Watershed Report for Biological Impairment of the Non-Tidal Anacostia River Watershed, Prince Georges and Montgomery Counties, Maryland and Washington D.C. Biological Stressor Identification Analysis Results and Interpretation

REVISED FINAL

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ERRATA: One of the designated uses listed on pages iii and 7, was identified as Use I-P and the correct use is Use I. This error has been corrected.

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List of Abbreviations

AR	Attributable Risk
BARC	Beltsville Agricultural Research Center
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DO	Dissolved Oxygen
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
NEB	Northeast Branch
NPDES	National Pollution Discharge Elimination System
NWB	Northwest Branch
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
USGS	United States Geological Survey
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 waters of the Anacostia River (MD basin number 02140205) in Maryland's Integrated Report as impaired by the following (listing years in parentheses): nutrients (1996); sediments (1996); fecal bacteria (2002); impacts to biological communities—non-tidal waters (2002); polychlorinated biphenyls (PCBs) and heptachlor epoxide—non-tidal waters (2002); trash/debris (2006); and PCBs in fish tissue in tidal waters (2006). 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. A fecal bacteria TMDLs for Maryland (MD) tidal and non-tidal areas of the Anacostia River were submitted in 2006 and subsequently approved by USEPA. Inter-jurisdictional TMDLs addressing Maryland's sediment, tidal PCBs and nutrients/biological oxygen demand listings were submitted in 2007, 2007 and 2008, respectively. All submitted TMDLs were approved by USEPA.

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 significant 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 Anacostia River is Use I (Water Contact Recreation and Protection of Nontidal Warmwater Aquatic Life). The Anacostia River Tidal Fresh is also designated as Use II – (Tidal Waters: Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting); Paint Branch and all tributaries are also designated as a Use III – (Nontidal Coldwater). Northwest Branch and all tributaries are also designated as Use IV – (Recreational Trout Waters) (COMAR 2009 a,b,c,d,e). The Anacostia River 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 determines 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 Anacostia 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 degradation of biological communities in the Anacostia River 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 Anacostia River can be summarized as follows:

- The BSID process has determined that the biological communities in the Anacostia River are likely degraded due to inorganic pollutants (i.e., chlorides and sulfates). Inorganic pollutants levels are significantly associated with degraded biological conditions and found in approximately 47% and 14% respectively of the stream miles with very poor to poor biological conditions in the Anacostia River 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 and 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 a Category 5 listing for chloride and sulfates in the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Anacostia River watershed.

- The BSID process has determined that biological communities in Anacostia River are also 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 a USEPA approved sediment TMDL in 2007 was an appropriate management action to begin addressing the impacts of this stressor on the biological communities in the Anacostia River.

- The BSID process has also determined that biological communities in the Anacostia River watershed are likely degraded due to anthropogenic channelization of stream segments. MDE considers channelization to be a form of pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution. Category 4c listings include segments impaired due to stream channelization or the lack of adequate flow. MDE recommends a Category 4c listing for the Anacostia River watershed based on channelization being present in approximately 57% of degraded stream miles.

- The BSID process has also determined that biological communities in the Anacostia River watershed are likely degraded due to anthropogenic alterations of riparian buffer zones. MDE considers inadequate riparian buffer zones as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution. MDE recommends a Category 4c listing for the Anacostia River watershed based on inadequate riparian buffer zones in approximately 27% of degraded stream miles.

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 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 Anacostia River watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Anacostia River Watershed Characterization

2.1 Location

The Anacostia River watershed is 173 square miles in area. Approximately 145 square miles of the watershed (84%) is contained in Maryland, and 28 square miles (16%) in Washington DC. The headwaters of the watershed are found within Montgomery and Prince George's Counties in the State of Maryland and its endpoint and intersection with the Potomac River can be found within Washington DC. It is highly urbanized, with a population of approximately a 1,000,000 residents. Underground springs and seeps begin at the upper reaches of the river's watershed in Maryland near Rt. 198, and flow downhill to form the streams, which feed the main river. As they travel further downhill, they increase in size, and join together at various confluence points. The Northeast Branch (NEB) and Northwest Branch (NWB) are the two largest tributary streams of the river, and they join together in Bladensburg, MD, near to the Peace Cross intersection of Bladensburg Road, Annapolis Road and Baltimore Avenue. This confluence point is the beginning of the main stem of the Anacostia River, and the river continues to flow southward into the District, until it meets the Potomac River at Hains Point (AWS 1998) (see Figure 1). The main channel of the Anacostia is an estuary with a variation in water level of approximately three feet over a tidal cycle. Tidal influence extends into the lower reaches of the river's tributaries to approximately the locations of the U.S. Geological Survey (USGS) gage stations 01649500 on the NEB and 01651800 on Watts Branch, and to the bridge at U.S. Route 1 (Rhode Island Avenue) on the NWB, as indicated in Figure 1. Approximately 70% of the main stem Anacostia River receives the drainage from the two largest tributaries, the NWB and the NEB. The other two major tributaries of the Anacostia, Lower Beaverdam Creek and Watts Branch, drain highly urbanized areas in Prince George's County and DC. The watershed is located in the Eastern Piedmont and Coastal Plains regions of three distinct eco-regions identified in the MBSS indices of biological integrity (IBI) metrics (Southerland et al. 2005) (see Figure 2).

