Watershed Report for Biological Impairment of the Cabin John Creek Basin in Montgomery County, 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
DNR	Maryland Department of Natural Resources
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
mg/L	Milligrams per liter
µeq/L	Micro equivalent per liter
µS/cm	Micro Siemens per centimeter
MS4	Municipal Separate Storm Sewer System
n	Number
NPDES	National Pollution Discharge Elimination System
PSU	Primary Sampling Unit
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

Executive Summary

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

The Cabin John Creek watershed (basin number 02-14-02-07), located in Montgomery County, was identified on the Integrated Report under Category 5 as impaired by nutrients, suspended sediments (1996 listings), fecal bacteria (2002 listing) and evidence of impacts to biological communities (2006 listing). All impairments are listed for non-tidal streams. 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 TMDL was completed for the Cabin John Creek watershed for fecal bacteria in 2008.

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 Cabin John Creek watershed is Use I-P – *water contact recreation, protection of nontidal warmwater aquatic life, and public water supply* (COMAR 2009a,b). The Cabin John Creek watershed is not attaining its designated use of supporting aquatic life because of biological impairments. As an indicator of designated use attainment, the Maryland Department of the Environment (MDE) uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause of reduced biological conditions, thus enabling the Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors, sources of stressors and the biological community, and the likely impact this stressor has 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 under 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 Cabin John Creek watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and which may be reviewed in more detail in the report entitled *Maryland Biological Stressor Identification Process* (MDE 2009). Data suggest that the biological communities of the Cabin John Creek watershed are strongly influenced by urban land use and its concomitant effects: altered hydrology and elevated levels of sulfate, chlorides, and conductivity (a measure of the presence of dissolved substances). 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 analysis, and the probable causes and sources of the biological impairments in the Cabin John Creek watershed can be summarized as follows:

- The BSID analysis has determined that the biological communities in the Cabin John Creek watershed are likely degraded due to inorganic pollutants (i.e., chloride, conductivity, sulfate). Inorganic pollutants levels are significantly associated with degraded biological conditions and found in approximately 95% of the stream miles with very poor to poor biological conditions in the Cabin John watershed. Impacts on water quality due to conductivity, chloride, and sulfate are dependent on prolonged exposure; future monitoring of these inorganic pollutants will help in determining the spatial and temporal extent of this impairment 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. Currently, there is a lack of monitoring data for many of these substances; therefore, additional monitoring of priority inorganic pollutants is needed to more precisely determine the specific cause(s) of impairment.

- The BSID analysis has determined that biological communities in the Cabin John Creek watershed are also likely degraded due to flow/sediment related stressors. Specifically, altered hydrology and increased stormwater runoff from urban impervious surfaces have resulted in elevated suspended sediment transport through the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus confirm the 1996 Category 5 listing for total suspended solids as an impairing substance in the Cabin John Creek watershed, and links this pollutant to biological conditions in these waters.

- The BSID process has also determined that biological communities in the Cabin John Creek 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 Cabin John Creek watershed based on channelization being present in approximately 57% of degraded stream miles.

- Although there is presently a Category 5 listing for phosphorus in Maryland's 2008 Integrated Report, the BSID analysis did not identify any nutrient stressors (i.e., total nitrogen, total phosphorus, dissolved oxygen, etc.) present and/or nutrient stressors 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. 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 Department of Natural Resources Maryland Biological Stream Survey (MDDNR 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 Cabin John Creek watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Cabin John Creek Watershed Characterization

2.1 Location

The Cabin John Creek watershed is located in southern Montgomery County, Maryland, just northwest of Washington, DC (see Figure 1). The Cabin John Creek watershed encompasses 16,500 acres. The headwaters of Cabin John Creek originate in the City of Rockville. The creek flows south about 10 miles, passing under Interstate 270, through Cabin John Regional Park under the Capital Beltway (I-495), and the historic Cabin John Bridge to its confluence with the Potomac River near the towns of Cabin John and Glen Echo. The watershed is bounded by Rockville Pike (Rte. 355) and Old Georgetown Pike (Rte. 187) to the east and Falls Road (Rte. 189) to the west (Van Ness and Haddaway 1999). The major tributaries of the Creek are Bogley Branch, Booze Creek, Buck Branch, Congressional Branch, Ken Branch, Old Farm Branch, Snakeden Branch and Thomas Branch (also called Beltway Branch). The watershed is located in the Piedmont eco-region, one of three distinct eco-regions identified in the MDDNR MBSS Index of Biological Integrity (IBI) metrics (Southerland et al. 2005) (see Figure 2).

