream miles that have poor to very poor biological conditions, and calculating whether this is significantly different from a reference condition watershed (i.e., healthy stream, <10% stream miles with poor to very poor biological condition).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Youghiogheny River and all of its tributaries is Use III - nontidal cold water and Use III-P – nontidal cold water and public water supply; suitable for the growth and propagation of trout and capable of supporting self-sustaining trout populations and their associated food organisms (COMAR 2013 a, b). The Youghiogheny River watershed is not attaining its designated use of protection of aquatic life because of impairments to the biological communities. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause of reduced biological conditions, thus enabling the Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors, sources of stressors and the biological community, and the likely impact these stressors would have on degraded sites in the watershed.

The BSID analysis uses data available from the statewide MDDNR MBSS. Once the BSID analysis is completed, a number of stressors may be identified as probable or unlikely causes of poor biological conditions within the Maryland 8-digit watershed study. BSID analysis results can be used as guidance to refine biological impairment listings in the Integrated Report by specifying the probable stressors and sources linked to biological degradation.

This Youghiogheny River watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and may be reviewed in more detail in the report entitled *Maryland Biological Stressor Identification Process* (MDE 2009). Data suggest that the Youghiogheny River watershed's biological communities are influenced by acidity and marginal in-stream habitat diversity.

The results of the BSID process, and the probable causes and sources of the biological impairments of the Youghiogheny River watershed can be summarized as follows:

- The BSID process has determined that biological communities in Youghiogheny River are likely degraded due to acidity related stressors. There are localized areas within the watershed impacted by acidity due to the absence of buffering geology as well as the presence of multiple acid sources. The BSID results confirm the establishment of a USEPA approved pH TMDL in 2008 was an appropriate management action to begin addressing the impact of this stressor on the biological communities in the Youghiogheny River.

- The BSID process has also determined that biological communities in Youghiogheny River are likely degraded due to habitat related stressors. Specifically, lack of riparian buffers and marginal to poor in-stream velocity/depth diversity are probable causes of impacts to biological communities. Additional analysis of MBSS round one biological data identifies sediment related stressors as impacting biological communities in the Youghiogheny River watershed. Sedimentation and loss of stream habitat diversity are typical "steps" in causal pathways leading to degraded conditions in stream ecosystems. Therefore, MDE considers the 2006 TSS TMDL to be the first step to address this decrease in habitat diversity causing stream degradation.

1.0 Introduction

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met. In 2002, the State began listing biological impairments on the Integrated Report. Maryland Department of the Environment (MDE) has developed a biological assessment methodology to support the determination of proper category placement for 8-digit watershed listings.

The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that guides the assignment of biological condition to Integrated Report categories. In the data quality review step, available relevant data are reviewed to ensure they meet the biological listing methodology criteria of the Integrated Report (MDE 2012). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or black water streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy stream, <10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report. If a watershed is not determined to differ significantly from the reference condition, the assessment must have an acceptable precision (i.e., margin of error) before the watershed is listed as meeting water quality standards (Category 1 or 2). If the level of precision is not acceptable, the status of the watershed is listed as inconclusive and subsequent monitoring options are considered (Category 3). If a watershed is still considered impaired but has a TMDL that has been completed or submitted to EPA the original listing will be amended to Category 4a. If a watershed is classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary.

The MDE biological stressor identification (BSID) analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of the biological impairment. Identification of stressors responsible for biological impairments was limited to the round two and three Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) dataset (2000–2009) because it provides a broad spectrum of paired data variables (i.e., biological monitoring and stressor information) to best enable a complete stressor

analysis. The BSID analysis then links potential causes/stressors with general causal scenarios and concludes with a review for ecological plausibility by State scientists. Once the BSID analysis is completed, one or several stressors may be identified as probable or unlikely causes of the poor biological conditions within the Maryland 8-digit watershed. BSID analysis results can be used together with a variety of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

The remainder of this report provides a characterization of the Youghiogheny River watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Youghiogheny River Watershed Characterization

2.1 Location

The Youghiogheny River is Maryland's western-most river system, occurring along its borders with West Virginia and Pennsylvania. The Youghiogheny originates in south southwest Garrett County and flows north into Pennsylvania, eventually joining the Ohio River and the Mississippi River. The Youghiogheny River is approximately 125 miles in length with nearly 75 miles in Pennsylvania, approximately 44 miles in Maryland, and about 6 miles in West Virginia (Figure 1).

The watershed is entirely located within the Appalachian Plateau physiographic region, which is categorized as Highlands. Highlands is one of three distinct eco-regions identified in the MDDNR MBSS Index of Biological Integrity (IBI) metrics (Southerland et al 2005) that also includes the Valley and Ridge region (see Figure 2).