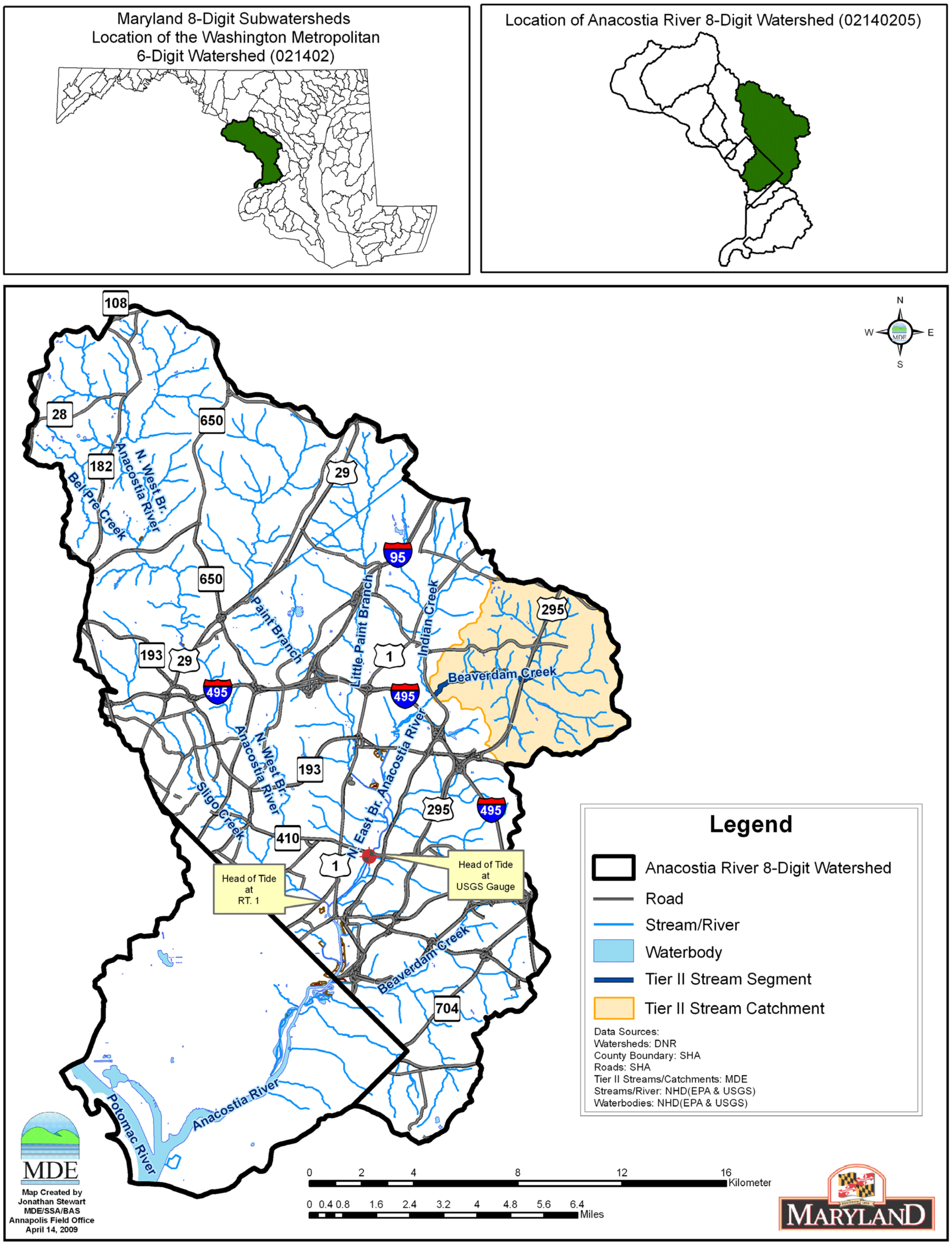

Figure 1. Location Map of the Anacostia River Watershed

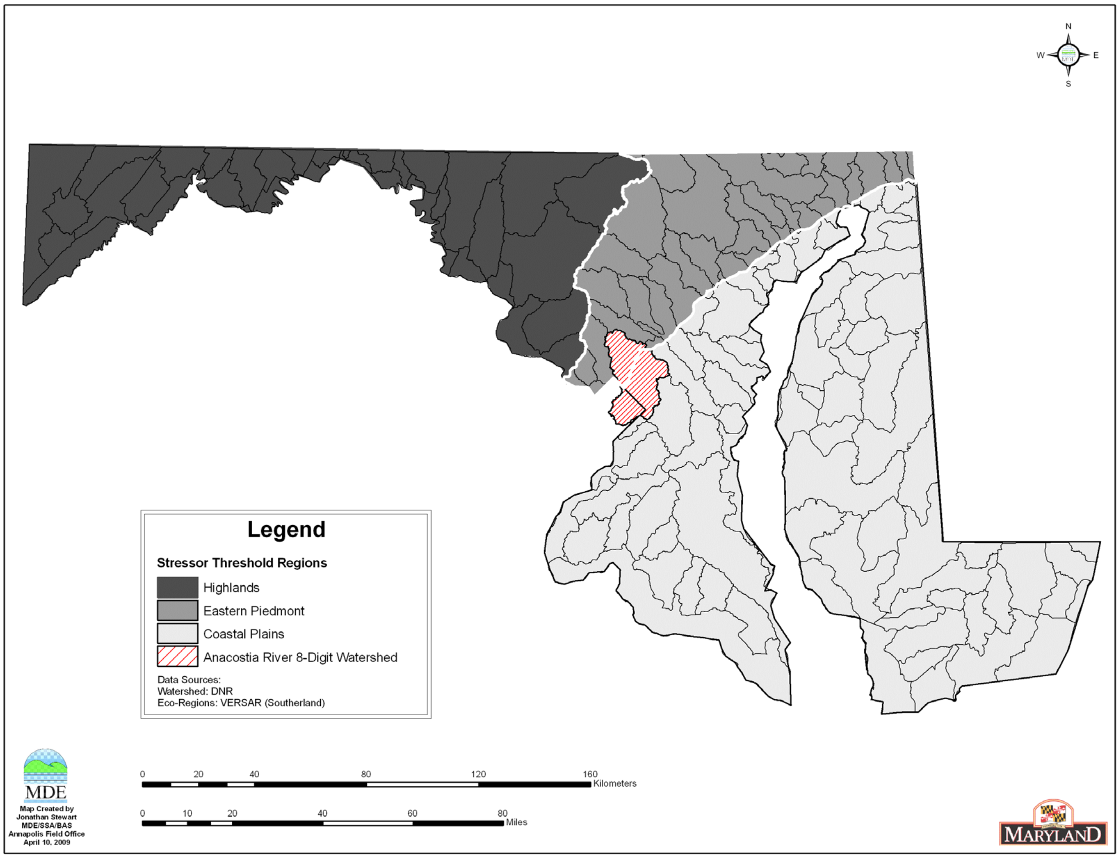

Figure 2. Eco-Region Location Map of the Anacostia River

2.2 Land Use

The Anacostia River watershed comprises a 173 square miles drainage area in Prince Georges and Montgomery Counties, Maryland and Washington DC. The watershed includes highly urbanized areas in DC, old and newly developing suburban neighborhoods in the surrounding metropolitan area of Maryland, croplands and pastures at the U.S. Department of Agriculture's Beltsville Agricultural Research Center (BARC), and forested parklands throughout the watershed (see Figure 3). Land use in the watershed is predominantly urban, with 23% of the watershed covered by impervious surfaces such as rooftops, paved roads, and parking lots. Urban land (primarily residential, commercial, and industrial) occupies approximately 75% of the watershed, with 20% of the watershed forested, and 5% in agricultural use. Virtually all of the agricultural land in the basin is associated with the BARC, located primarily in the Upper Beaverdam Creek subwatershed. In summary, the land use distribution in the Anacostia River watershed consists of urban and impervious surfaces (75%), forest (20%), and agricultural (5%) land uses. (see Figure 4) (MDP 2002).