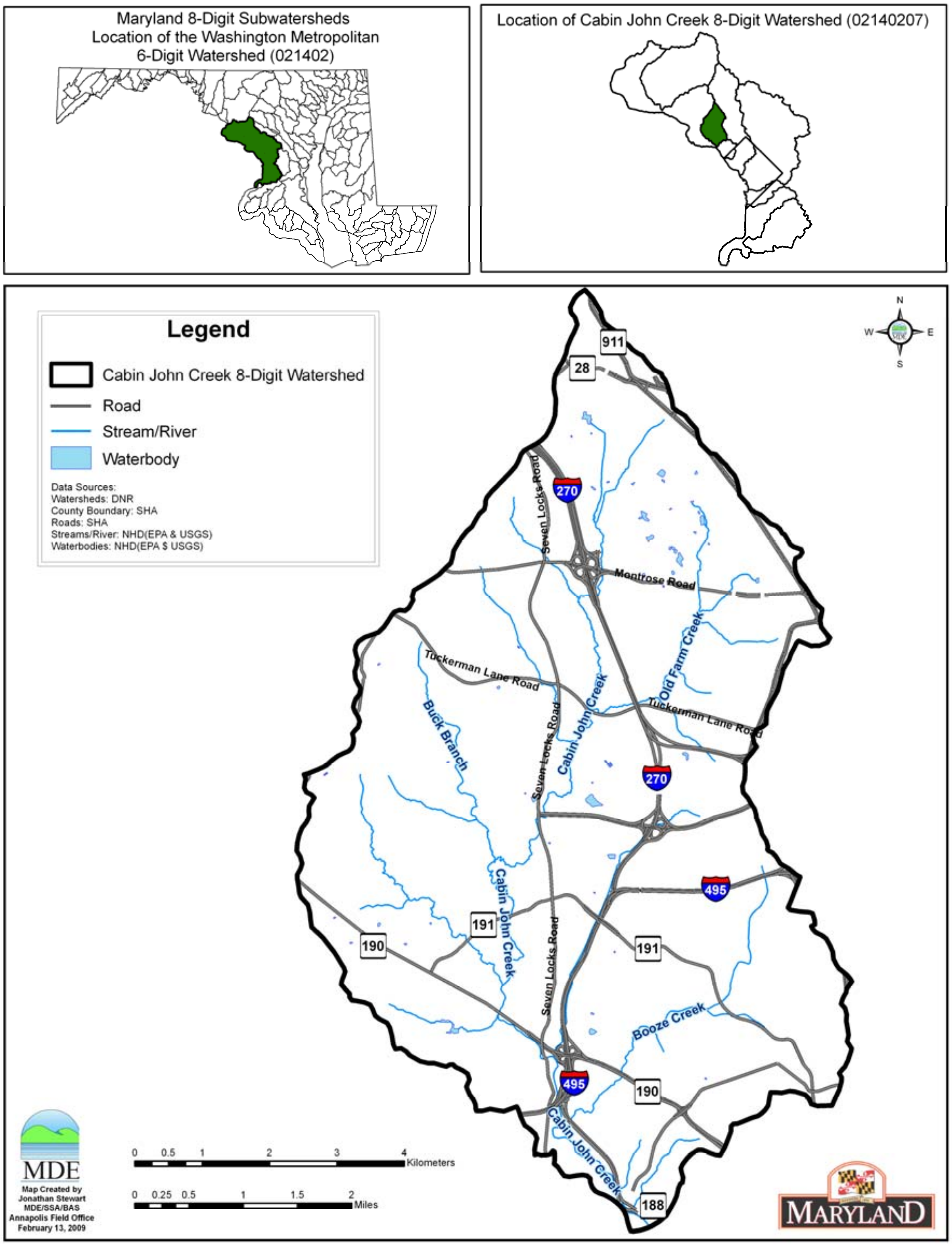

Figure 1. Location Map of the Cabin John Creek Watershed

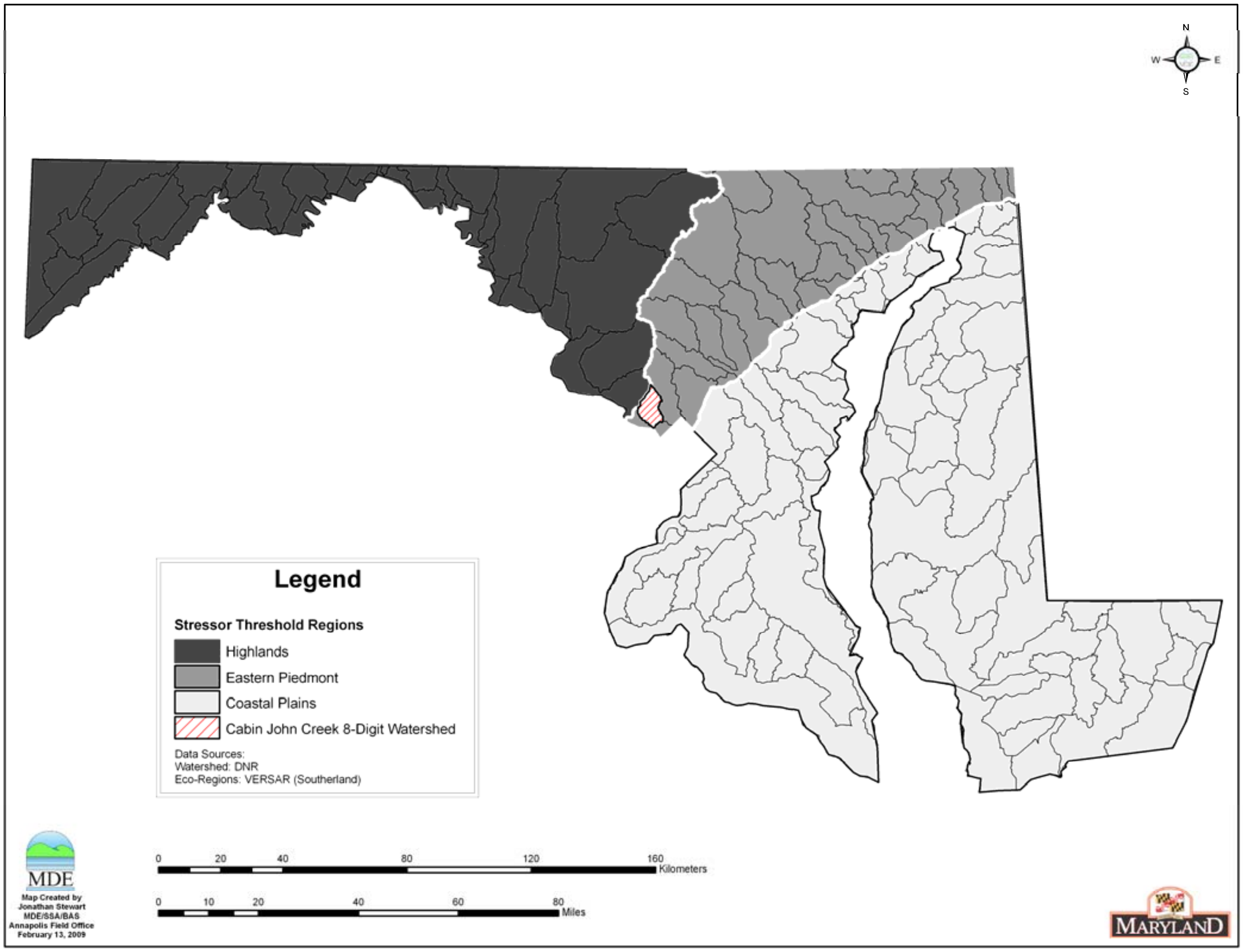

Figure 2. Eco-Region Location Map of the Cabin John Creek Watershed

2.2 Land Use

The Cabin John Creek watershed contains primarily urban land use (see Figure 3). The watershed has been significantly affected by high-density residential (73%) and commercial (13%) development. There are parks, trails, and natural areas throughout the watershed. In addition to the regional park, there are wooded parklands and buffer areas along several miles of the creek mainstem and tributaries. The land use distribution in the watershed is approximately 13% forest/herbaceous, 86% urban, 1% (0.6%) agricultural and 0% (0.2%) water (see Figure 4) (MDP 2002).