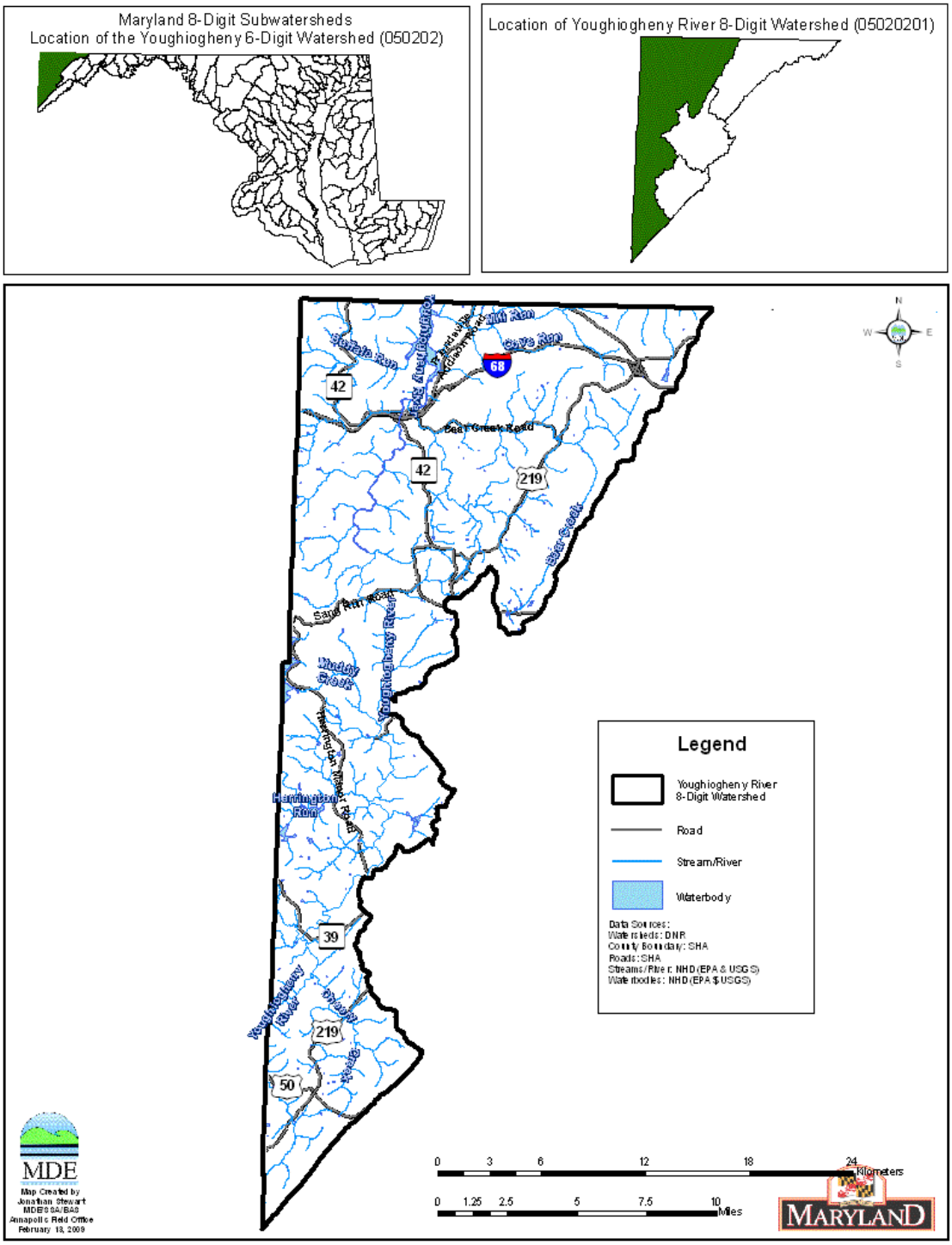

Figure 1. Location Map of the Youghiogheny River Watershed

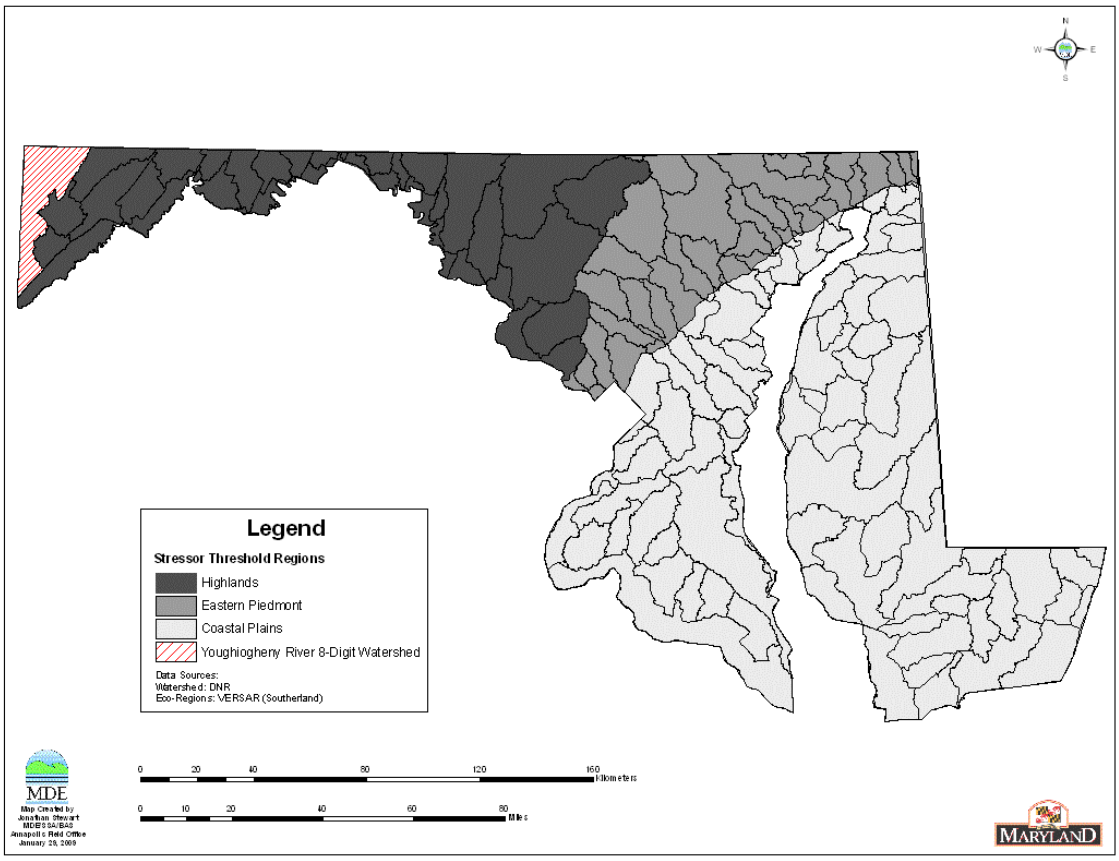

Figure 2. Eco-Region Location Map of the Youghiogheny River Watershed

2.2 Land Use

The pattern of development in the Youghiogheny River watershed reflects the influence of its steep terrain. Rolling plateaus support light to moderate urban areas, particularly in the southern third of the drainage area, including the town of Oakland. This area also supports large agricultural operations. Stream valleys become more deeply incised northward, resulting in relatively small and disconnected centers of development, the largest of which is the town of Accident. The Youghiogheny River valley does not widen adequately for development until just upstream of the Youghiogheny Reservoir, where the town of Friendsville is located. In Garrett County, only areas within town limits have zoning regulations. Thus, most development includes a scattered collage of agriculture, residences, retailers and industry.