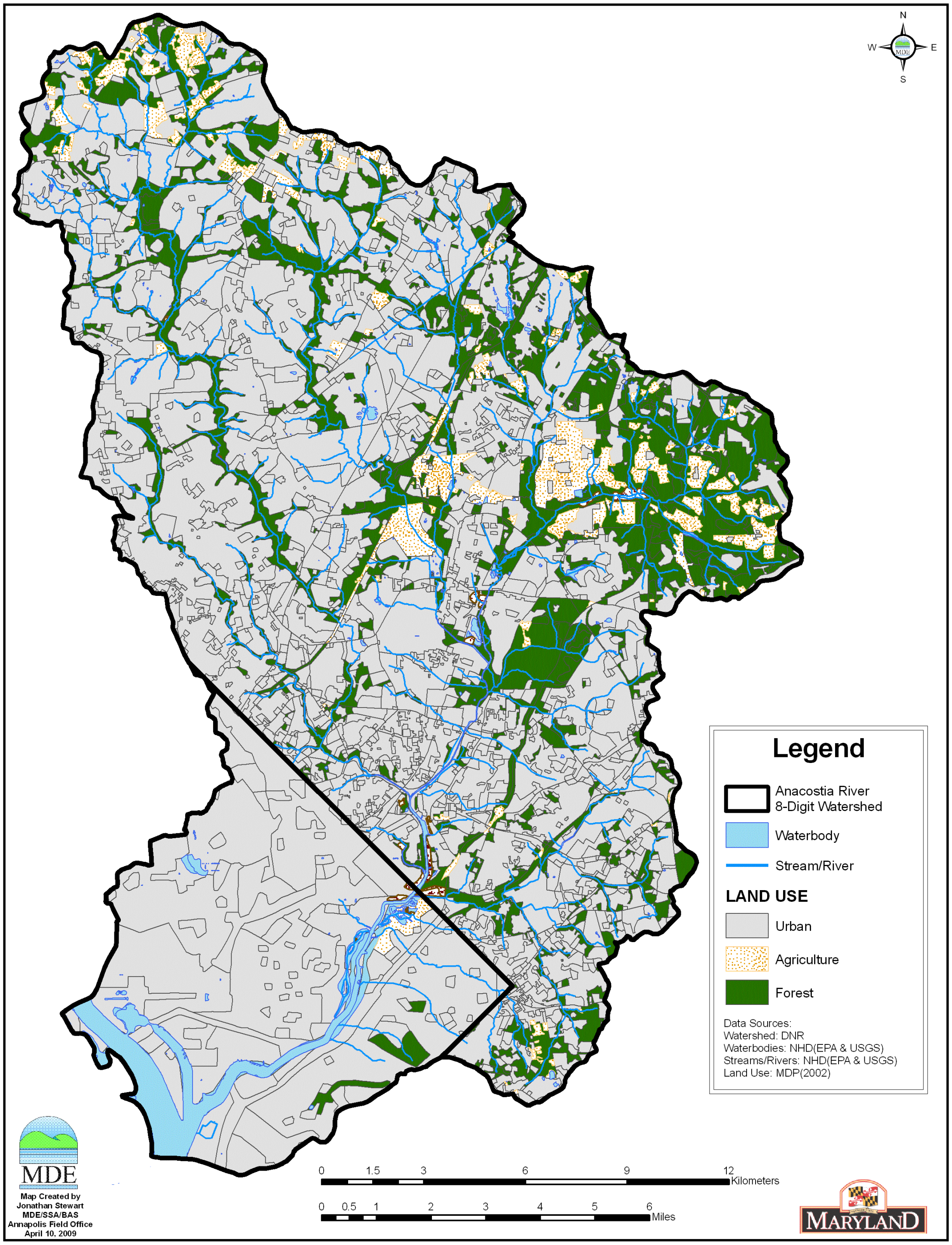

Figure 3. Land Use Map of the Anacostia River Watershed

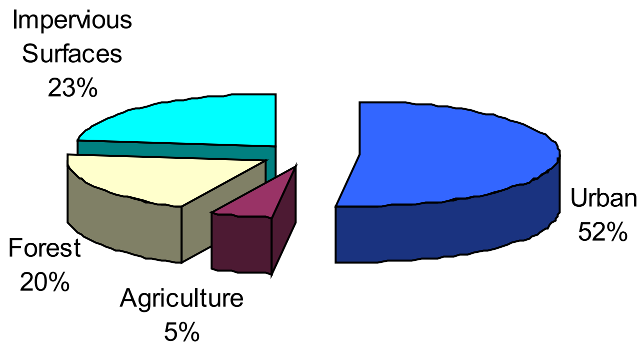

Figure 4. Proportions of Land Use in the Anacostia River Watershed

2.3 Soils/hydrology

The watershed lies within two physiographic provinces, the Piedmont and the Coastal Plains, whose division runs approximately along the line dividing Montgomery and Prince George's Counties, MD. The upper northwestern portion of the watershed is in the Piedmont Plateau province, characterized by steep stream valleys and well-drained loamy soils underlain by metamorphic rock. The Piedmont portion of the watershed ranges in elevation from 200 to 400 feet above sea level, and streambeds tend to be rocky, with relatively steep gradients. The remainder of the basin lies within the Coastal Plains province, a wedge-shaped mass of primarily unconsolidated sediments covered by sandy soils. The Coastal Plains portion of the watershed, ranging from 0 to 200 feet above sea level, is characterized by lower relief, and is drained by slowly meandering streams with shallow channels and gentle slopes (MGS 2007).

The NWB tributary lies predominantly in the Manor-Glenelg-Chester soil series. Soils in this series are fine-loamy, mixed, mesic Typic Hapludults and are very deep and well-drained (Maryland Soil Conservation Service, Montgomery County, MD 1995). The NEB lies mostly in the Sunnyside-Christiana-Muirkirk soil series. The Sunnyside soils are mostly red, deep, and well-drained. The Christiana-Muirkirk are also red and deep soils but are less permeable than the Sunnyside soils (Maryland Soil Conservation Service Prince George's County, MD 1967). The portion of the watershed below the NWB and NEB drainage areas lies mainly in the Sunnyside-Christiana-Muirkirk soil series; and the Beltsville-Croom-Sassafras soil series (STATSGO). These soils are gently sloping to steep and dominantly gravelly soils (Maryland Soil Conservation Service, Prince George's County, MD 1967).

