Watershed Report for Biological Impairment of the Non-Tidal Potomac River Montgomery County Watershed, Montgomery and Frederick Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation

REVISED FINAL

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List of Abbreviations

AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
MD	Maryland
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
MH	Mantel-Haenszel
mg/L	Milligrams per liter
NPDES	National Pollution Discharge Elimination System
PCBs	Polychlorinated Biphenyls
RESAC	Regional Earth Science Application Center
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
WMA	Wildlife Management Area
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Facility

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*, 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 Maryland Department of the Environment (MDE) has identified the non-tidal waters of the Potomac River Montgomery County (MD basin number 02140202) in Maryland's Integrated Report as impaired by nutrients, sediments (1996 listings); impacts to biological communities—non-tidal waters (2006 listing); and polychlorinated biphenyls (PCBs) in fish tissues non-tidal waters (2006 listing). The 1996 nutrients listing was refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance. Similarly, the 1996 suspended sediment listing was refined in the 2008 Integrated Report to a listing for total suspended solids.

In 2002, the State began listing biological impairments on the Integrated Report. The current 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, how TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds with multiple impacted sites by measuring the percentage of stream miles that have an Index of Biotic Integrity (IBI) score less than 3, and calculating whether this is significantly different from a reference condition watershed (i.e., healthy stream, <10% stream miles degraded).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the waters of the Potomac River Montgomery County is Use I-P (Water Contact Recreation, Protection of Nontidal Warmwater Aquatic Life, and Public Water Supply) (COMAR 2010 a,b,c). The Potomac River Montgomery County watershed is not attaining its designated use of protection of aquatic life because of biological impairments. 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-controlled, risk-based approach to systematically and objectively

determine the predominant cause of reduced biological conditions, which will enable 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 the 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 (pollutants) 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 Potomac River Montgomery County watershed report presents a brief discussion of the BSID process on which the watershed analysis is based; the process may be reviewed in more detail in the report entitled *Maryland Biological Stressor Identification Process* (MDE 2009). Data suggest that the degradation of biological communities in the Potomac River Montgomery County is strongly influenced by urban land use and its concomitant effects: altered hydrology and elevated levels of chlorides, sulfates, and conductivity from impervious surface runoff. The urbanization of landscapes creates broad and interrelated forms of degradation (i.e., hydrological, morphological, and water chemistry) that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between highly urbanized landscapes and degradation in the aquatic health of non-tidal stream ecosystems.

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

- The BSID process has determined that biological communities in Potomac River Montgomery County are likely degraded due to sediment and in-stream habitat related stressors. Specifically, altered hydrology and increased runoff from urban impervious surfaces have resulted in channel alteration, channel erosion, scouring and transport of suspended sediments in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results confirm the establishment of USEPA approved sediment TMDL in 2011 was an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Potomac River Montgomery County.

- The BSID process has determined that the biological communities in the Potomac River Montgomery County are likely degraded due to inorganic pollutants (i.e., chlorides and sulfates). Chloride and sulfates levels are significantly associated with degraded biological conditions and found in approximately 30% and 14% of the stream miles with poor to very poor biological conditions in the watershed. Impervious surfaces and urban runoff cause an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to

surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed. The BSID results thus support Category 5 listings of chloride and sulfate as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Potomac River Montgomery County watershed.

- BSID analysis did not identify any nutrient related stressors present and/or showing a significant association with degraded biological conditions.

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. The 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 2008). 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 blackwater 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 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 Maryland Biological Stream Survey (MBSS) dataset (2000–2004) 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 (pollutants) 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 Potomac River Montgomery County watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Potomac River Montgomery County Watershed Characterization

2.1 Location

The Potomac River Montgomery County watershed, which is located predominately in Montgomery County, MD, covers 89,617 acres. Small portions also extend into Frederick County, MD (448 acres) and Washington, DC (1,369 acres). The watershed contains the mainstem of the Potomac River within Montgomery County and all tributaries except Seneca Creek and Cabin John Creek.
(see Figure 1). The watershed encompasses numerous sub-watersheds: Little Monocacy River, Broad Run, Horsepen Branch, Muddy Branch, Watts Branch, and Piney Branch.

The headwaters of the Little Monocacy River begin in the rural countryside along Comus Road southwest of the town of Comus. Agriculture is the most prevalent land use in this sub-watershed, withthe small towns of Barnesville, Sellman, and Dickerson representing the only concentrated areas of imperviousness (MCDEP 2009).

Broad Run originates west of Poolesville near Wasche and West Hunter Road. Flowing south toward the Potomac River, it passes through a part of Montgomery County that has changed little in the past one hundred years. This region, a part of the County's agricultural preserve, is characterized by rolling hills and many forested stream buffer areas (MCDEP 2009).

Horsepen Branch originates south of Poolesville near the intersection of Westerly and West Willard Road. Horsepen Branch is a typical piedmont headwater stream with a series of pools and riffles along its length. At River Road, the Horsepen Branch abruptly leaves the upland areas around Poolesville and enters the Potomac River floodplain in the McKee-Besher Wildlife Management Area (WMA). Many areas of the stream within the WMA have been impounded to provide different types of wetland habitat for many kinds of wildlife (MCDEP 2009).

Muddy Branch originates in the City of Gaithersburg and, like many of the tributaries of the mid-Potomac basin in Montgomery County, has been influenced by development, which occurred early in the County's history along major transportation corridors such as

Route 355 and the railroad. Developed areas with the highest levels of imperviousness are located in the headwaters of the watershed (MCDEP 2009).

The Watts Branch sub-watershed consists primarily of residential land uses. The City of Rockville occupies the headwaters of Watts Branch, and over time, the I-270 corridor has been significantly developed making the upper portion of the sub-watershed a major population center. Land uses gradually transition to lower densities and predominately residential uses in the downstream reaches of Watts Branch (MCDEP 2009).

The Piney Branch tributary was designated a Special Protection Area in 1995 in recognition of the high quality of stream condition and the need for special protection measures as its upper reaches become developed. The high water quality and cool steady baseflow found in this tributary are important to maintaining conditions downstream in the mainstem. This fragile tributary has a relatively small channel and is particularly sensitive to flow conditions, with very little assimilative capacity to deal with impacts (MCDEP 2009).

The Potomac River Montgomery County watershed is located in Highlands and Eastern Piedmont regions, two of the three distinct eco-regions identified in the MBSS indices of biological integrity (IBI) metrics (Southerland et al. 2005) (see Figure 2).