According to the Chesapeake Bay Program's Phase 5.2 Model the land use distribution in the watershed is approximately 76% forest/herbaceous, 20% agricultural and 4% urban (USEPA 2010) (see Figure 3 and Figure 4).

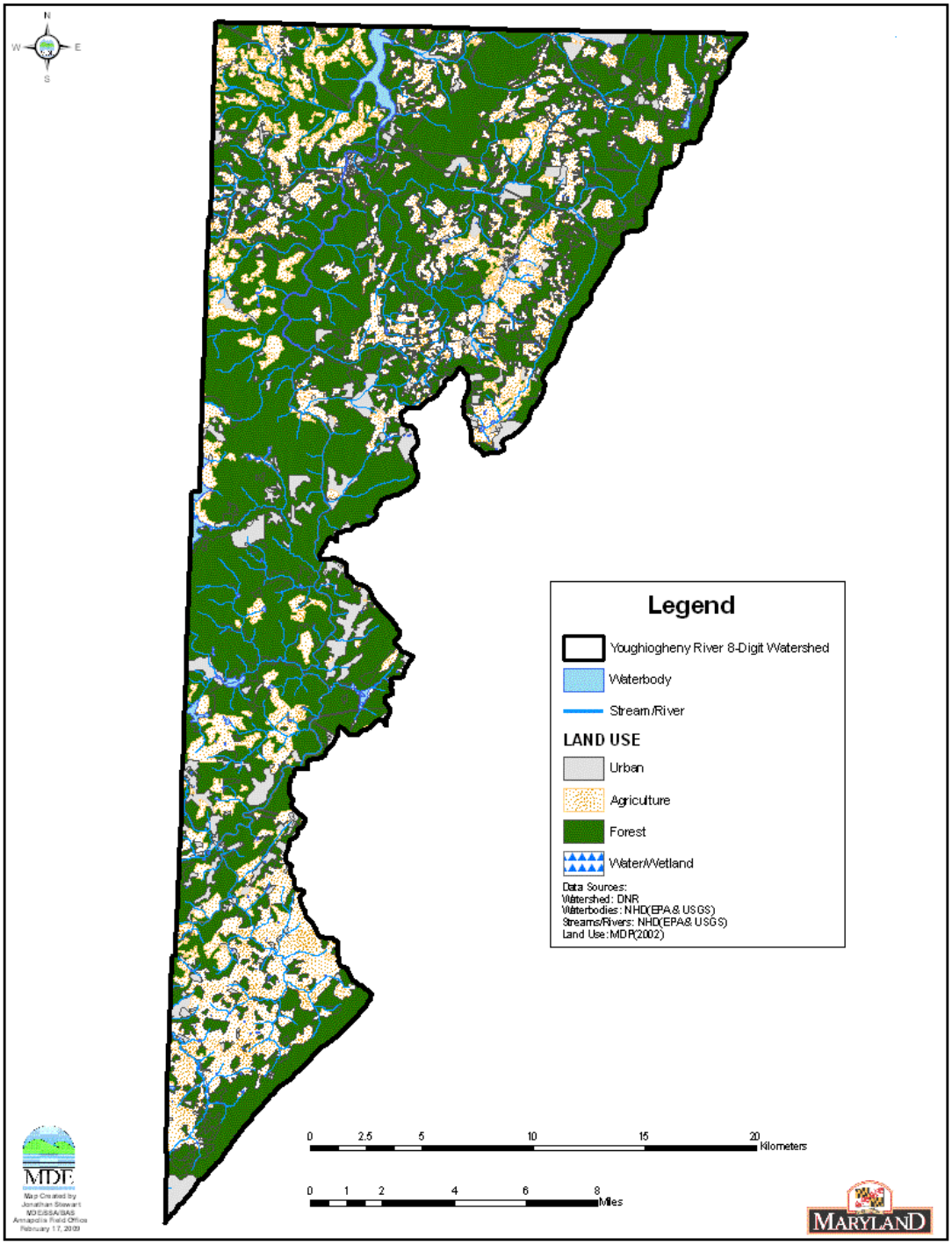

Figure 3. Land Use Map of the Youghiogheny River Watershed

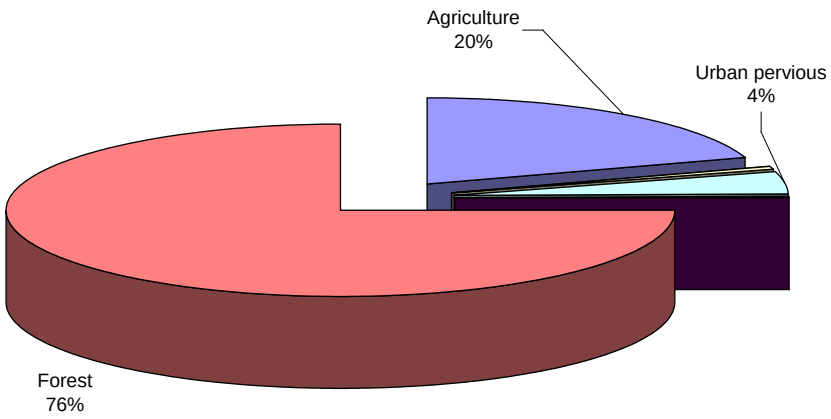

Figure 4. Proportions of Land Use in the Youghiogheny River Watershed

2.3 Soils/hydrology

The Youghiogheny River watershed is located in the Appalachian Plateau physiographic region, which is characterized by broad elevated plateaus deeply and abruptly incised by river valleys. Hydrology, soils, and topology reflect the underlying geology and geologic history of the Youghiogheny River Watershed. Geologic processes like folding have modified initial erosion-resistance of consolidated sedimentary rocks of Devonian, Mississippian, and Pennsylvanian ages. Resulting geological features such as synclines, anticlines, and lineaments reveal millions of years of differential weathering and erosion that have exploited weaknesses across the landscape. Sandstones of the geologically young Pottsville Group (Pennsylvanian age) typically remain on high ridges along compressed, resistant synclines. More rapid erosion along weaker anticlines has resulted in lower, rolling hills protected now by older (Devonian age) sands and shales (MDP 1967).