3.0 Anacostia River Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Maryland Department of the Environment (MDE) has identified the waters of the Anacostia River (MD basin number 02140205) in the Maryland's Integrated Report as impaired by the following (listing years in parentheses): nutrients (1996); sediments (1996); fecal bacteria (2002); impacts to biological communities—non-tidal waters (2002); polychlorinated biphenyls (PCBs) and heptachlor epoxide—non-tidal waters (2002); trash/debris (2006); and PCBs in fish tissue in tidal waters (2006). The 1996 nutrients listing were 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. Fecal bacteria TMDLs for Maryland (MD) tidal and non-tidal areas of the Anacostia River were submitted in 2006 and subsequently approved by USEPA. Inter-jurisdictional TMDLs addressing Maryland's sediment, tidal PCBs listings and nutrients/biological oxygen demand were submitted in 2007, 2007 and 2008, respectively. All submitted TMDLs were approved by USEPA.

3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the waters of the Anacostia River is Use I-P (Water Contact Recreation and Protection of Nontidal Warmwater Aquatic Life). The Anacostia River Tidal Fresh is also designated as Use II – (Tidal Waters: Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting); Paint Branch and all tributaries are also designated as a Use III – (Nontidal Coldwater). Northwest Branch and all tributaries are also designated as Use IV – (Recreational Trout Waters) (COMAR 2009 a,b,c,d,e). 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 Anacostia River watershed is listed under Category 5 of the 2008 Integrated Report as impaired for impacts to biological communities. Approximately 95% of stream miles in the Anacostia River basin are estimated as having fish and and/or benthic indices of biological integrity 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 thirty-seven sites. Thirty-three of the thirty-seven 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 nineteen MBSS sites with seventeen having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Anacostia River watershed.