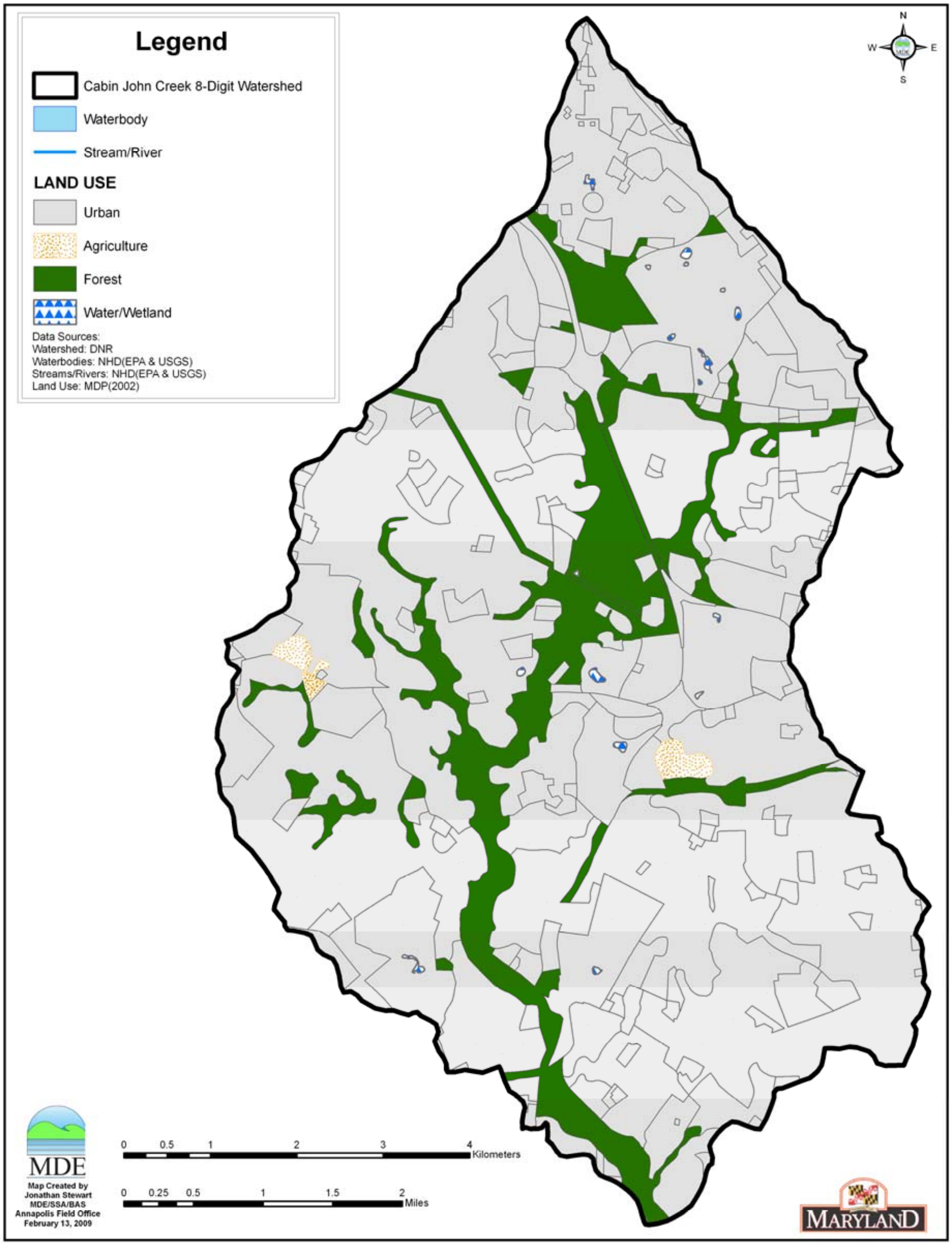

Figure 3. Land Use Map of the Cabin John Creek Watershed

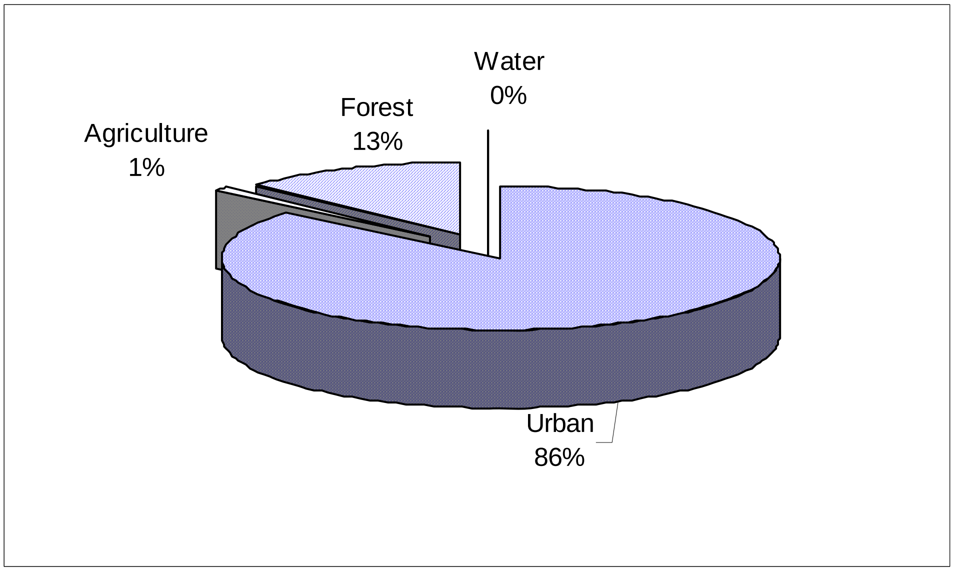

Figure 4. Proportions of Land Use in the Cabin John Creek Watershed

2.3 Soils/hydrology

The Cabin John Creek watershed lies entirely in the Piedmont Plateau Physiographic Province. This province is characterized by gentle to steep rolling topography, low hills, and ridges. The Cabin John Creek watershed drains in a southerly direction, following the dip of the underlying crystalline bedrock in the Piedmont Plateau Physiographic Province, to a confluence with the Potomac River between the Little Falls Dam and Great Falls. Crystalline igneous and metamorphic rocks of volcanic origin consisting primarily of schist and gneiss characterize the surficial geology of the watershed (Edwards 1981). The Cabin John Creek watershed lies predominantly in the Baile soil series; soils in this series are fine-loamy, mixed, mesic Typic Ochraquults and are very deep and poorly drained soils (SCS 1995).

3.0 Cabin John Creek Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Cabin John Creek watershed (basin number 02-14-02-07), located in Montgomery County, was identified on the Integrated Report under Category 5 as impaired by nutrients, suspended sediments (1996 listings), fecal bacteria (2002 listing) and evidence of biological impacts (2006 listing). All impairments are listed for non-tidal streams. 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 TMDL for the Cabin John Creek watershed for fecal bacteria was completed in 2008.

3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Cabin John Creek watershed is Use I-P – *water contact recreation, protection of nontidal warmwater aquatic life and public water supply* (COMAR 2009a,b). A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life, primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. 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 Cabin John Creek watershed is listed under Category 5 of the 2008 Integrated Report as impaired for evidence of biological impacts. One-hundred percent of the stream miles in the Cabin John Creek watershed are estimated as degraded based on benthic and and/or fish 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 eight stations. All eight stations have degraded benthic and/or fish index of biotic integrity (BIBI, FIBI) scores significantly lower than 3.0 (i.e., very poor to poor). The principal dataset, i.e., MBSS Round 2, contains three MBSS sites, all have BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Cabin John Creek watershed.