The broad, rolling drainage area in much of the southern-most Youghiogheny River watershed (Deer Park anticline) is responsible for the calm, winding nature of the river channel upstream of Oakland, Maryland. Within the 13 miles between Route 50 and its confluence with the Little Youghiogheny River, the Youghiogheny drops a modest 59 feet in elevation (2422' to 2363'). North of Oakland, the Youghiogheny River begins to descend more rapidly (falling 73 feet within the 8.5 miles to Swallow Falls Road at 2290' elevation) before transitioning into a violent cascade that drops an average of 53 feet per river mile until it reaches Friendsville, Maryland (1493'). Swallow Falls State Park

showcases the waterfalls of this extreme hydrology that includes Muddy Creek Falls, which is the tallest waterfall in Maryland with a vertical drop of 54 feet.

Most of the Youghiogheny River streambed consists of rocky bottoms that provide turbulence and create good aeration and high levels of dissolved oxygen in the stream. The river has rocky bottoms with steep slopes and estimated average stream velocities ranging from 1.0 to 3.5 fps during low- flow conditions. The watershed soils are typically classified as rocky, consisting of carbonate and siliciclastic. The streambeds consist predominantly of gray to yellowish sandstone and shale rocks (USDA 1974).

Soils within the Youghiogheny River watershed vary only locally in their hydrologic properties and expected erodibility. The majority of the watershed contains Group C soils. Group C soils have moderately high runoff potential when thoroughly wet, and water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silty loam, sandy clay loam, clay loam, and silty clay loam textures. There are three relatively small, localized areas containing Group B soils in the Youghiogheny River watershed: 1) the southwest watershed boundary along Backbone Mountain; 2) a small area north of the confluence of the Youghiogheny River and Deep Creek; and 3) an even smaller area near Mill Run near Youghiogheny River Lake. Group B soils have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures (USDA 1995).

3.0 Youghiogheny River Watershed Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Youghiogheny River watershed (basin code 05020201) is located in Garrett County was identified on the 2012 Integrated Report under various Category listings for the watershed and sub-watersheds. Table 1, below, identifies the Category listings associated with this watershed.

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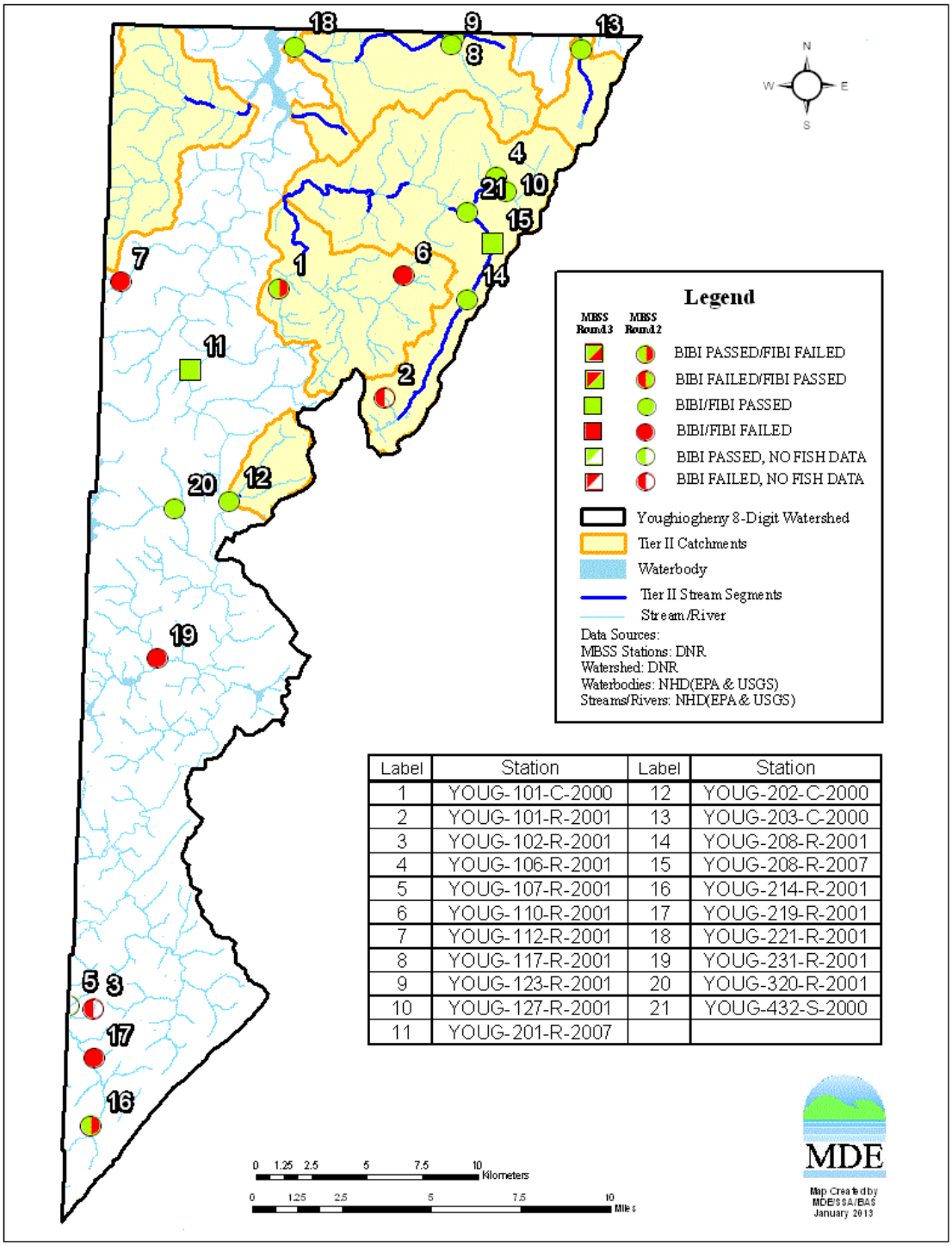
			Aquatic Life and Wildlife	1996	Low pH	4a
			Aquatic Life and Wildlife	-	Total Phosphorus	2
			Aquatic Life and Wildlife	-	Total Nitrogen	2
		Sub-watershed	Water Contact Sport	-	Escherichia coli	2
		Sub-watershed	Aquatic Life and Wildlife	-	Low pH	2
	Cherry Creek	Sub-watershed	Water Contact Sport	2008	Escherichia coli	4a
	Lake Louise	Impoundment	Aquatic Life and Wildlife	-		3
	Youghiogheny River Lake	Impoundment	Fishing	-	PCBs in Fish Tissue	2
	Youghiogheny River Lake	Impoundment	Fishing	2010	Mercury in Fish Tissue	5