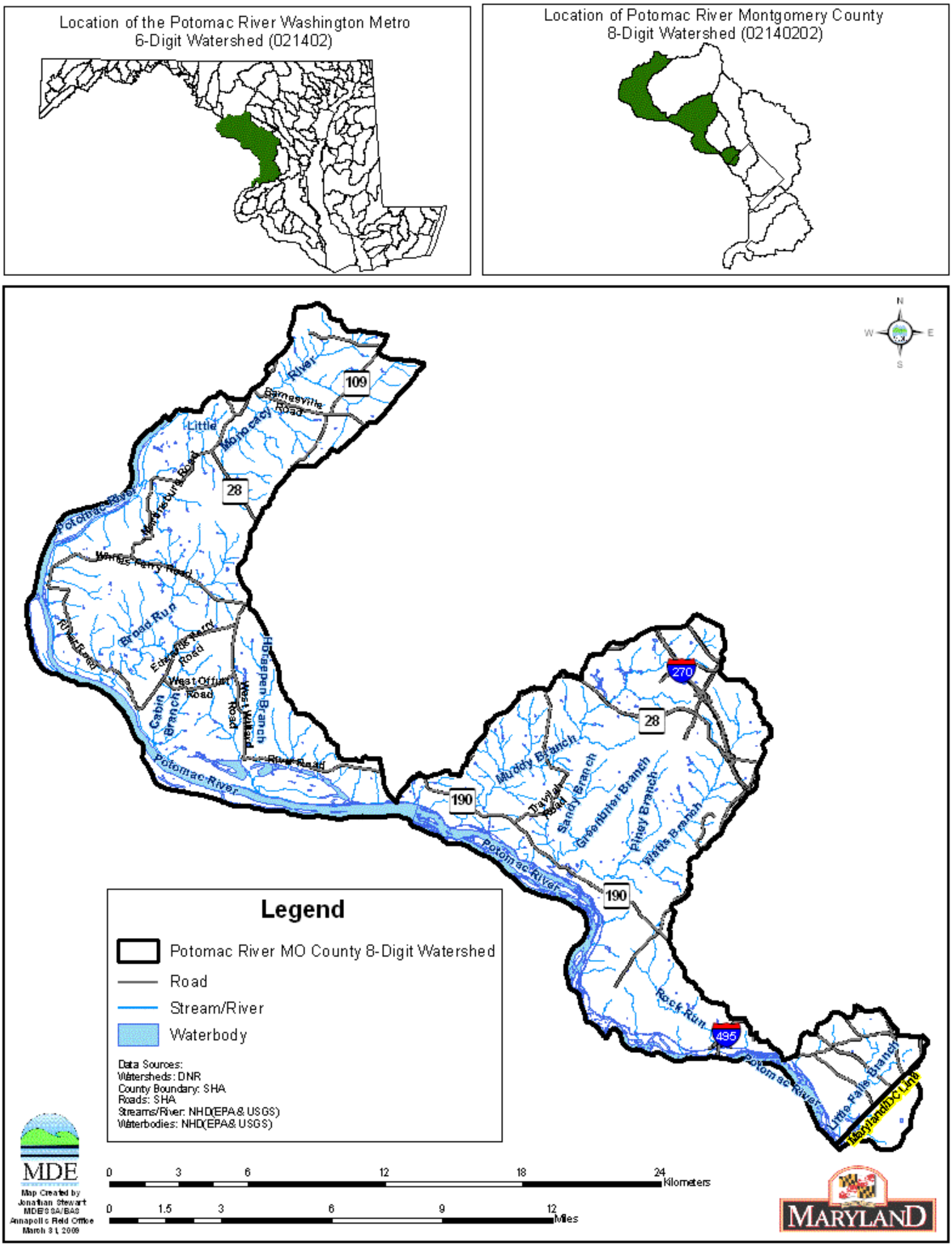

Figure 1. Location Map of the Potomac River Montgomery County Watershed

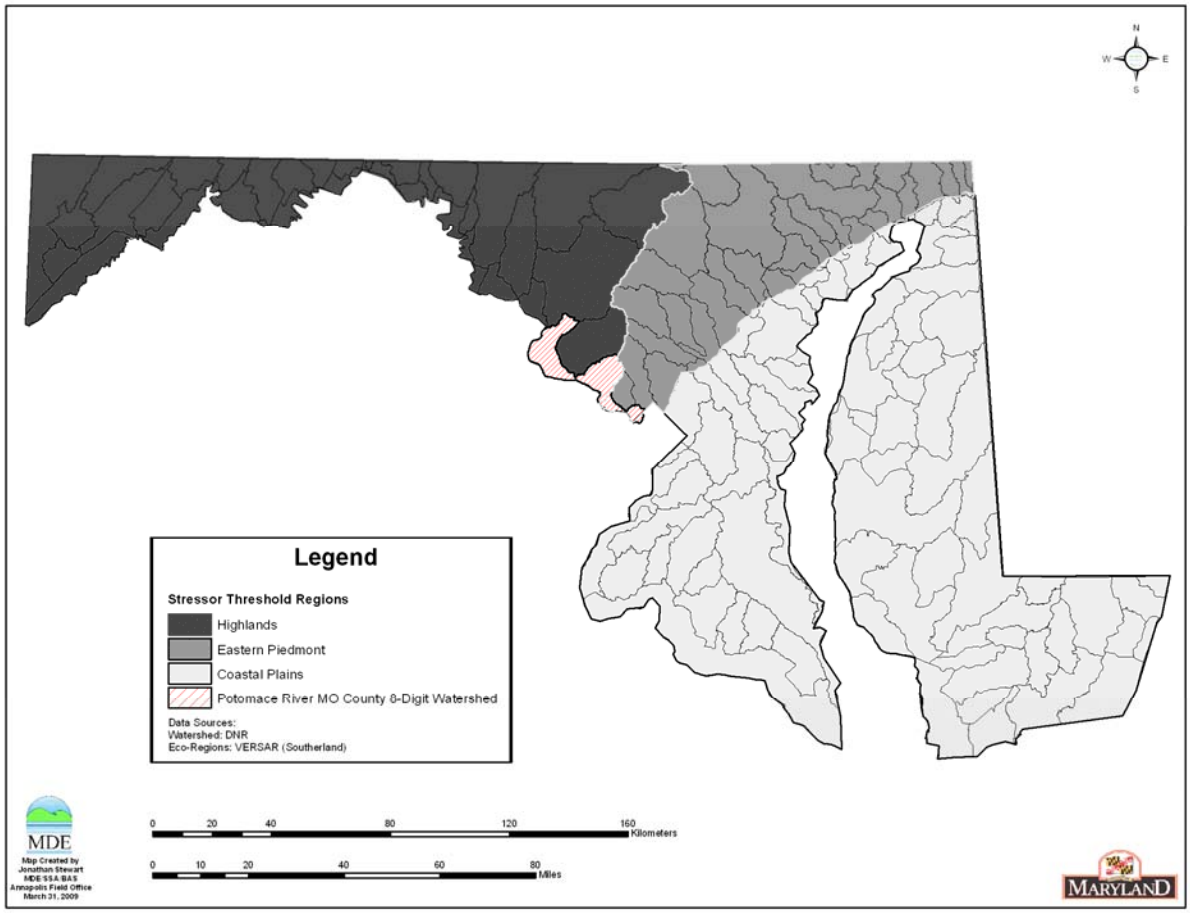

Figure 2. Eco-Region Location Map of the Potomac River Montgomery County

2.2 Land Use

The Potomac River Montgomery County watershed comprises a 130 square miles drainage area, located predominately in Montgomery County, Maryland. The eastern portion of the watershed contains highly urbanized areas of old and newly developed suburban neighborhoods. The western portion of the watershed contains areas of agriculture and rural pastures; there is a scattering of forested parklands throughout the watershed (see Figure 3). Based on the Chesapeake Bay Program's Phase 5.2 Watershed Model, urban land occupies approximately 42% of the watershed (7% impervious surfaces), with 38% of the watershed forested, and 20% agricultural (see Figure 4).