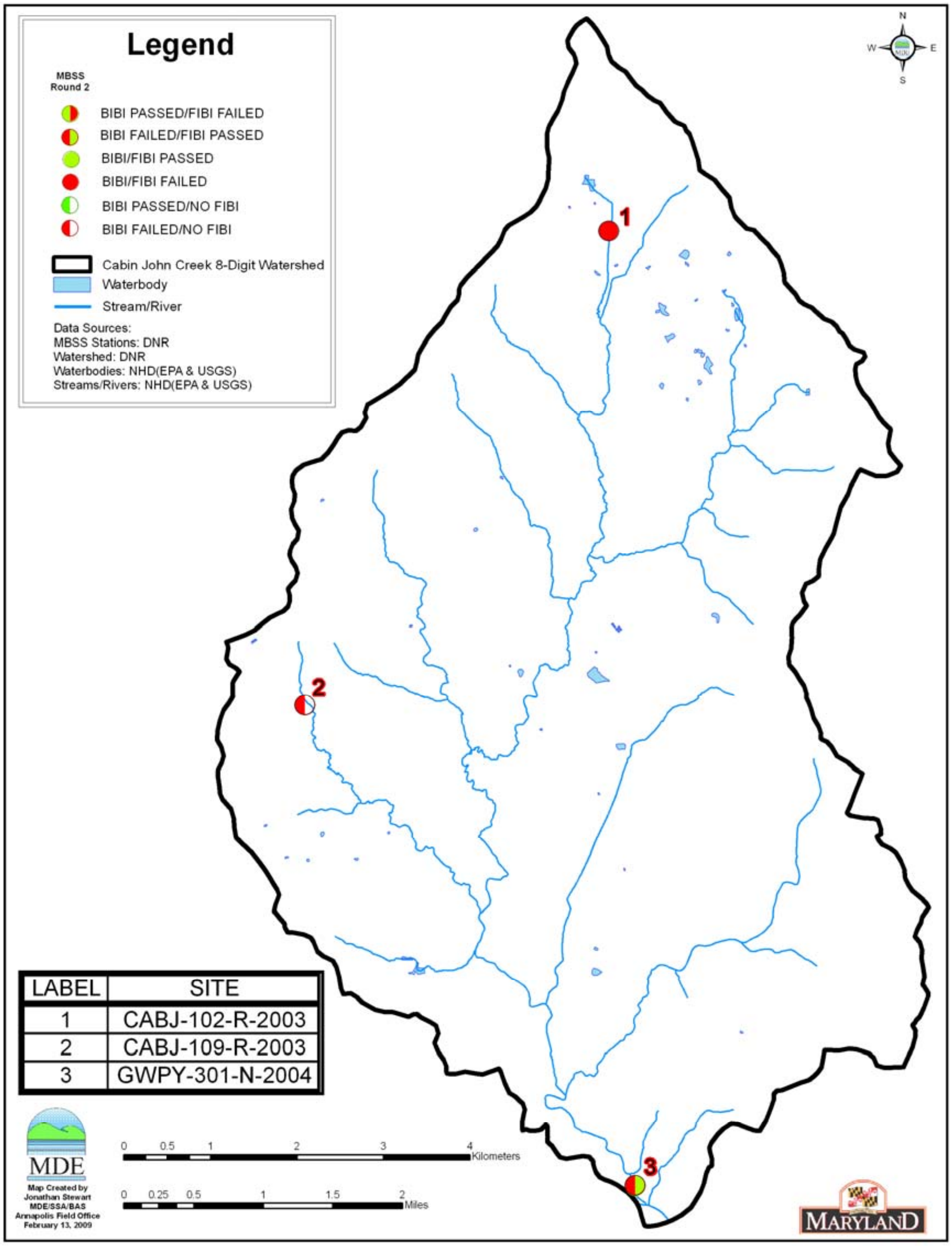

Figure 5. Principal Dataset Sites for the Cabin John Creek Watershed

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 – 1^{st} and 2^{nd}-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 defined 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 data analysis, MDE identified sediment, habitat parameters, water chemistry parameters, and potential sources significantly associated with poor to very poor fish and/or benthic 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 Cabin John Creek watershed. Parameters identified as representing possible sources are listed in Table 4 and include various urban land use types. Table 5 shows the summary of combined AR values for the stressor groups in the Cabin John Creek watershed. Table 6 shows the summary of combined AR values for the source groups in the Cabin John Creek watershed.

Table 1. Sediment Biological Stressor Identification Analysis Results for the Cabin John Creek 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 stressor 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	3	3	87	33%	13%	No	----
	moderate bar formation present	3	3	87	67%	42%	No	----
	bar formation present	3	3	87	67%	90%	No	----
	channel alteration marginal to poor	3	3	87	100%	41%	Yes	58%
	channel alteration poor	3	3	87	33%	12%	No	----
	high embeddedness	3	3	87	0%	8%	No	----
	epifaunal substrate marginal to poor	3	3	87	33%	13%	No	----
	epifaunal substrate poor	3	3	87	0%	2%	No	----
	moderate to severe erosion present	3	3	87	67%	62%	No	----
	severe erosion present	3	3	87	0%	12%	No	----
	poor bank stability index	3	3	87	0%	5%	No	----
	silt clay present	3	3	87	100%	100%	No	----

Table 2. Habitat Biological Stressor Identification Analysis Results for the Cabin John Creek 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 stressor 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	3	3	87	67%	10%	Yes	57%
	instream habitat structure marginal to poor	3	3	87	67%	12%	Yes	56%
	instream habitat structure poor	3	3	87	0%	1%	No	----
	pool/glide/eddy quality marginal to poor	3	3	87	33%	47%	No	----
	pool/glide/eddy quality poor	3	3	87	0%	1%	No	----
	riffle/run quality marginal to poor	3	3	87	33%	17%	No	----
	riffle/run quality poor	3	3	87	0%	1%	No	----
	velocity/depth diversity marginal to poor	3	3	87	33%	48%	No	----
	velocity/depth diversity poor	3	3	87	0%	0%	No	----
	concrete/gabion present	3	3	87	0%	1%	No	----
	beaver pond present	3	3	87	0%	3%	No	----
Riparian Habitat	no riparian buffer	3	3	87	67%	24%	No	----
	low shading	3	3	87	0%	8%	No	----

Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Cabin John Creek 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 stressor 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	3	3	165	33%	47%	No	----
	high total dissolved nitrogen	0	0	0	0%	0%	No	----
	ammonia acute with salmonid present	3	3	165	0%	5%	No	----
	ammonia acute with salmonid absent	3	3	165	0%	3%	No	----
	ammonia chronic with salmonid present	3	3	165	0%	15%	No	----
	ammonia chronic with salmonid absent	3	3	165	0%	4%	No	----
	low lab pH	3	3	165	0%	2%	No	----
	high lab pH	3	3	165	0%	2%	No	----
	low field pH	3	3	164	0%	4%	No	----
	high field pH	3	3	164	0%	2%	No	----
	high total phosphorus	3	3	165	0%	6%	No	----
	high orthophosphate	3	3	165	0%	8%	No	----
	dissolved oxygen < 5mg/l	3	3	164	0%	1%	No	----
	dissolved oxygen < 6mg/l	3	3	164	0%	2%	No	----
	low dissolved oxygen saturation	3	3	152	0%	1%	No	----
	high dissolved oxygen saturation	3	3	152	0%	0%	No	----
	acid neutralizing capacity below chronic level	3	3	165	0%	1%	No	----
	acid neutralizing capacity below episodic level	3	3	165	0%	7%	No	----
	high chlorides	3	3	165	100%	5%	Yes	95%
	high conductivity	3	3	165	100%	6%	Yes	94%
	high sulfates	3	3	165	67%	4%	Yes	62%

Table 4. Stressor Source Identification Analysis Results for the Cabin John Creek 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	3	3	164	100%	3%	Yes	97%
	high % of high intensity urban in watershed	3	3	165	100%	21%	Yes	79%
	high % of low intensity urban in watershed	3	3	165	100%	5%	Yes	95%
	high % of transportation in watershed	3	3	165	67%	9%	Yes	58%
	high % of high intensity urban in 60m buffer	3	3	164	33%	4%	No	----
	high % of low intensity urban in 60m buffer	3	3	164	67%	6%	Yes	61%
	high % of transportation in 60m buffer	3	3	164	33%	6%	No	----
Sources Agriculture	high % of agriculture in watershed	3	3	165	0%	22%	No	----
	high % of cropland in watershed	3	3	165	0%	3%	No	----
	high % of pasture/hay in watershed	3	3	165	0%	29%	No	----
	high % of agriculture in 60m buffer	3	3	164	33%	13%	No	----
	high % of cropland in 60m buffer	3	3	164	0%	3%	No	----
	high % of pasture/hay in 60m buffer	3	3	164	33%	23%	No	----
Sources Barren	high % of barren land in watershed	3	3	165	0%	10%	No	----
	high % of barren land in 60m buffer	3	3	164	0%	10%	No	----
Sources Anthropogenic	low % of forest in watershed	3	3	165	67%	8%	Yes	59%
	low % of forest in 60m buffer	3	3	164	67%	9%	Yes	58%
Sources Acidity	atmospheric deposition present	3	3	165	0%	5%	No	----
	AMD acid source present	3	3	165	0%	0%	No	----
	organic acid source present	3	3	165	0%	0%	No	----
	agricultural acid source present	3	3	165	0%	2%	No	----

Table 5. Summary of Combined Attributable Risk Values for the Stressor Groups in the Cabin John Creek Watershed

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	58%	95%
In-Stream Habitat	88%	
Riparian Habitat	----	
Water Chemistry	95%	

Table 6. Summary of Combined Attributable Risk Values for the Source Groups in the Cabin John Creek Watershed

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	97%	97%
Agriculture	----	
Barren Land	----	
Anthropogenic	92%	
Acidity	----	

Sediment Conditions

BSID analysis results for the Cabin John Creek watershed identified one sediment parameter that has a statistically significant association with poor to very poor stream biological condition: *channel alteration (marginal to poor).*

Channel alteration (marginal to poor) was identified as significantly associated with degraded biological conditions and found to impact 58% of the stream miles with very poor to poor biological conditions in the Cabin John Creek. 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*. A marginal to poor rating is expected in unstable stream channels that experience frequent high flows.

Eighty- six percent of the Cabin John Creek watershed is comprised of urban land uses. As development and urbanization increased in the Cabin John 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 accompanies urbanization alters 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). The flashiness of the Cabin John has resulted in significant channel alteration within the watershed as demonstrated by the statistically significant stressor associated with sediment condition. The scouring associated with these increased flows leads to accelerated channel alteration and erosion, thereby increasing sediment deposition throughout the streambed either through the formation of bars or settling of sediment in the stream substrate. 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, continuous displacement of biological communities that require frequent re-colonization and the loss of sensitive taxa, with a shift in biological communities to more tolerant species.

The combined AR is used to measure the extent of stressor impact of degraded stream miles, very poor to poor biological conditions. The combined AR for the sediment stressor group is approximately 58% suggesting that this stressor impacts a percentage of degraded stream miles in the Cabin John Creek watershed (Table 5).

In-stream Habitat Conditions

BSID analysis results for the Cabin John Creek watershed identified two in-stream habitat parameters that have a statistically significant association with poor to very poor stream biological condition, *channelization present* and *in-stream habitat structure (marginal to poor).*

Channelization present was identified as significantly associated with degraded biological conditions and found in 57% of the stream miles with very poor to poor biological conditions in the Cabin John Creek. 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* rating) was identified as significantly associated with degraded biological conditions and found in 56% of the stream miles with very poor to poor biological conditions in the Cabin John Creek. Instream habitat structure 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. 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. A marginal to poor rating of this measure indicates excessive erosion and/or sedimentation.