3.2 Impacts to Biological Communities

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Youghiogheny River and all of its tributaries is Use III - nontidal cold water and Use III-P – nontidal cold water and public water supply; suitable for the growth and propagation of trout and capable of supporting self-sustaining trout populations and their associated food organisms (COMAR 2013 a, b). A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life; primary or secondary contact recreation, drinking water supply, and trout waters. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

The Youghiogheny River watershed is listed under Category 5 of the 2012 Integrated Report for impacts to biological communities. Approximately 29% of stream miles in the Youghiogheny River watershed are estimated as having benthic and/or fish indices of biological integrity in the poor to very poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data, which include 65 stations. Nineteen of the sixty-five stations have benthic and/or fish index of biotic integrity (BIBI, FIBI) scores significantly lower than 3.0 (i.e., poor to very poor). The principal dataset, MBSS round two and round three (2000-2009) contains 21 MBSS sites; with eight having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Youghiogheny River watershed.



Label	Station	Label	Station
1	YOUG-101-C-2000	12	YOUG-202-C-2000
2	YOUG-101-R-2001	13	YOUG-203-C-2000
3	YOUG-102-R-2001	14	YOUG-208-R-2001
4	YOUG-106-R-2001	15	YOUG-208-R-2007
5	YOUG-107-R-2001	16	YOUG-214-R-2001
6	YOUG-110-R-2001	17	YOUG-219-R-2001
7	YOUG-112-R-2001	18	YOUG-221-R-2001
8	YOUG-117-R-2001	19	YOUG-231-R-2001
9	YOUG-123-R-2001	20	YOUG-320-R-2001
10	YOUG-127-R-2001	21	YOUG-432-S-2000
11	YOUG-201-R-2007		

Figure 5. Principal Dataset Sites for the Youghiogheny River Watershed

4.0 Stressor Identification Results

The BSID process uses results from the BSID data analysis to evaluate each biologically impaired watershed and determine potential stressors and sources. Interpretation of the BSID data analysis results is based upon components of Hill's Postulates (Hill 1965), which propose a set of standards that could be used to judge when an association might be causal. The components applied are: 1) the strength of association which is assessed using the odds ratio; 2) the specificity of the association for a specific stressor (risk among controls); 3) the presence of a biological gradient; 4) ecological plausibility which is illustrated through final causal models; and 5) experimental evidence gathered through literature reviews to help support the causal linkage.

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores lower than 3.0 (i.e., poor to very poor). The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups – 1^{st} and 2^{nd}-4^{th} order), that have fair to good biological conditions.

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the Mantel-Haenzel (1959) approach and is based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are poor to very poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and poor to very poor biological conditions and is used to identify potential stressors.

Once potential stressors are identified (i.e., odds ratio significantly greater than one), the risk attributable to each stressor is quantified for all sites with poor to very poor biological conditions within the watershed (i.e., cases). The attributable risk (AR) defined herein is the portion of the cases with poor to very poor biological conditions that are associated with the stressor. The AR is calculated as the difference between the proportion of case sites with the stressor present and the proportion of control sites with the stressor present.

Once the AR is calculated for each possible stressor, the AR for groups of stressors is calculated. Similar to the AR calculation for each stressor, the AR calculation for a group of stressors is also summed over the case sites using the individual site

characteristics (i.e., stressors present at that site). The only difference is that the absolute risk for the controls at each site is estimated based on the stressor present at the site that has the lowest absolute risk among the controls.

After determining the AR for each stressor and the AR for groups of stressors, the AR for all potential stressors is calculated. This value represents the proportion of cases, sites in the watershed with poor to very poor biological conditions, which would be improved if the potential stressors were eliminated (Van Sickle and Paulsen 2008). The purpose of this metric is to determine if stressors have been identified for an acceptable proportion of cases (MDE 2009).

The parameters used in the BSID analysis are segregated into five groups: land use sources, and stressors representing sediment, in-stream habitat, riparian habitat, and water chemistry conditions. Through the BSID data analysis of the Youghiogheny River watershed, MDE identified sources, and water chemistry stressors as having significant association with poor to very poor fish and/or benthic biological conditions. Parameters identified as representing possible sources in the watershed are listed in Table 2 and include various urban land uses and impervious surfaces. Table 3 shows the summary of combined AR values for the source groups in the Youghiogheny River watershed. As shown in Table 4 through Table 6, a number of parameters from the water chemistry group were identified as possible biological stressors. Table 7 shows the summary of combined AR values for the stressor groups in the Youghiogheny River watershed.

Table 2. Stressor Source Identification Analysis Results for the Magothy River Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Sources - Acidity	Atmospheric deposition present	21	8	169	75%	41%	0.076	Yes	34%
	Agricultural acid source present	21	8	169	0%	1%	1	No	_
	AMD acid source present	21	8	169	0%	5%	1	No	_
	Organic acid source present	21	8	169	0%	0%	1	No	_
Sources - Agricultural	High % of agriculture in watershed	21	8	172	0%	11%	1	No	_
	High % of agriculture in 60m buffer	21	8	172	13%	6%	0.402	No	_
Sources - Anthropogenic	Low % of forest in watershed	21	8	172	0%	5%	1	No	_
	Low % of wetland in watershed	21	8	172	0%	0%	1	No	_
	Low % of forest in 60m buffer	21	8	172	13%	2%	0.205	No	_
	Low % of wetland in 60m buffer	21	8	172	0%	0%	1	No	_
Sources - Impervious	High % of impervious surface in watershed	21	8	172	25%	5%	0.065	Yes	20%
	High % of impervious surface in 60m buffer	21	8	172	25%	11%	0.236	No	_
	High % of roads in watershed	21	8	172	13%	8%	0.509	No	_
	High % of roads in 60m buffer	21	8	172	0%	8%	1	No	_
Sources - Urban	High % of high-intensity developed in watershed	21	8	172	0%	2%	1	No	_
	High % of low-intensity developed in watershed	21	8	172	13%	3%	0.242	No	_
	High % of medium-intensity developed in watershed	21	8	172	0%	3%	1	No	_
	High % of early-stage residential in watershed	21	8	172	25%	6%	0.105	No	_