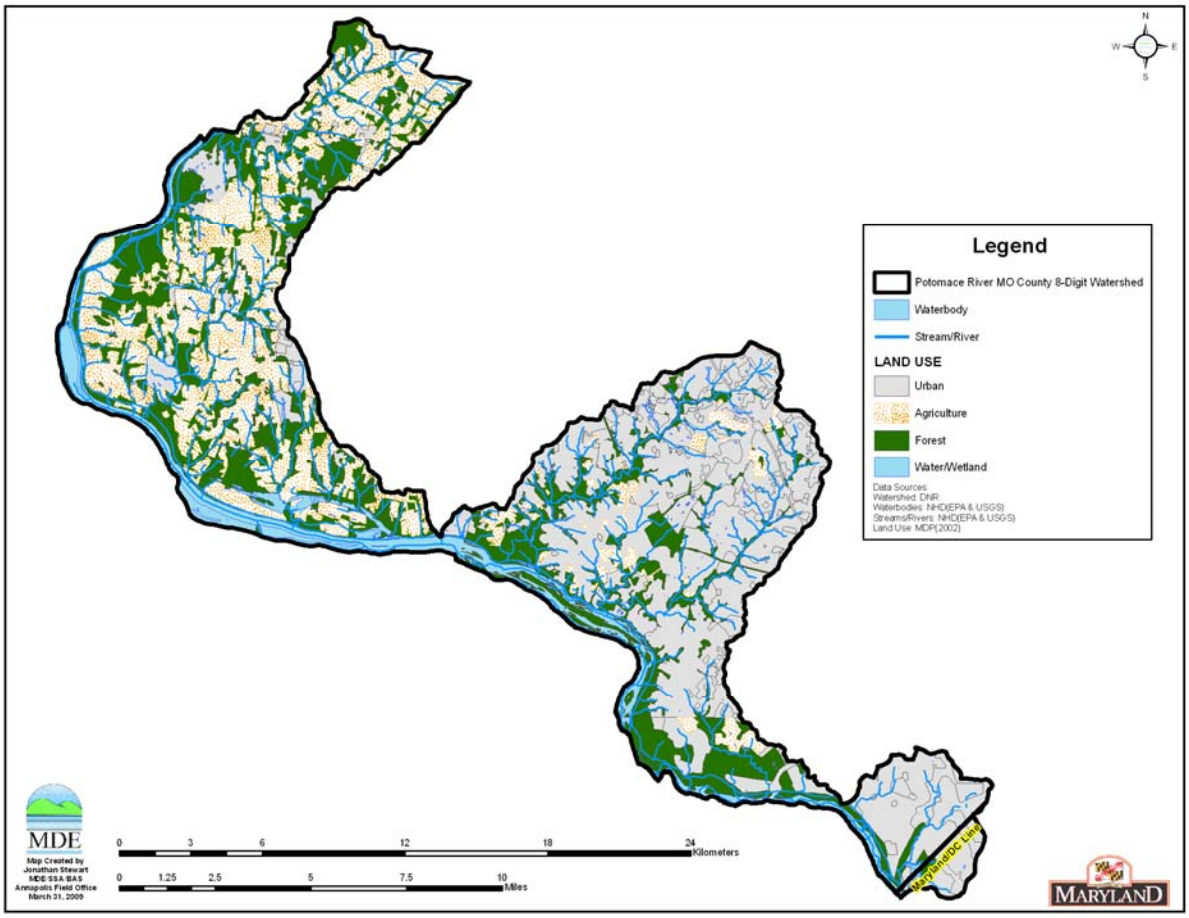

Figure 3. Land Use Map of the Potomac River Montgomery County Watershed

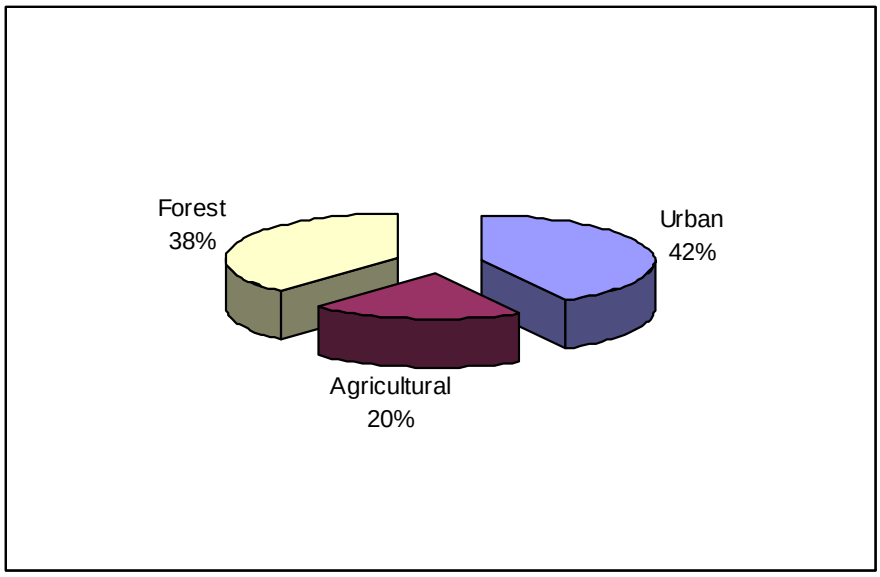

Figure 4. Proportions of Land Use in the Potomac River Montgomery County Watershed

2.3 Soils/hydrology

Based on the Maryland Geological Survey the Potomac River Montgomery County watershed lies within the Piedmont Plateau Physiographic Province. Most of the watershed contains rolling to hilly uplands interrupted by steep-walled gorges. However, in the very western section the topography becomes relatively flat to gentle rolling surfaces with distinctive red soils. Lands immediately adjacent to the Potomac River mainstem occupy a well-defined floodplain.

With the exception of the broad lowland in the western portion of the watershed, the Piedmont Plateau Province area is characterized by rounded hills and V-shaped valleys cut in pre-Cambrian schists and gneisses which have been intruded in many places by younger igneous rocks. Deep zones of soil and weathered rock are common in the valley walls and beneath the uplands (MGS 2007).

Soils typically found in the Potomac River Montgomery County watershed are the Chrome, Baile, Penn, Lehigh, and Waynesboro series. The Chrome series consists of moderately deep, well drained soils. The Baile series consists of very deep, poorly drained, moderately low to moderately high saturated hydraulic conductivity, soils on upland depressions and footslopes. The Penn series consists of moderately deep, well drained soils formed in residuum weathered from noncalcareous reddish shale, siltstone, and fine-grained sandstone of the Triassic age. The Lehigh series consists of deep, moderately well and somewhat poorly drained soils formed in residuum from metamorphosed sandstone and shale. The Waynesboro series consist of very deep, well

drained, moderately permeable soils that formed in old alluvium or unconsolidated material of sandstone, shale, and limestone origin (U.S. Department of Agriculture (USDA) 1977).