The stressors identified for the in-stream habitat parameter group are intricately linked with habitat heterogeneity. The presence or severity for these habitat stressors lower the diversity of a stream's microhabitats and substrates, subsequently causing a reduction in the diversity of biological communities. The flashiness and channelization of the Cabin John Creek watershed have resulted in significant channel and streambed alteration within the watershed. Channelization has been used extensively in urban landscapes for flood control. Fifty-seven percent of the degraded stream miles in the Cabin John watershed have channelized streams. 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 Shellberg 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 et al. 1998, Haapala and Muotka 1998). The combination of the altered flow regime and artificial channelization in the Cabin John Creek watershed results in loss of available habitat and an unstable stream ecosystem, characterized by a continuous displacement of biological communities that require frequent re-colonization impacting the dynamics (structure and abundance) of stream benthic organisms (Allan 2004). Consequently, an 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, very poor to poor biological conditions. The combined AR for in-stream habitat stressor group is approximately 88% suggesting that these stressors impacts the majority of degraded stream miles in the Cabin John Creek watershed (Table 5).

Riparian Habitat Conditions

BSID analysis results for Cabin John Creek did not identify any riparian habitat 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).

Water Chemistry

BSID analysis results for the Cabin John Creek watershed identified three water chemistry parameters that have statistically significant association with a very poor to poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters are *high conductivity*, *high chlorides*, and *high sulfates.*

High conductivity was identified as significantly associated with degraded biological conditions and found in 94% of the stream miles with very poor to poor biological conditions in the Cabin John Creek. 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). Conductivity, chlorides and sulfates are closely related. Streams with elevated levels of chlorides and sulfates typically display high conductivity.

High chlorides was identified as significantly associated with degraded biological conditions and found in 95% of the stream miles with very poor to poor biological conditions in the Cabin John Creek. High concentrations of chlorides can result from industrial discharges, metals contamination, and application of road salts in urban landscapes. The Cabin John Creek watershed is located in Montgomery County, a Phase I National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm

Sewer System (MS4) permit jurisdiction. The MS4 permit covers stormwater discharges from the municipal separate stormwater sewer system in the County. There is one industrial facility (Stoneyhurst Quarries, Inc.) that is regulated for flow, solids (settleable), total suspended solids, and pH. Since NPDES permitting enforcement does not require chloride testing at this facility, data was not available to verify/identify chlorides as a specific pollutant in this watershed. Since there are no metals impairments, application of road salts in the watershed is a likely source of the chlorides and high conductivity levels. Although chloride can originate from natural sources and point source discharges, usually most of the chloride that enters the environment is associated with the storage and application of road salt (Smith et al. 1987). According to Church and Friesz (1993), road salt accumulation and persistence in watersheds poses risks to aquatic ecosystems and to water quality. Approximately 55% of road-salt chlorides are transported in surface runoff, with the remaining 45% infiltrating through soils and into groundwater aquifers.

High sulfates was identified as significantly associated with degraded biological conditions and found in 62% of the stream miles with very poor to poor biological conditions in the Cabin John Creek. Sulfate 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 is one industrial facility (Stoneyhurst Quarries, Inc.) that is regulated for various parameters including flow, solids (settleable), total suspended solids, and pH. Since NPDES permitting enforcement does not require sulfate testing at any of these facilities, data were not available to verify/identify sulfate as a specific pollutant in this watershed.

In summary, water chemistry is another major determinant of the integrity of surface waters that is strongly influenced by land-use. Land development in the Cabin John watershed can lead to increases in contaminant loads from point and nonpoint sources by adding sediments, nutrients, road salts, toxics, petroleum products, and inorganic pollutants to surface waters. Increased levels of many pollutants like chlorides, sulfates, and conductivity 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, very poor to poor biological conditions. The combined AR for water chemistry stressor group is approximately 95% suggesting that inorganic pollutant stressors impact almost all the degraded stream miles in the Cabin John Creek watershed (Table 5).

Currently in Maryland there are no specific numeric criteria that quantify the impact of conductivity and chlorides 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 the specific pollutant(s) from the array of potential inorganic pollutants inferred from the BSID analysis.

Sources

All six stressor parameters, identified in Tables 1-3, that are significantly associated with biological degradation in the Cabin John Creek watershed BSID analysis are representative of impacts from urban landscapes. 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.

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 *low % of forest land use* is likely a result of the increased urbanization in the watershed. 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. 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).

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 97% suggesting that urban development potentially impact almost all the degraded stream miles in Cabin John Creek (See Table 6).

Summary

The Cabin John Creek watershed has been significantly impacted by suburban development. Rockville Pike and the City of Rockville occupy the headwaters of Cabin John Creek and on-site stormwater runoff controls are uncommon in Cabin John (Van Ness and Haddaway 1999). The BSID analysis results suggest that degraded biological communities in the Cabin John Creek watershed are a result of increased urban land use causing alterations to hydrologic regime, channelization and altering in-stream habitat conditions. The channelization and altered hydrology has caused frequent high flow events, degradation to in-stream habitat quality, and increased sediment loads, resulting in an unstable stream ecosystem that eliminates optimal habitat.

Due to the increased proportions of urban land use in the Cabin John Creek watershed, the watershed has experienced an increase in contaminant loads from point and nonpoint sources, resulting in levels of inorganic pollutants that can be extremely toxic to aquatic organisms. Alterations to the hydrologic regime, physical habitat, and inorganic pollutant loading, have all combined to degrade the Cabin John Creek watershed, leading to a loss of diversity in the biological community. The combined AR for all the stressors is approximately 95%, suggesting that sediment, in-stream habitat and water chemistry stressors identified in the BSID analysis would adequately account for the biological impairment in the Cabin John Creek watershed (Table 5).