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
	High % of residential developed in watershed	21	8	172	13%	3%	0.242	No	_
	High % of rural developed in watershed	21	8	172	0%	3%	1	No	_
	High % of high-intensity developed in 60m buffer	21	8	172	0%	1%	1	No	_
	High % of low-intensity developed in 60m buffer	21	8	172	0%	5%	1	No	_
	High % of medium-intensity developed in 60m buffer	21	8	172	0%	1%	1	No	_
	High % of early-stage residential in 60m buffer	21	8	172	25%	3%	0.042	Yes	22%
	High % of residential developed in 60m buffer	21	8	172	0%	5%	1	No	_
	High % of rural developed in 60m buffer	21	8	172	0%	7%	1	No	_

Table 3. Summary of Combined Attributable Risk Values for Source Groups in the Youghiogheny River Watershed

Source Group	% of degraded sites associated with specific source group (attributable risk)
Sources - Acidity	34%
Sources - Impervious	20%
Sources - Urban	22%
All Sources	***65%***

4.1 Sources Identified by BSID Analysis

The BSID source analysis (Table 2) identifies three land use/land covers within the watershed and sixty meter buffer as potential sources of stressors that may cause negative biological impacts. Forty-two percent of impaired stream miles in the Youghiogheny River watershed are associated with combination of urban and impervious areas. This is a significant result because according to the Chesapeake Bay Program's Phase 5.2 Model, only four percent (4%) of the watershed is comprised of urban land use (USEPA 2010). Large proportions of impervious surface alter the hydrologic cycle to increase runoff and accelerate erosion.

'Early-Stage' residential areas may be associated with exposed soils in addition to increased runoff. This land use classification represents those areas which are in transition from one land use activity to another. Approximately 22% of impaired stream segments in the Youghiogheny River watershed have relatively high (i.e., threshold) proportions of 'early-stage' residential within a 60 meter stream buffers upstream. This transitional land use phase occurs when, for example, forest lands are cleared, wetlands are drained, or when any type of land use ceases as areas become temporarily bare as construction is planned for such future uses as residences, shopping centers, industrial sites, or suburban and rural residential subdivisions.

Acidity sources are associated with 34% of impaired streams in the Youghiogheny watershed. There are both local (e.g., acid mine drainage (AMD)) and ubiquitous sources of acidity (e.g., atmospheric deposition) that may contribute to impairments. Decreased infiltration associated with impervious surface and transitional areas may also increase acidity delivered to streams by disconnecting surface flow from any potentially neutralizing properties that subsurface rocks and soils could provide.

The combined AR for all source groups is approximately 65% suggesting these sources are the probable causes of biological degradation in the Youghiogheny River watershed (Table 3).

The remainder of this section will discuss stressors identified by the BSID analysis (Table 4, 5, and 6) and their link to degraded biological conditions in the watershed.

Table 4. Sediment Biological Stressor Identification Analysis Results for the Youghiogheny River Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Sediment	Extensive bar formation present	21	8	83	0%	7%	1	No	_
	Moderate bar formation present	21	9	85	44%	38%	0.729	No	_
	Bar formation present	21	8	83	88%	84%	1	No	_
	Channel alteration moderate to poor	19	8	69	38%	40%	1	No	_
	Channel alteration poor	19	8	69	0%	6%	1	No	_
	High embeddedness	21	8	82	0%	3%	1	No	_
	Epifaunal substrate marginal to poor	21	8	83	38%	17%	0.148	No	_
	Epifaunal substrate poor	21	8	83	0%	2%	1	No	_
	Moderate to severe erosion present	21	8	83	25%	25%	1	No	_
	Severe erosion present	21	8	83	0%	2%	1	No	_
	Silt clay present	21	8	83	88%	97%	0.249	No	_

Table 5. Habitat Biological Stressor Identification Analysis Results for the Youghiogheny River Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Instream Habitat	Channelization present	21	8	87	0%	10%	1	No	_
	Concrete/gabion present	19	8	76	0%	2%	1	No	_
	Beaver pond present	21	8	83	0%	1%	1	No	_
	Instream habitat structure marginal to poor	21	8	83	25%	19%	0.649	No	_
	Instream habitat structure poor	21	8	83	0%	0%	1	No	_
	Pool/glide/eddy quality marginal to poor	21	8	83	63%	46%	0.439	No	_
	Pool/glide/eddy quality poor	21	8	83	0%	5%	1	No	_
	Riffle/run quality marginal to poor	21	8	83	38%	30%	0.689	No	_
	Riffle/run quality poor	21	8	83	13%	5%	0.36	No	_
	Velocity/depth diversity marginal to poor	21	8	83	88%	53%	0.052	Yes	35%
	Velocity/depth diversity poor	21	8	83	0%	6%	1	No	_
Riparian Habitat	No riparian buffer	19	8	71	50%	21%	0.067	Yes	30%
	Low shading	21	8	83	0%	4%	1	No	_

Table 6. Water Chemistry Biological Stressor Identification Analysis Results for the Youghiogheny River Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Chemistry - Inorganic	High chlorides	21	8	172	0%	6%	1	No	_
	High conductivity	21	8	172	0%	8%	1	No	_
	High sulfates	21	8	172	0%	8%	1	No	_
Chemistry - Nutrients	Dissolved oxygen < 5mg/l	21	8	166	0%	2%	1	No	_
	Dissolved oxygen < 6mg/l	21	8	166	0%	5%	1	No	_
	Low dissolved oxygen saturation	21	8	166	0%	7%	1	No	_
	High dissolved oxygen saturation	21	8	166	0%	4%	1	No	_
	Ammonia acute with salmonid present	21	8	172	0%	0%	1	No	_
	Ammonia acute with salmonid absent	21	8	172	0%	0%	1	No	_
	Ammonia chronic with early life stages present	21	8	172	0%	0%	1	No	_
	Ammonia chronic with early life stages absent	21	8	172	0%	0%	1	No	_
	High total nitrogen	21	8	172	13%	6%	0.402	No	_
	High total phosphorus	21	8	172	13%	8%	0.509	No	_
	High orthophosphate	21	8	172	13%	8%	0.484	No	_
Chemistry - pH	Acid neutralizing capacity below chronic level	21	8	172	38%	6%	0.013	Yes	32%
	Acid neutralizing capacity below episodic level	21	8	172	75%	44%	0.144	No	_
	Low field pH	21	8	166	38%	11%	0.065	Yes	26%
	High field pH	21	8	166	0%	1%	1	No	_
	Low lab pH	21	8	172	38%	5%	0.011	Yes	32%
	High lab pH	21	8	172	0%	2%	1	No	_