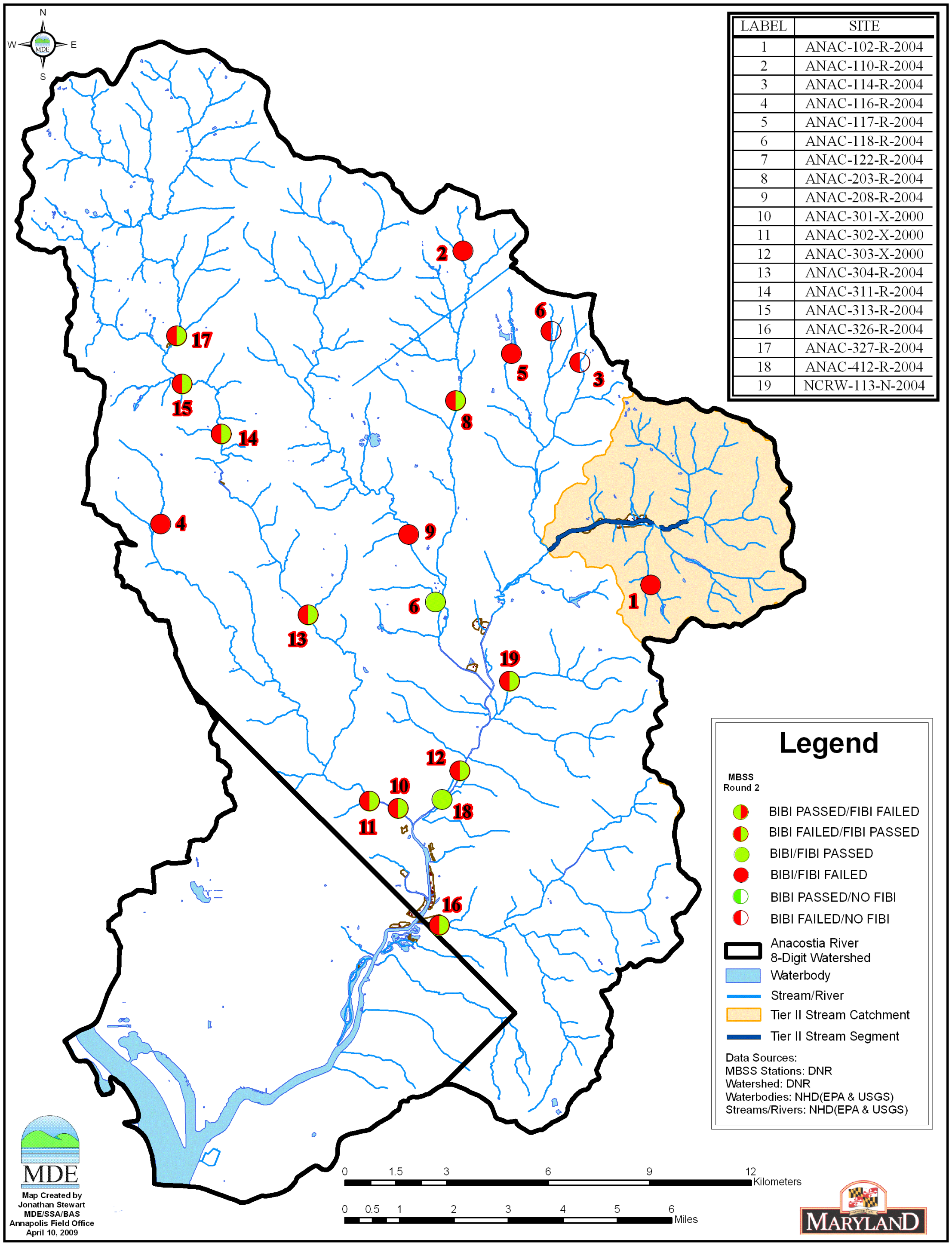

Figure 5. Principle Dataset Sites for the Anacostia River Watershed

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 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-Haenzel (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, riparian 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, instream and riparian habitat, and water chemistry groups are identified as possible biological stressors in the Anacostia River. Parameters identified as representing possible sources are listed in Table 4 and include various urban land use types. Table 5 shows a summary of combined AR values for each stressor group. Table 6 shows a summary of combines AR values for each source group is shown in.

Table 1. Sediment Biological Stressor Identification Analysis Results for Anacostia River

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	19	17	91	29%	18%	No	----
	moderate bar formation present	19	17	91	59%	50%	No	----
	bar formation present	19	17	91	100%	84%	Yes	16%
	channel alteration marginal to poor	19	17	90	88%	54%	Yes	36%
	channel alteration poor	19	17	90	41%	19%	Yes	25%
	high embeddedness	19	17	91	12%	3%	No	----
	epifaunal substrate marginal to poor	19	17	91	59%	27%	Yes	36%
	epifaunal substrate poor	19	17	91	18%	5%	Yes	14%
	moderate to severe erosion present	19	17	91	41%	51%	No	----
	severe erosion present	19	17	91	24%	13%	No	----
	poor bank stability index	19	17	91	18%	16%	No	----
	silt clay present	19	17	91	100%	99%	No	----

Table 2. Habitat Biological Stressor Identification Analysis Results for the Anacostia River

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	19	17	92	71%	13%	Yes	57%
	instream habitat structure marginal to poor	19	17	91	41%	23%	Yes	23%
	instream habitat structure poor	19	17	91	6%	2%	No	----
	pool/glide/eddy quality marginal to poor	19	17	91	29%	31%	No	----
	pool/glide/eddy quality poor	19	17	91	6%	2%	No	----
	riffle/run quality marginal to poor	19	17	91	47%	29%	Yes	22%
	riffle/run quality poor	19	17	91	18%	12%	No	----
	velocity/depth diversity marginal to poor	19	17	91	41%	42%	No	----
	velocity/depth diversity poor	19	17	91	6%	6%	No	----
	concrete/gabion present	19	17	94	12%	2%	Yes	9%
	beaver pond present	19	17	90	0%	5%	No	----
Riparian Habitat	no riparian buffer	19	17	92	41%	15%	Yes	26%
	low shading	19	17	91	18%	9%	No	----

Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Anacostia River

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	19	17	188	0%	34%	No	----
	high total dissolved nitrogen	3	3	44	0%	25%	No	----
	ammonia acute with salmonid present	19	17	188	24%	25%	No	----
	ammonia acute with salmonid absent	19	17	188	6%	16%	No	----
	ammonia chronic with salmonid present	19	17	188	29%	45%	No	----
	ammonia chronic with salmonid absent	19	17	188	24%	35%	No	----
	low lab pH	19	17	188	0%	24%	No	----
	high lab pH	19	17	188	0%	1%	No	----
	low field pH	19	17	187	0%	25%	No	----
	high field pH	19	17	187	6%	1%	No	----
	high total phosphorus	19	17	188	0%	4%	No	----
	high orthophosphate	19	17	188	0%	11%	No	----
	dissolved oxygen < 5mg/l	19	17	186	6%	8%	No	----
	dissolved oxygen < 6mg/l	19	17	186	12%	14%	No	----
	low dissolved oxygen saturation	15	13	164	8%	8%	No	----
	high dissolved oxygen saturation	15	13	164	8%	0%	Yes	8%
	acid neutralizing capacity below chronic level	19	17	188	0%	6%	No	----
	acid neutralizing capacity below episodic level	19	17	188	0%	31%	No	----
	high chlorides	19	17	188	53%	6%	Yes	47%
	high conductivity	19	17	188	76%	6%	Yes	71%
	high sulfates	19	17	188	18%	4%	Yes	14%

Table 4. Stressor Source Identification Analysis Results for the Anacostia River

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	19	17	190	82%	4%	Yes	78%
	high % of high intensity urban in watershed	19	17	191	94%	14%	Yes	79%
	high % of low intensity urban in watershed	19	17	191	47%	4%	Yes	43%
	high % of transportation in watershed	19	17	191	65%	8%	Yes	56%
	high % of high intensity urban in 60m buffer	19	17	189	47%	6%	Yes	41%
	high % of low intensity urban in 60m buffer	19	17	189	35%	5%	Yes	30%
	high % of transportation in 60m buffer	19	17	189	47%	8%	Yes	39%
Sources Agriculture	high % of agriculture in watershed	19	17	191	0%	20%	No	----
	high % of cropland in watershed	19	17	191	0%	17%	No	----
	high % of pasture/hay in watershed	19	17	191	0%	15%	No	----
	high % of agriculture in 60m buffer	19	17	189	0%	10%	No	----
	high % of cropland in 60m buffer	19	17	189	0%	12%	No	----
	high % of pasture/hay in 60m buffer	19	17	189	0%	14%	No	----
Sources Barren	high % of barren land in watershed	19	17	191	6%	18%	No	----
	high % of barren land in 60m buffer	19	17	189	0%	8%	No	----

Table 4. Stressor Source Identification Analysis Results for the Anacostia River (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 stressor (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	19	17	191	18%	6%	No	----
	low % of forest in 60m buffer	19	17	189	18%	6%	No	----
Sources Acidity	atmospheric deposition present	19	17	188	0%	25%	No	----
	AMD acid source present	19	17	188	0%	0%	No	----
	organic acid source present	19	17	188	0%	4%	No	----
	agricultural acid source present	19	17	188	0%	5%	No	----

Table 5. Summary AR Values for Stressor Groups for Anacostia River

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	73%	95%
In-Stream Habitat	69%	
Riparian Habitat	26%	
Water Chemistry	78%	

Table 6. Summary AR Values for Source Groups for Anacostia River

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	89%	89%
Agriculture	----	
Barren Land	----	
Anthropogenic	----	
Acidity	----	

Sediment Conditions

BSID analysis results for the Anacostia River identified five sediment parameters that have a statistically significant association with poor to very poor stream biological condition:*, bar formation present, channel alteration (marginal to poor* & *poor), and epifaunal substrate (marginal to poor* & *poor).*

Bar formation present was identified as significantly associated with degraded biological conditions and found in 16% of the stream miles with very poor to poor biological conditions in the Anacostia River. 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 Anacostia River, and found to impact approximately 36% (*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.

Epifaunal Substrate was identified as significantly associated with degraded biological conditions in the Anacostia River, and found to impact approximately 36% (*marginal to poor* rating) and 14% (*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 in-stream habitat, 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.

The watershed of the Anacostia River and its tributaries contain extensive areas with high-density urban development including: Bladensburg, College Park, Silver Spring, and 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).

Seventy- five percent of the Anacostia River watershed contains urban type land uses. As development and urbanization increased in the Anacostia River 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. Increases in impervious surface cover that accompany urbanization alter stream hydrology, forcing runoff to occur more readily and quickly during rainfall events, thus decreasing the amount of time it takes water to reach streams, causing urban streams to be more "flashy" (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). All of these processes 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, and poor epifaunal substrate) are the typical effects of the scouring associated with a "flashy" hydrological regime.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with very poor to poor biological conditions. The combined AR for the sediment stressor group is approximately 73%, suggesting these stressors impact a considerable proportion of the degraded stream miles in the Anacostia River (See Table 5).

In-stream Habitat Conditions

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

Channelization present was identified as significantly associated with degraded biological conditions and found in 57% of the degraded stream miles in the Anacostia River. This stressor measures the presence/absence of channelization in stream banks and its presence is a metric for the channel alteration rating. It describes both the straightening of channels and their fortification with concrete or other hard materials. Channelization inhibits the natural flow regime of a stream resulting in increased flows during storm events that can lead to scouring and, consequently, displacement of biological communities. The resulting bank/channel erosion creates unstable channels and excess sediment deposits downstream.

Instream habitat structure (marginal to poor) was identified as significantly associated with degraded biological conditions in the Anacostia River, and found to impact approximately 23% 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. Like embeddedness, 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 Anacostia River, and found to impact approximately 22% 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 Anacostia River, and found to impact approximately 9% of the stream miles with poor to very poor biological conditions. *Concrete/gabion present*, like 'channelized,' 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, which often occurs in streams with "flashy" hydrologic regimes, results in a more homogeneous in-stream habitat.