3.0 Potomac River Montgomery County Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Maryland Department of the Environment (MDE) has identified the non-tidal waters of the Potomac River Montgomery County (MD basin number 02140202) in Maryland's Integrated Report as impaired by nutrients, sediments (1996 listings); impacts to biological communities—non-tidal waters (2006 listing); and polychlorinated biphenyls (PCBs) in fish tissues non-tidal waters (2006 listing). The 1996 nutrients listing was refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance. Similarly, the 1996 suspended sediment listing was refined in the 2008 Integrated Report to a listing for total suspended solids.

3.2 Impacts to Biological Communities

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the waters of the Potomac River Montgomery County is Use I-P (Water Contact Recreation, Protection of Nontidal Warmwater Aquatic Life, and Public Water Supply) (COMAR 2009 a,b,c). 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 Potomac River Montgomery County watershed is listed under Category 5 of the 2008 Integrated Report as impaired for impacts to biological communities. Approximately 67% of stream miles in the Potomac River Montgomery County basin are estimated as having fish and and/or benthic indices of biological impairment in the very poor to 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 forty-two sites. Twenty-eight of the forty-two 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, i.e. MBSS Round 2 contains thirty MBSS sites with twenty-two having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Potomac River Montgomery County watershed.

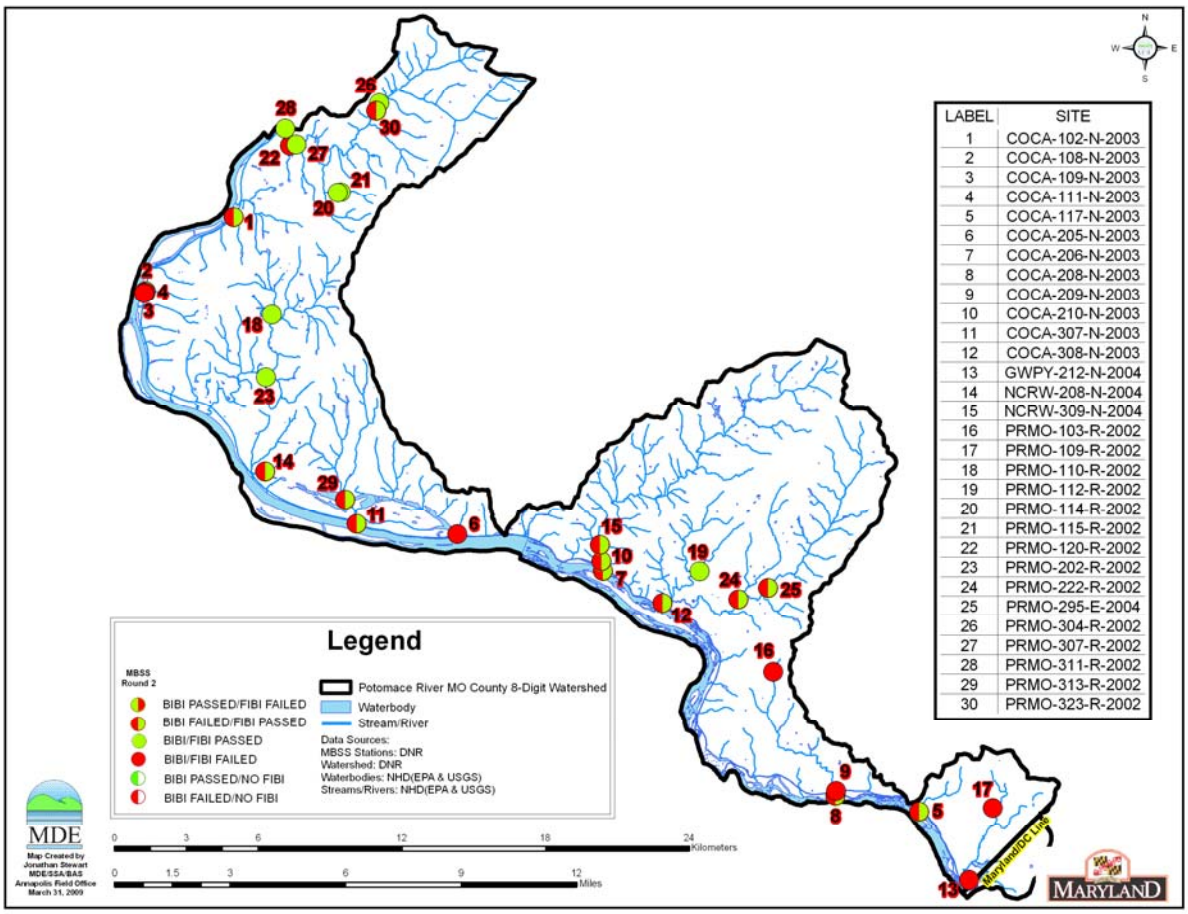

Figure 5. Principle Dataset Sites for the Potomac River Montgomery County Watershed

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 significantly 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 – 1st and 2nd-4th order), that have 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-Haenszel (MH) (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 very poor to 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 very poor to 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 very poor to poor biological conditions within the watershed (i.e., cases). The attributable risk (AR) defined herein is the portion of the cases with very poor to 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).

Through the BSID analysis, MDE identified sediment, in-stream habitat, water chemistry parameters, and potential sources significantly associated with poor to very poor benthic and/or fish biological conditions. As shown in Table 1 through Table 3, parameters from the sediment, habitat, and water chemistry groups are identified as possible biological

stressors in the Potomac River Montgomery County watershed. Parameters identified as representing possible sources are listed in Table 4 and include various urban land use types. A summary of combined AR values for each stressor group is shown in Table 5. A summary of combined AR values for each source group is shown in Table 6.

Table 1. Sediment Biological Stressor Identification Analysis Results for Potomac River Montgomery County 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 Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Sediment	extensive bar formation present	30	22	76	32%	12%	Yes	20%
	moderate bar formation present	30	22	76	64%	46%	No	----
	bar formation present	30	22	76	91%	90%	No	----
	channel alteration marginal to poor	30	22	76	68%	45%	Yes	23%
	channel alteration poor	30	22	76	36%	11%	Yes	25%
	high embeddedness	30	22	76	23%	4%	Yes	18%
	epifaunal substrate marginal to poor	30	22	76	41%	16%	Yes	26%
	epifaunal substrate poor	30	22	76	18%	2%	Yes	16%
	moderate to severe erosion present	30	22	76	64%	35%	Yes	28%
	severe erosion present	30	22	76	27%	6%	Yes	21%
	poor bank stability index	30	22	76	50%	5%	Yes	45%
	silt clay present	30	22	76	95%	99%	No	----

Table 2. Habitat Biological Stressor Identification Analysis Results for the Potomac River Montgomery County 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 Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
In-Stream Habitat	channelization present	30	22	78	14%	11%	No	----
	instream habitat structure marginal to poor	30	22	76	36%	15%	Yes	22%
	instream habitat structure poor	30	22	76	14%	1%	Yes	13%
	pool/glide/eddy quality marginal to poor	30	22	76	50%	36%	No	----
	pool/glide/eddy quality poor	30	22	76	9%	4%	No	----
	riffle/run quality marginal to poor	30	22	76	41%	22%	Yes	20%
	riffle/run quality poor	30	22	76	9%	5%	No	----
	velocity/depth diversity marginal to poor	30	22	76	45%	40%	No	----
	velocity/depth diversity poor	30	22	76	0%	4%	No	----
	concrete/gabion present	30	22	78	14%	4%	Yes	9%
	beaver pond present	30	22	76	0%	2%	No	----
Riparian Habitat	no riparian buffer	30	22	78	32%	22%	No	----
	low shading	30	22	76	5%	13%	No	----

Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Potomac River Montgomery County 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 Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Water Chemistry	high total nitrogen	30	22	161	9%	19%	No	----
	high total dissolved nitrogen	0	0	0	0%	0%	No	----
	ammonia acute with salmonid present	30	22	161	0%	3%	No	----
	ammonia acute with salmonid absent	30	22	161	0%	2%	No	----
	ammonia chronic with salmonid present	30	22	161	5%	7%	No	----
	ammonia chronic with salmonid absent	30	22	161	0%	3%	No	----
	low lab pH	30	22	161	0%	4%	No	----
	high lab pH	30	22	161	9%	1%	Yes	8%
	low field pH	30	22	157	0%	11%	No	----
	high field pH	30	22	157	0%	1%	No	----
	high total phosphorus	30	22	161	9%	4%	No	----
	high orthophosphate	30	22	161	9%	5%	No	----
	dissolved oxygen < 5mg/l	30	22	157	5%	2%	No	----
	dissolved oxygen < 6mg/l	30	22	157	9%	6%	No	----
	low dissolved oxygen saturation	22	15	142	7%	3%	No	----
	high dissolved oxygen saturation	22	15	142	0%	1%	No	----
	acid neutralizing capacity below chronic level	30	22	161	0%	5%	No	----
	acid neutralizing capacity below episodic level	30	22	161	0%	33%	No	----
	high chlorides	30	22	161	36%	7%	Yes	30%
	high conductivity	30	22	161	23%	4%	Yes	18%
	high sulfates	30	22	161	18%	4%	Yes	14%

Table 4. Stressor Source Identification Analysis Results for the Potomac River Montgomery County Watershed

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Urban	high impervious surface in watershed	30	22	158	50%	1%	Yes	49%
	high % of high intensity urban in watershed	30	22	161	55%	9%	Yes	46%
	high % of low intensity urban in watershed	30	22	161	59%	7%	Yes	52%
	high % of transportation in watershed	30	22	161	41%	9%	Yes	32%
	high % of high intensity urban in 60m buffer	30	22	160	41%	5%	Yes	36%
	high % of low intensity urban in 60m buffer	30	22	160	59%	7%	Yes	52%
	high % of transportation in 60m buffer	30	22	160	23%	8%	Yes	15%
Sources Agriculture	high % of agriculture in watershed	30	22	161	14%	10%	No	----
	high % of cropland in watershed	30	22	161	0%	5%	No	----
	high % of pasture/hay in watershed	30	22	161	14%	14%	No	----
	high % of agriculture in 60m buffer	30	22	160	5%	8%	No	----
	high % of cropland in 60m buffer	30	22	160	0%	4%	No	----
	high % of pasture/hay in 60m buffer	30	22	160	18%	12%	No	----
Sources Barren	high % of barren land in watershed	30	22	161	23%	8%	Yes	15%
	high % of barren land in 60m buffer	30	22	160	18%	7%	Yes	11%

Table 4. Stressor Source Identification Analysis Results for the Potomac River Montgomery County Watershed (Cont.)

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor2 (Odds of stressor in cases significantly higher that odds or sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Anthropogenic	low % of forest in watershed	30	22	161	59%	6%	Yes	53%
	low % of forest in 60m buffer	30	22	160	23%	6%	Yes	16%
Sources Acidity	atmospheric deposition present	30	22	161	0%	29%	No	----
	AMD acid source present	30	22	161	0%	3%	No	----
	organic acid source present	30	22	161	0%	2%	No	----
	agricultural acid source present	30	22	161	0%	2%	No	----

Table 5. Summary AR Values for Stressor Groups for Potomac River Montgomery County

Stressor Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Sediment	85%	92%
In-Stream Habitat	47%	
Riparian Habitat	----	
Water Chemistry	47%	

Table 6. Summary AR Values for Source Groups for Potomac River Montgomery County

Source Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Urban	57%	79%
Agriculture	----	
Barren Land	20%	
Anthropogenic	53%	
Acidity	----	

Sediment Conditions

BSID analysis results for the Potomac River Montgomery County identified nine sediment parameters that have a statistically significant association with poor to very poor stream biological condition: *extensive bar formation present, channel alteration (marginal to poor & poor), high embeddedness, epifaunal substrate (marginal to poor & poor), erosion present (moderate to severe & severe),* and *poor banks stability index.*

Extensive bar formation present was identified as significantly associated with degraded biological conditions and found in 20% of the stream miles with very poor to poor biological conditions in the Potomac River Montgomery County watershed. This stressor measures the movement of sediment in a stream system, and typically results from significant deposition of gravel and fine sediments. Although some bar formation is natural, extensive bar formation indicates channel instability related to frequent and intense high flows that quickly dissipate and rapidly lose the capacity to transport the sediment loads downstream. Excessive sediment loading is expected to reduce and homogenize available feeding and reproductive habitat, degrading biological conditions.

Channel alteration was identified as significantly associated with degraded biological conditions in the Potomac River Montgomery County watershed, and found to impact approximately 23% (*moderate to poor* rating) and 25% (*poor* rating) of the stream miles with poor to very poor biological conditions. Channel alteration measures large-scale modifications in the shape of the stream channel due to the presence of artificial structures (channelization) and/or bar formations. Marginal to poor and poor ratings are expected in unstable stream channels that experience frequent high flows.

High Embededdness was identified as significantly associated with degraded biological conditions and found in 18% of the stream miles with very poor to poor biological conditions in the Potomac River Montgomery County watershed. Embeddedness is determined by the percentage of fine sediment surrounding gravel, cobble, and boulder particles in the streambed. Embeddedness is categorized as a percentage from 0% to 100% with low values as optimal and high values as poor. High embeddedness is a result of excessive sediment deposition. Presence of this stressor suggests that sediment may interfere with feeding or reproductive processes and result in biological impairment. Although embeddedness is confounded by natural variability (e.g., Coastal Plain streams will naturally have more embeddedness than Highlands streams), embeddedness values higher than reference streams are indicative of anthropogenic sediment inputs from overland flow or stream channel erosion.

Epifaunal Substrate was identified as significantly associated with degraded biological conditions in the Potomac River Montgomery County watershed, and found to impact approximately 26% (*marginal to poor* rating) and 16% (*poor* rating) of the stream miles with poor to very poor biological conditions. Epifaunal substrate is a visual observation of the abundance, variety, and stability of substrates that offer the potential for full colonization by benthic macroinvertebrates. The varied habitat types such as cobble, woody debris, aquatic vegetation, undercut banks, and other commonly productive surfaces provide valuable habitat for benthic macroinvertebrates. Like embeddedness and epifaunal substrate is confounded by natural variability (i.e., streams will naturally have more or less available productive substrate). Greater availability of productive substrate increases the potential for full colonization; conversely, less availability of productive substrate decreases or inhibits colonization by benthic macroinvertebrates. Epifaunal substrate conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, where stable substrate is lacking, or particles are over 75% surrounded by fine sediment and/or flocculent material; and 2) marginal to poor, where large boulders and/or bedrock are prevalent and cobble, woody debris, or other preferred surfaces are uncommon.