Table 7. Summary of Combined Attributable Risk Values of the Stressor Group in the Youghiogheny River Watershed

Stressor Group	% of degraded sites associated with specific stressor group (attributable risk)
Instream Habitat	35%
Riparian Habitat	30%
Chemistry - pH	32%
All Chemistry	32%
All Stressors	***80%***

4.2 Stressors Identified by BSID Analysis

All five stressor parameters identified by the BSID analysis (Tables 5 and 6), are significantly associated with biological degradation in the Youghiogheny River watershed and are representative of impacts from urban developed landscapes.

Sediment Conditions

BSID analysis results for the Youghiogheny River did not identify any stressor parameters that have a statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community) (Table 4).

In-stream Habitat Conditions

BSID analysis results for the Youghiogheny River watershed identified one instream habitat parameter, *velocity/ depth diversity marginal to poor*, that has statistically significant association with poor to very poor stream biological condition (i.e., removal of stressor would result in improved biological community) (Table 5).

Velocity/Depth Diversity is a visual observation and quantitative measurement based on the variety of velocity/depth regimes present at a site (i.e., slow-shallow, slow-deep, fast-shallow, and fast-deep). The increase in the number of different velocity/depth regimes likely increases the abundance and diversity of fish species within the stream segment. The decrease in the number of different velocity/depth regimes likely decreases the abundance and diversity of fish species within the stream segment. The 'marginal' or 'poor' diversity categories could identify the absence of available habitat to sustain a diverse aquatic community. This measure may reflect natural conditions (e.g., bedrock),

anthropogenic conditions (e.g., widened channels, dams, channel dredging, etc.) or excessive erosional conditions (e.g., bar formation, entrenchment, etc.).

Velocity/depth diversity conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, defined as the stream segment being dominated by one velocity/depth regime, usually pools; and 2) marginal, defined as having only two out of the four velocity/depth diversity regimes present with in the stream segment. Conditions considered for the BSID analysis are velocity/depth diversity marginal to poor and velocity/depth diversity poor.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the instream habitat stressor group is approximately 35% suggesting these stressors impacts a moderate proportion of the degraded stream miles in the Youghiogheny River watershed (See Table 7).

Riparian Habitat Conditions

BSID analysis results for the Youghiogheny River watershed identified one riparian habitat parameter, *no riparian buffer*, that has statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community) (Table 5).

Riparian Buffer Width represents the minimum width of vegetated buffer in meters, looking at both sides of the stream. Riparian buffer width is measured from 0 m to 50 m, with 0 m having no buffer and 50 m having a full buffer. Riparian buffers serve a number of critical ecological functions. They control erosion and sedimentation, modulate stream temperature, provide organic matter, and maintain benthic macroinvertebrate communities and fish assemblages (Lee, Smyth, and Boutin 2004).

Riparian buffer threshold values are determined by comparing the 10th percentile width among very poor, poor, fair, and good biological conditions. A statistically significant minimum riparian buffer threshold value was not identified when considering data statewide or within any of the three eco-regions. It was decided that a stream segment having no (zero meters) riparian buffer width would indicate a potential impact to biological degradation. The condition considered for the BSID analysis is no riparian buffer. Approximately 30% of stream miles with poor or very poor biological conditions in the Youghiogheny River watershed have no riparian buffer.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the riparian habitat group is approximately 30% suggesting these stressors impacts a moderate proportion of the degraded stream miles in the Youghiogheny River watershed (See Table 7).

Water Chemistry Conditions

BSID analysis results for the Youghiogheny River watershed identified three water chemistry parameters that have statistically significant association with a very poor to poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters are *low lab pH, low field pH, and acid neutralizing capacity below chronic level (ANC)*(Table 6).

Low pH was identified as significantly associated with degraded biological conditions in the Youghiogheny River watershed and found to impact approximately 32% (lab pH) and 26% (field pH) of the stream miles with poor to very poor biological conditions. MDDNR MBSS collects pH samples once during the spring, which are analyzed in the laboratory (*pH lab*), and measured once in situ during the summer (*pH field*). pH is a measure of acidity that uses a logarithmic scale ranging from 0 to 14, with 7 being neutral. Most stream organisms prefer a pH range of 6.5 to 8.5. *Low pH* values (less than 6.5) can be damaging to aquatic life. Low pH may allow concentrations of toxic elements (such as ammonia, nitrite, and aluminum) and high amounts of dissolved heavy metals (such as copper and zinc) to be mobilized for uptake by aquatic plants and animals. The pH threshold values, at which levels below 6.5 and above 8.5 may indicate biological degradation, are established from state regulations (COMAR 2013 c, d). Some types of plants and animals are able to tolerate acidic waters. Others, however, are acid-sensitive and will be lost as the pH declines. Generally, the young of most species are more sensitive to environmental conditions than adults. At pH 5, most fish eggs cannot hatch. At lower pH levels, some adult fish die (Baker et al 1990). Low pH values are a common occurrence in surface waters affected by AMD.

Low ANC below chronic level was identified as significantly associated with degraded biological conditions in the Youghiogheny River basin and found in approximately 32% of the stream miles with poor to very poor biological conditions. ANC is a measure of the capacity of dissolved constituents in the water to react with and neutralize acids. ANC can be used as an index of the sensitivity of surface waters to acidification. The higher the ANC, the more acid a system can assimilate before experiencing a decrease in pH. Repeated additions of acidic materials, like those found in AMD, generally cause a decrease in ANC. ANC values less than 50µeq/l are considered to demonstrate chronic (highly sensitive to acidification) exposures for aquatic organisms, and values less than 200 are considered to demonstrate episodic (sensitive to acidification) exposures (Kazyak et al 2005, Southerland et al 2007).