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 scenarios (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 Casual Model for the Cabin John Creek

Casual model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr, 1991 and USEPA 2007). 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 casual model for the Cabin John Creek watershed, with pathways bolded or highlighted to show the watershed’s probable stressors as indicated by the BSID analysis.

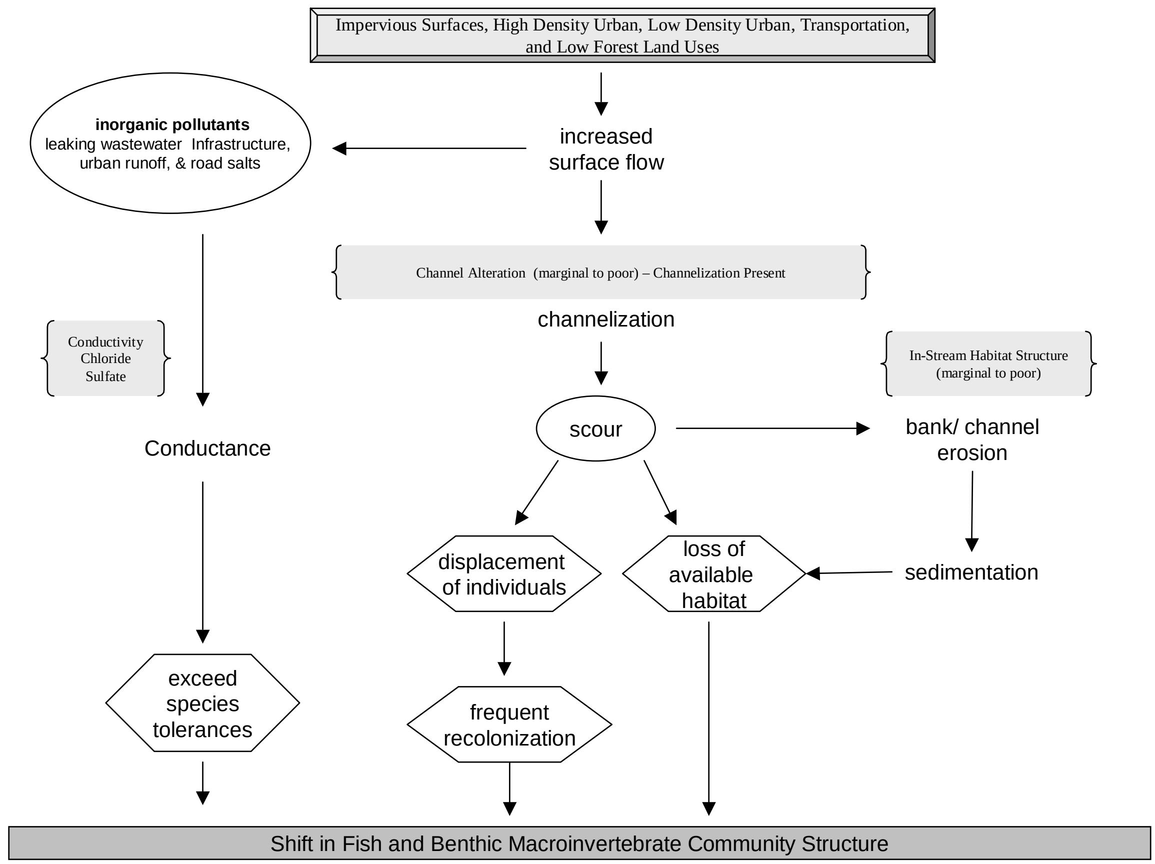

Figure 6. Final Causal Model for the Cabin John Creek Watershed

5.0 Conclusion

Data suggest that the Cabin John Creek watershed's biological communities are strongly influenced by urban land use, which alters the hydrologic regime resulting in increased erosion, sediment, 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 analysis, the following actions to address the biological impairments of the Cabin John Creek watershed are proposed:

- The BSID analysis has determined that the biological communities in the Cabin John Creek watershed are likely degraded due to inorganic pollutants (i.e., chloride, conductivity, sulfate). Inorganic pollutants levels are significantly associated with degraded biological conditions and found in approximately 95% of the stream miles with very poor to poor biological conditions in the Cabin John watershed. Impacts on water quality due to conductivity, chlorides, and sulfates are dependent on prolonged exposure; future monitoring of these inorganic pollutants will help in determining the spatial and temporal extent of this impairment 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. Currently, there is a lack of monitoring data for many of these substances; therefore, additional monitoring of priority inorganic pollutants is needed to more precisely determine the specific cause(s) of impairment.

- The BSID analysis has determined that biological communities in the Cabin John Creek watershed are also likely degraded due to flow/sediment related stressors. Specifically, altered hydrology and increased stormwater runoff from urban impervious surfaces have resulted in elevated suspended sediment transport through the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus confirm the 1996 Category 5 listing for total suspended solids as an impairing substance in the Cabin John Creek watershed, and links this pollutant to biological conditions in these waters.

- The BSID process has also determined that biological communities in the Cabin John Creek 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 Cabin John Creek watershed based on channelization being present in approximately 57% of degraded stream miles.

- Although there is presently a Category 5 listing for phosphorus in Maryland’s 2008 Integrated Report, the BSID analysis did not identify any nutrient stressors, (i.e., total nitrogen, total phosphorus, dissolved oxygen, etc.) present and/or nutrient stressors showing a significant association with degraded biological conditions.

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