Erosion Severity was identified as significantly associated with degraded biological conditions in the Potomac River Montgomery County watershed, and found to impact approximately 28% (*moderate to severe* rating) and 21% (*severe* rating) of the stream miles with poor to very poor biological conditions. Erosion severity represents a visual observation that the stream discharge is frequently exceeding the ability of the channel and/or floodplain to attenuate flow energy, resulting in channel instability, which in turn affects bank stability. Where such conditions are observed, flow energy is considered to have increased in frequency or intensity, accelerating channel and bank erosion. Increased flow energy suggested by this measure is also expected to negatively influence stream biology.

Erosion severity is described categorically as minimal, moderate, or severe. Conditions indicating biological degradation are set at two levels, moderate and severe. A level of severe indicates that a substantial amount of stream banks show severe erosion and the stream segment exhibits high levels of instability due to erosion. A level of moderate to severe indicates that a marginal amount of stream banks show erosion and the stream segment shows elevated levels of instability due to erosion.

Bank Stability Index was identified as significantly associated with degraded biological conditions and found in 45% of the stream miles with very poor to poor biological conditions in the Potomac River Montgomery County watershed. Bank stability index is a composite score that combines a visual rating based on the presence or absence of riparian vegetation and other stabilizing bank materials (e.g., boulders, root-wads) with quantitative measures of erosion extent and erosion severity. Bank stability index is based on a numeric score from 0-20, with low values as poor and high values as optimal. A poor bank stability index score indicates that the amount of stream bank soil that is being eroded and deposited in the stream is likely different from sites with fair to good biological conditions. In short, bank stability is a measure of channel erosion. Lower scores on this index are considered to demonstrate that discharge is frequently exceeding the ability of the channel and/or floodplain to attenuate flow energy. The index may further identify conditions, in which stream banks are vulnerable regardless of flood severity or frequency, thus demonstrate increased probability of high sediment loadings.

The watershed of the Potomac River Montgomery County and its tributaries contain extensive areas with high-density urban development including: Gaitherburg, Rockville, Glen Echo, and parts of Chevy Chase bordering Washington DC. Many portions of these areas were built before modern stormwater runoff controls were required by the State. The realization that human activities can seriously harm and degrade our waterways led to the authorization of sediment control regulations in the early 1960s, but a statewide sediment and erosion control program did not exist until 1970. About ten years later, in 1982, the Maryland General Assembly passed the State Stormwater Management Act, designed to address stormwater runoff generated during the land development process. Stormwater management helps to settle and filter many pollutants before runoff is discharged into a receiving body of water. But research indicates that most conventional stormwater management controls can still harm streams and rivers. Today, street-level storm drains that flush debris into the river during heavy rains are one of the biggest sources of pollution and “floatable” trash in the watershed (DNR 2002). Accelerated flow from stormwater management discharges can scour streambeds, erode banks, deposit sediment, and decrease overall stream health, stability, and habitat diversity (FCG 2009).

Forty-two percent of the Potomac River Montgomery County watershed contains urban type land uses. As development and urbanization increased in the Potomac River Montgomery County watershed so did the morphological changes that affect a stream’s habitat. The most critical of these environmental changes are those that alter the watershed’s hydrologic regime. Changes to hydrographs are perhaps the most obvious and consistent changes to stream ecosystems influenced by urban land use, with urban

streams tending to be more "flashy", i.e., they have more frequent, larger flow events (Walsh et al. 2005). When stormwater flows through stream channels faster, more often, and with more force, the results are stream channel alteration and streambed scouring. The scouring associated with these increased flows leads to accelerated channel erosion, thereby increasing sediment deposition throughout the streambed either through the formation of bars or settling of sediment in the stream substrate. Some of the impacts associated with sedimentation are smoothing of benthic communities, reduced survival rate of fish eggs, and reduced habitat quality from embedding of the stream bottom (Hoffman et al. 2003).

Changes in channel morphology and streambed scouring are processes that often result in an unstable stream ecosystem that impacts habitat and the dynamics (structure and abundance) of stream benthic organisms (Allan 2004). An unstable stream ecosystem often results in a loss of available habitat and continuous displacement of biological communities from scouring that requires frequent re-colonization and the loss of sensitive taxa, with a shift in biological communities to more tolerant species. All of the stressors identified for the sedimentation parameter groups (e.g., bar formation, channel alteration, erosion severity, bank stability, high embeddedness, and poor epifauanal substrate) are the typical effects of the streambed scouring and sedimentation transport associated with a "flashy" hydrological regime.

The watershed contains a relatively narrow area land bordering the Maryland shore of the Potomac River. Lands immediately adjacent to the Potomac River mainstem occupy a well-defined floodplain. There are numerous MBSS stations on tributaries draining into the mainstem, which have small drainage areas and are heavily influenced by seasonal water table fluctuations due to their location on the Potomac floodplain. The lower reaches of these tributaries are subject to Potomac River floodwaters that back water up into the tributaries and cause bank erosion and sediment deposition. These tributaries' "confluence areas" tend to be highly susceptible to erosion during flood events and to become depositional areas as floodwaters subside. These areas also tend to have cut stream banks and silted bottoms, therefore making the habitat unstable compared to the Potomac River mainstem or the "out-of-influence" upstream tributaries. The unstable habitat in these confluence areas is caused by natural events, although often exacerbated by anthropogenic land-use issues, but it is atypical and should not be compared to reference conditions.

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 sediment stressor group is approximately 85 %, suggesting these stressors impact a substantial proportion of the degraded stream miles in the Potomac River Montgomery County (See Table 5).

In-stream Habitat Conditions

BSID analysis results for the Potomac River Montgomery County identified four in-stream habitat parameter that has a statistically significant association with poor to very poor stream biological condition: *instream habitat structure (marginal to poor & poor), riffle/run quality (marginal to poor),* and *concrete/gabion present.*

In-stream habitat structure was identified as significantly associated with degraded biological conditions in the Potomac River Montgomery County watershed, and found to impact approximately 22% (*marginal to poor* rating) and 13% (*poor* rating) of the stream miles with poor to very poor biological conditions. In-stream habitat is a visual rating based on the perceived value of habitat within the stream channel to the fish community. Multiple habitat types, varied particle sizes, and uneven stream bottoms provide valuable habitat for fish. High in-stream habitat scores are evidence of the lack of sediment deposition. In-stream habitat is confounded by natural variability (i.e., some streams will naturally have more or less in-stream habitat). Low in-stream habitat values can be caused by high flows that collapse undercut banks and by sediment inputs that fill pools and other fish habitats. In-stream habitat conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, which is defined as less than 10% stable habit where lack of habitat is obvious; and 2) marginal to poor, where there is a 10-30% mix of stable habitat but habitat availability is less than desirable.

Riffle/run quality (marginal to poor) was identified as significantly associated with degraded biological conditions in the Potomac River Montgomery County watershed, and found to impact approximately 20% of the stream miles with poor to very poor biological conditions. Riffle/run quality is a visual observation and quantitative measurement based on the depth, complexity, and functional importance of riffle/run habitat within the stream segment. An increase in the heterogeneity of riffle/run habitat within the stream segment likely increases the abundance and diversity of fish species, while a decrease in heterogeneity likely decreases abundance and diversity. Riffle/run quality conditions indicating biological degradation are set at two levels: 1) poor, defined as riffle/run depths < 1 cm or riffle/run substrates concreted; and 2) marginal to poor, defined as riffle/run depths generally 1 – 5 cm with a primarily single current velocity.