Channelization and concrete/gabion has been used in the Anacostia River watershed for flood control. The purpose is to increase channel capacity and flow velocities so water moves more efficiently downstream. However, channelization 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 than those in channelized streams. The natural structures impacting stream hydrology, which were removed for channelization, also provide critical habitat for stream species and impact nutrient availability in stream microhabitats (Bolton and Schellberg 2001). The refuge cavities removed by channelization not only provide concealment for fish, but also serve as traps for detritus, and are areas colonized by benthic macroinvertebrates. Subsequently, channelized streams retained less leaf litter and supported lower densities of detritivore invertebrates than natural streams. The overall densities and biomasses of macroinvertebrates in channelized streams are very low by comparison with intact natural streams (Laasonen, Muotka, and Kivijaervi 1998; Haapala and 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 very poor to poor biological conditions. The combined AR for the in-stream habitat stressor group is approximately 69%, suggesting these stressors impacts a considerable proportion of the degraded stream miles in the Anacostia River (See Table 5).

Riparian Habitat Conditions

BSID analysis results for the Anacostia River identified one riparian habitat parameter that has a statistically significant association with poor to very poor stream biological condition: *no riparian buffer.*

No riparian buffer was identified as significantly associated with degraded biological conditions in the Anacostia River, and found to impact approximately 26% of the stream miles with poor to very poor biological conditions. 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 et al. 2004). Natural forested headwater streams generally rely on allochthonous input of leaf litter as the major energy source, but agricultural land use typically reduces or eliminates the trees in the riparian area that would contribute detritus. This reduction can have strong impacts on stream communities; exclusion of leaf litter can decrease invertebrate biomass and/or abundance in many of the invertebrate shredder, collector and predator taxa (Wallace et al. 1997). Decreased riparian buffer also leads to reduced amounts of large wood in the stream. Stable wood substrate in streams performs multiple functions, influencing channel features, flow, habitat, and providing cover for fish.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with very poor to poor biological conditions. The combined AR for the riparian habitat stressor group is approximately 26%, suggesting this stressor impacts a moderate proportion of the degraded stream miles in the Anacostia River (See Table 5).

Water Chemistry

BSID analysis results for the Anacostia River 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 dissolved oxygen saturation.*

High conductivity levels was identified as significantly associated with degraded biological conditions in the Anacostia River, and found to impact approximately 71% 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 Anacostia River, and found to impact approximately 47% 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 Anacostia River watershed. In MD there is one industrial facility, NASA-Goddard Space Flight Center (MD0067482). Since National Pollution Discharge Elimination System (NPDES) permitting enforcement does not require chlorides testing at this facility, data was not available to verify/identify chlorides as a specific pollutant. Smith, Alexander, and Wolman (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 very poor to poor biological conditions in the Anacostia River 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. There are two municipal wastewater treatment plants (WWTPs) in the Anacostia River watershed, the USDA West Side WWTP (MD0020851) and the USDA East Side WWTP (MD0020842), and one industrial facility, NASA-Goddard Space Flight Center (MD0067482) all are located in MD. Since NPDES permitting enforcement does not require sulfate testing at any of these facilities, data was not available to verify/identify sulfates as a specific pollutant in this watershed.

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 dissolved oxygen saturation was significantly associated with degraded biological conditions and found in 8% of the stream miles with very poor to poor biological conditions in the Anacostia River watershed. Dissolved Oxygen (DO) saturation accounts for physical solubility limitations of oxygen in water and provides a more targeted assessment of oxygen dynamics than concentration alone. Percent saturation is relative to the amount of oxygen that water can hold, as determined by temperature and atmospheric pressure. Natural diurnal fluctuations can become exaggerated in streams with excessive primary production, enabling stressor risk analyses. DO saturation levels less than 60% saturation (like DO concentrations <5mg/L) are considered to demonstrate high respiration associated with excessive decomposition of organic material. Additionally, DO saturation greater than 125% is considered to demonstrate oxygen production associated with high levels of photosynthesis. Sources are agricultural, forested and urban land uses. Only one station was reported to have high DO saturation values and the BSID analysis for the watershed did not identify any nutrient stressors as having significant association with degraded biological conditions. There is no evidence that excessive primary production is occurring in the watershed.

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 Anacostia River 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 exceedances in species tolerances.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with very poor to poor biological conditions. The combined AR for the water chemistry stressor group is approximately 78% suggesting that these stressors impact a substantial proportion of degraded stream miles in the Anacostia River (Table 5).

Sources

All seven stressor parameters, identified in Tables 1-3, that are significantly associated with biological degradation in the Anacostia River watershed BSID analysis are representative of impacts from urban landscapes. The watershed contains mostly high-density urban centers including Bladensburg, College Park, Silver Spring, and Washington DC. Many of these areas were built before modern stormwater runoff controls were required by the State.

The scientific community (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 alter 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 Anacostia River watershed within Montgomery County and then combined these 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 land uses as potential sources of stressors that may cause negative biological impacts. The combined AR for the source group is approximately 89%, suggesting that urban development and impervious surfaces potentially impact a substantial proportion of the degraded stream miles in Anacostia River (Table 6).

Summary

The BSID analysis results suggest that degraded biological communities in the Anacostia River watershed are a result of increased urban land uses causing alteration to hydrology and habitat, repeated streambed scouring, and increased sedimentation, resulting in an unstable stream ecosystem that eliminates habitat heterogeneity. High proportions of these land uses also typically results in increased contaminant loads from point and nonpoint sources by adding sediments and inorganic pollutants to surface waters, resulting in levels that can potentially be toxic to aquatic organisms.