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the water chemistry stressor group is approximately 32% suggesting that these stressors impact a moderate proportion of degraded stream miles in the Youghiogheny River watershed (Table 7).

4.3 Discussion

The BSID process has determined that biological communities in the Youghiogheny River are in large part degraded due to water chemistry stressors related to acidity. Specifically, the neutralizing capacity (ANC) of the basin's geology is insufficient to counter probable sources of acidity, including natural and anthropogenic sources. Potential sources of acid include atmospheric deposition (e.g., CO_2 (natural), NO_X, SO_X), natural and anthropogenic (AMD) exposure of pyritic geology to water and oxygen, agricultural nitrogen fertilizers, and natural decomposition of organic materials in wetlands. This BSID results confirms the establishment of a USEPA approved pH TMDL in 2007 as an appropriate management action to begin addressing the impact of this stressor on the biological communities in the Youghiogheny River.

Marginal in-stream habitat conditions identified in the Youghiogheny River BSID are related to deficiency of a variety of depths and velocities observed within 75 meter stream stations. Channel modifications such as dams, channelization, or channel widening could result in such conditions, thus directly influence biological conditions. It is also plausible that marginal depth/velocity diversities may result naturally in the Youghiogheny River watershed due to the extent of physical extremes associated with the basin (e.g., slow moving streams across broad highland areas or rapid sheet flow over sloping sheets of bedrock). Such communities may naturally support fewer species such that they either approximate degraded biological conditions or are more vulnerable to additional biological stressors.

A third possible process that could result in more homogenous depth and velocity structure involves excess erosion/sedimentation processes that could result in bar formation or entrenchment resulting in loss of habitat diversity. Although this BSID analysis did not identify any related sediment stressors, it is noteworthy to point out that inclusion of data from an older dataset (MBSS round one) that triples the total number of stations and the number of cases (i.e., biologically impaired stations) identifies three additional *sediment* related stressors, 'channel alteration poor', 'high embeddedness', and 'epifaunal substrate marginal to poor'. The analysis of round one, two, and three BSID results support the establishment of a USEPA approved Total Suspended Solids TMDL in 2006 as an appropriate management action to begin addressing sediment related impacts on the biological communities in the Youghiogheny River.

The BSID analysis evaluates numerous key stressors using the most comprehensive data sets available that meet the requirements outlined in the methodology report. It is important to recognize that stressors could act independently or act as part of a complex causal scenario (e.g., urbanization, habitat modification). Also, uncertainties in the analysis could arise from the absence of unknown key stressors and other limitations of the principal data set. The results are based on the best available data at the time of evaluation.

4.4 Final Causal Model for the Youghiogheny River Watershed

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr 1991; USEPA 2013). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 6 illustrates the final causal model for the Youghiogheny watershed, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

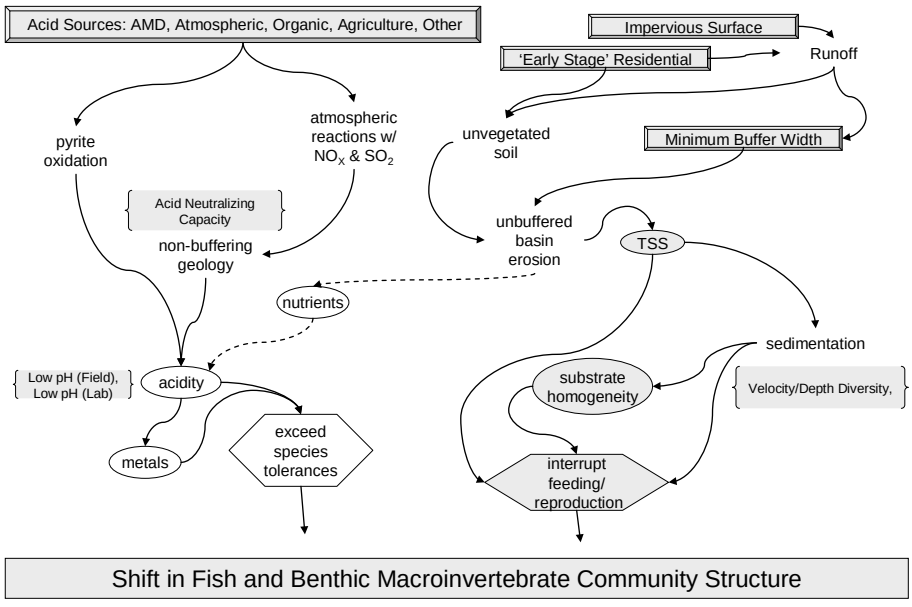


Figure 6. Final Causal Model for the Youghiogheny River Watershed

5.0 Conclusions

Data suggest that the Youghiogheny River watershed's biological communities are influenced by acidity and habitat availability. Based upon the results of the BSID process, the probable causes and sources of the biological impairments of the Youghiogheny River watershed are summarized as follows:

- The BSID process has determined that biological communities in Youghiogheny River are likely degraded due to acidity related stressors. There are localized areas within the watershed impacted by acidity due to the absence of buffering geology as well as the presence of multiple acid sources. The BSID results confirm the establishment of a USEPA approved pH TMDL in 2008 was an appropriate management action to begin addressing the impact of this stressor on the biological communities in the Youghiogheny River.

- The BSID process has also determined that biological communities in Youghiogheny River are likely degraded due habitat related stressors. Specifically, lack of riparian buffers and marginal to poor in-stream velocity/depth diversity are probable causes of impacts to biological communities. Additional analysis of MBSS round one biological data identifies sediment related stressors as impacting biological communities in the Youghiogheny River watershed. Sedimentation and loss of stream habitat diversity are typical "steps" in causal pathways leading to degraded conditions in stream ecosystems. Therefore, MDE considers the 2006 TSS TMDL to be the first step to address this decrease in habitat diversity causing stream degradation.

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