Concrete/gabion present was identified as significantly associated with degraded biological conditions in the Potomac River Montgomery County watershed, and found to impact approximately 9% of the stream miles with poor to very poor biological conditions. The presence of concrete/gabion present in a stream inhibits the heterogeneity of stream morphology needed for colonization, abundance, and diversity of fish and benthic communities. Concrete channelization increases flow and provides a homogeneous substrate, conditions which are detrimental to diverse and abundant colonization.

The stressors identified for the in-stream habitat parameter group are intricately linked with habitat heterogeneity. The presence of these in-stream habitat stressors lower the diversity of a stream's microhabitats and substrates, subsequently causing a reduction in the diversity of biological communities. The scouring of streambeds and/or sedimentation, which often occurs in streams with "flashy" hydrologic regimes, results in a more homogeneous in-stream habitat.

Reinforcing a stream with concrete/gabion has been used in the Potomac River Montgomery County watershed for flood control. The purpose is to increase channel capacity and flow velocities so water moves more efficiently downstream. However, using concrete/gabion in a stream is detrimental for the "well being" of streams and rivers through the elimination of suitable habitat and the creation of excessive flows. Stream bottoms are made more uniform. Habitats of natural streams contain numerous bends, riffles, runs, pools and varied flows, and tend to support healthier and more diversified plant and animal communities. The refuge cavities removed by concreting not only provide concealment for fish, but also serve as traps for detritus, and are areas colonized by benthic macroinvertebrates. Subsequently, these streams retained less leaf litter and supported lower densities of detritivore invertebrates than natural streams. The overall densities and biomasses of macroinvertebrates are very low by comparison with intact natural streams (Laasonen et al. 1998; Haapala & Muotka 1998). Consequently, streams with extensive channelization often have impaired biological community with poor IBI scores is observed.

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 in-stream habitat stressor group is approximately 47 % suggesting these stressors impacts a moderate proportion of the degraded stream miles in the Potomac River Montgomery County (See Table 5).

Riparian Habitat Conditions

BSID analysis results for Potomac River Montgomery County did not identify any riparian habitat parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community) (See Table 5).

Water Chemistry

BSID analysis results for the Potomac River Montgomery County identified four 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 *high conductivity, chlorides, sulfates,* and *high lab pH.*

High conductivity levels was identified as significantly associated with degraded biological conditions in the Potomac River Montgomery County, and found to impact approximately 18% of the stream miles with poor to very poor biological conditions. Conductivity is a measure of water's ability to conduct electrical current and is directly related to the total dissolved salt content of the water. Most of the total dissolved salts of surface waters are comprised of inorganic compounds or ions such as chloride, sulfate, carbonate, sodium, and phosphate (IDNR 2008). Urban runoff, road salts, agricultural runoffs (i.e., fertilizers), and leaking wastewater infrastructure are typical sources of inorganic compounds.

High chloride levels are significantly associated with degraded biological conditions in Potomac River Montgomery County, and found to impact approximately 30% of the stream miles with poor to very poor biological conditions. High concentrations of chlorides can result from natural causes, metals contamination, industrial discharges, impervious surface runoff, and application of road salts. There is no known metals impairment in the Potomac River Montgomery County watershed. There are numerous industrial and two municipal wasterwater facilities in the watershed. Since National Pollution Discharge Elimination Sytem (NPDES) permitting enforcement does not require chlorides testing at any of these facilities, data was not available to verify/identify chlorides as a specific pollutant. Smith et al. (1987) have identified that, although chloride can originate from natural sources, in urban watersheds road salts can be a likely source of high chloride and conductivity levels.

High sulfates concentrations are significantly associated with degraded biological conditions and found in 14% of the stream miles with poor to very poor biological conditions in the Potomac River Montgomery County watershed. Sulfates in urban areas can be derived from natural and anthropogenic sources, including combustion of fossil fuels such as coal, oil, diesel, discharge from industrial sources, and discharge from municipal wastewater treatment facilities. The is one industrial facility in the watershed with NPDES permit limitations for sulfate; however, there are no MBSS stations downstream of this discharge.

Currently in Maryland there are no specific numeric criteria that quantify the impact of conductivity, chlorides, and sulfates on the aquatic health of non-tidal stream systems. Since the exact sources and extent of inorganic pollutant loadings are not known, MDE determined that current data are not sufficient to enable identification of all the different compounds of inorganic pollutants found in urban runoff from the BSID analysis.

High lab pH levels above 8.5 was identified as significantly associated with degraded biological conditions in the Potomac River, and found to impact approximately 8% of the stream miles with poor to very poor biological conditions. pH is a measure of the acid balance of a stream and uses a logarithmic scale range from 0 to 14, with 7 being neutral.

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*). Most stream organisms prefer a pH range of 6.5 to 8.5. Exceedances of 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 2007). Intermittent high pH (greater than 8.5) is often associated with elevated nutrient concentrations and eutrophication related to increased algal blooms. Since the BSID analysis for the watershed did not identify dissolved oxygen, phosphorus, or nitrogen as having a significant association with degraded biological conditions, there is no supporting evidence that excessive primary production is occurring in the watershed, at this time.

Water chemistry is another major determinant of the integrity of surface waters that is strongly influenced by land-use. Impervious surfaces allow many types of pollutants, derived from a variety of sources, to accumulate upon them. Many of these pollutants are subsequently washed into water bodies by storm water runoff, severely degrading water quality. Land development and increased impervious surfaces within the Potomac River Montgomery County watershed has lead to increases in contaminant loads from nonpoint sources by adding sediments and inorganic pollutants to surface waters. Increased levels of many pollutants like chlorides and sulfates can be toxic to aquatic organisms and lead to exceedences in species tolerances.

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 47% suggesting that these stressors impact a moderate proportion of degraded stream miles in the Potomac River Montgomery County (Table 5).

Sources

All seventeen stressor parameters, identified in Tables 1-3, that are significantly associated with biological degradation in the Potomac River Montgomery County watershed BSID analysis are representative of impacts from urban landscapes. The watershed contains numerous high-density urban centers including, Gaithersburg, Rockville, Glen Echo, and heavily developed urban areas outside of Washington DC. Many of these areas were built before modern stormwater runoff controls were required by the State.

Scientific literature (Booth 1991, Konrad and Booth 2002, and Meyer et al. 2005) has consistently identified negative impacts to biological conditions as a result of increased urbanization. A number of systematic and predictable environmental responses have been noted in streams affected by urbanization, and this consistent sequence of effects

has been termed "urban stream syndrome" (Meyer et al. 2005). Symptoms of urban stream syndrome include flashier hydrographs, altered habitat conditions, degradation of water quality, and reduced biotic richness, with increased dominance of species tolerant to anthropogenic (and natural) stressors.