Due to significant anthropogenic changes of natural stream channels and riparian buffers zones within the watershed, health and diversity of biological communities are severely impacted. The stressors c*hannelization present* and *no riparian buffer* were identified as significantly associated with degraded biological conditions, and found to impact approximately 57% and 27% of the stream miles with poor to very poor biological conditions in the Anacostia River watershed.

Alterations to the hydrologic regime, physical habitat, and water chemistry have all combined to degrade the Anacostia River, leading to a loss of diversity in the biological community. The combined AR for all the stressors is approximately 95%, suggesting that altered hydrology/sediment, habitat, and water chemistry stressors adequately account for the biological impairment in the Anacostia 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., 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 Anacostia River

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 2009). 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 Anacostia River, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

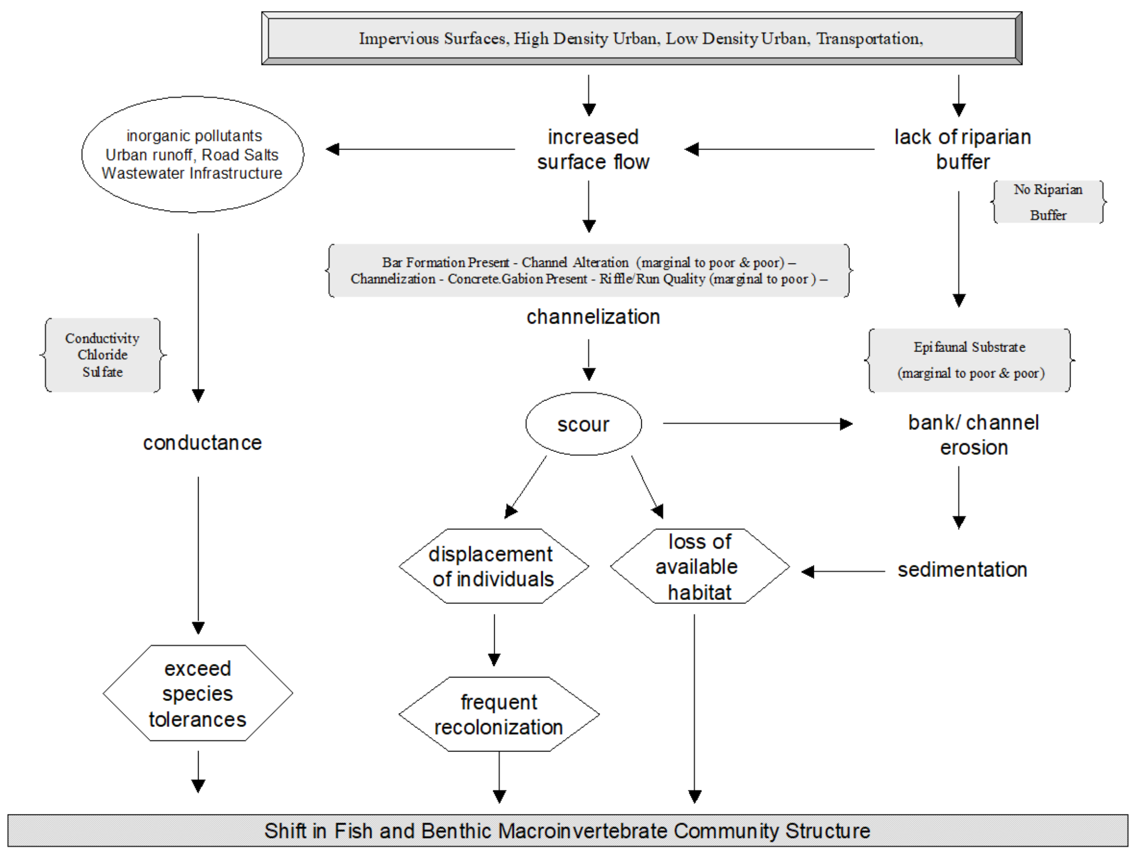

Figure 6. Final Causal Model for the Anacostia River Watershed

5.0 Conclusion

Data suggest that the Anacostia River 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 Anacostia River are summarized as follows:

- The BSID process has determined that the biological communities in the Anacostia River are likely degraded due to inorganic pollutants (i.e., chlorides and sulfates). Inorganic pollutants levels are significantly associated with degraded biological conditions and found in approximately 47% and 14% respectively of the stream miles with very poor to poor biological conditions in the Anacostia River 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, and 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 a Category 5 listing for chloride and sulfates in the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Anacostia River watershed.

- The BSID process has determined that biological communities in Anacostia River are also 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 a USEPA approved sediment TMDL in 2007 was an appropriate management action to begin addressing the impacts of this stressor on the biological communities in the Anacostia River.

- The BSID process has also determined that biological communities in the Anacostia River watershed are likely degraded due to anthropogenic channelization of stream segments. MDE considers a channelization as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution.

Category 4c listings include segments impaired due to stream channelization or the lack of adequate flow. MDE recommends a Category 4c listing for the Anacostia River watershed based on channelization being present in approximately 57% of degraded stream miles.

- The BSID process has also determined that biological communities in the Anacostia River watershed are likely degraded due to anthropogenic alterations of riparian buffer zones. MDE considers inadequate riparian buffer zones as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards as a result of pollution. MDE recommends a Category 4c listing for the Anacostia River watershed based on inadequate riparian buffer zones in approximately 27% of degraded stream miles.

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