Increases in impervious surface cover that accompany urbanization alters stream hydrology, forcing runoff to occur more readily and quickly during rainfall events, decreasing the time it takes water to reach streams and causing them to be more "flashy" (Walsh et al. 2005). Land development can also cause an increase in contaminant loads from point and nonpoint sources by adding sediments, nutrients, road salts, toxics, and inorganic pollutants to surface waters. In virtually all studies, as the amount of impervious area in a watershed increases, fish and benthic communities exhibit a shift away from sensitive species to assemblages consisting of mostly disturbance-tolerant taxa (Walsh et al. 2005). In an effort to link the land cover of watersheds with the quality of the stream life the Mid-Atlantic Regional Earth Science Application Center (RESAC) worked with collaborators at the Maryland Department of Natural Resources, the Montgomery County Department of Environment, and the Maryland National Capitol Parks and Planning Commission. These groups sampled benthic and fish communities in each of 246 small sub-watersheds of the Potomac River watershed within Montgomery County and then combined this data with physical and chemical measurements (like temperature and dissolved oxygen) to create watershed rankings of excellent, good, fair, and poor. Using statistical regression techniques they determined that the factors accounting for the most variation in stream health rating was the proportion of impervious surface area, followed by the proportion of tree cover in a watershed (RESAC 2008).

The BSID source analysis (Table 4) identifies various types of urban and barren land uses, as well as low forest in the watershed as potential sources of stressors that may cause negative biological impacts. The combined AR for the source group is approximately 79% suggesting that urban development and impervious surfaces potentially impacts a substantial proportion of the degraded stream miles in Potomac River Montgomery County (Table 6).

Summary

The Potomac River Montgomery County watershed is a highly urbanized watershed (42%), with approximately 7% impervious surface cover. In urbanizing basins, where small streams must carry increased stormwater runoff, stream characteristics change both physically and biologically. Aquatic life that cannot tolerate the radical changes in the altered stream environment simply disappear because their habitat requirements are no longer being met. A stream that supported a diversity of aquatic species prior to urbanization will often support few species afterward. The results of the BSID analysis suggest that degraded biological communities in the Potomac River Montgomery County

watershed are due to urbanization that has caused alterations to the hydrologic regime and stream morphology.

The results of the BSID analysis also suggest that inorganic water chemistry parameters are degrading biological communities in the Potomac River Montgomery County watershed. Specifically, urbanization and associated impervious surfaces have resulted in the potential for elevated inorganic contaminants in the watershed that may impact biological communities. The combined AR for all the stressors is approximately 92%, suggesting that altered hydrology/sediment, habitat, and water chemistry stressors adequately account for the biological impairment in the Potomac River Montgomery County.

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., eutrophication, 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.

Final Causal Model for the Potomac River Montgomery County

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 1991and USEPA 2010). 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 conceptual model for the Potomac River Montgomery County, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

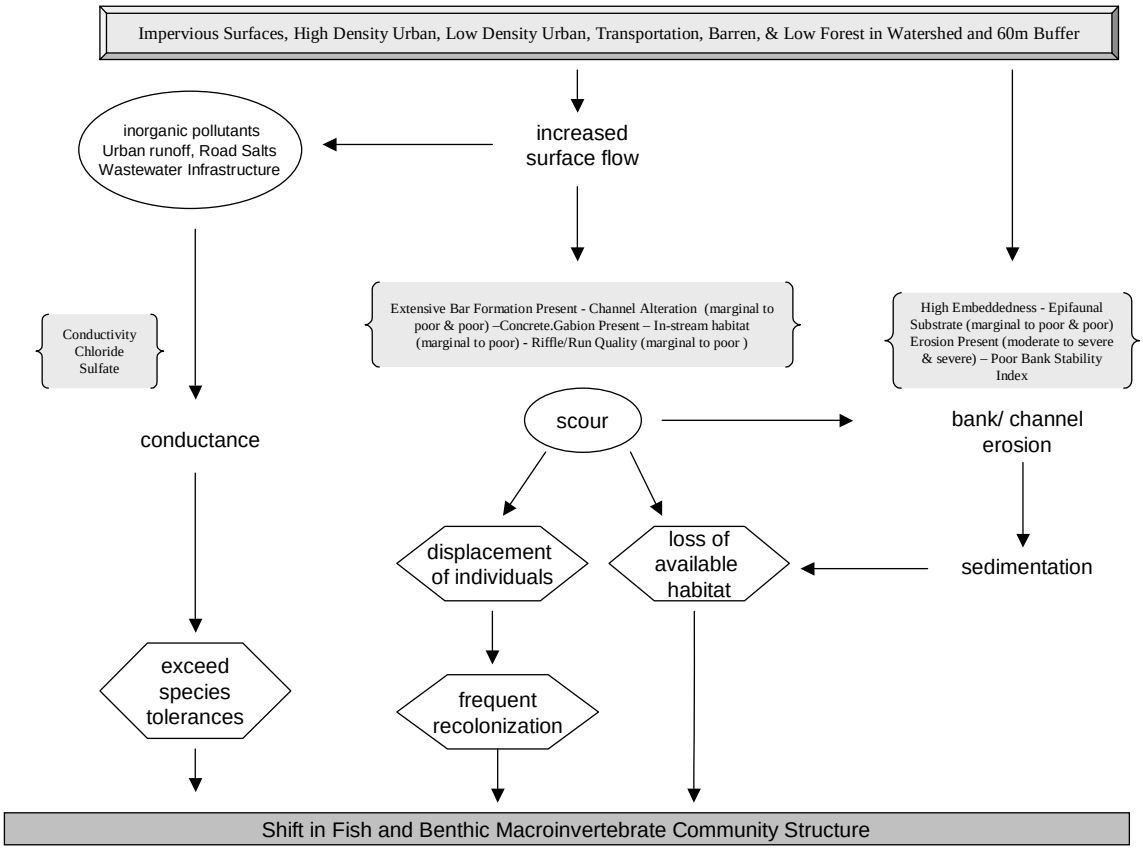

Figure 6. Final Causal Model for the Potomac River Montgomery County Watershed

5.0 Conclusion

Data suggest that the Potomac River Montgomery County watershed's biological communities are strongly influenced by urban land uses, which alters the hydrologic regime resulting in increased channel alteration, streambed scouring, loss of available habitat, and inorganic pollutant loading. There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to urban landscapes, which often cause flashy hydrology in streams and increased contaminant loads from runoff. Based upon the results of the BSID process, the probable causes and sources of the biological impairments of the Potomac River Montgomery County are summarized as follows:

- The BSID process has determined that biological communities in Potomac River Montgomery County are likely degraded due to sediment and in-stream habitat related stressors. Specifically, altered hydrology and increased runoff from urban impervious surfaces have resulted in channel alteration, channel erosion, scouring and transport of suspended sediments in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results confirm the establishment of USEPA approved sediment TMDL in 2011 was an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Potomac River Montgomery County.

- The BSID process has determined that the biological communities in the Potomac River Montgomery County are likely degraded due to inorganic pollutants (i.e., chlorides and sulfates). Chloride and sulfates levels are significantly associated with degraded biological conditions and found in approximately 30% and 14% of the stream miles with poor to very poor biological conditions in the watershed. Impervious surfaces and urban runoff cause an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed. The BSID results thus support Category 5 listings of chloride and sulfate as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Potomac River Montgomery County watershed.

- BSID analysis did not identify any nutrient related stressors present and/or showing a significant association with degraded biological conditions.

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