Watershed Report for Biological Impairment of the West River in Anne Arundel County, Maryland Biological Stressor Identification Analysis Results and Interpretation

FINAL

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Submitted to:

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1650 Arch Street
Philadelphia, PA 19103-2029

January 2012

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List of Abbreviations

ANC	Acid Neutralizing Capacity
AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
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 West River watershed (basin code 02131004), located in Anne Arundel County, MD is associated with three assessment units in the Integrated Report (IR): non-tidal (8-digit basin) and two estuary portions (Chesapeake Bay segments). The Chesapeake Bay segments related to the West River are the West River and Rhode River Mesohaline. Below is a table identifying the listings associated with this watershed.

Table E1. 2010 Integrated Report Listings for the West River Watershed

<table>
<tr><th>Watershed</th><th>Basin Code</th><th>Non-tidal/Tidal</th><th>Subwatershed</th><th>Designated Use</th><th>Year listed</th><th>Identified Pollutant</th><th>Listing Category</th></tr>
<tr><td>West River</td><td>02131004</td><td>Non-tidal</td><td></td><td>Aquatic Life and Wildlife</td><td>2002</td><td>Impacts to Biological Communities</td><td>5</td></tr>
<tr><td rowspan="8">West River Mesohaline</td><td rowspan="8">WSTMH</td><td rowspan="8">Tidal</td><td></td><td>Fishing</td><td>2006</td><td>PCB in Fish Tissue</td><td>5</td></tr>
<tr><td></td><td>Aquatic Life and Wildlife</td><td>2010 assessment</td><td>Estuarine Bioassessments</td><td>3</td></tr>
<tr><td></td><td rowspan="2">Open-Water Fish and Shellfish Subcategory</td><td rowspan="2">1996</td><td>TP</td><td rowspan="2">5</td></tr>
<tr><td></td><td>TN</td></tr>
<tr><td></td><td rowspan="3">Seasonal Migratory Fish spawning and nursery Subcategory</td><td rowspan="3">1996</td><td>TN</td><td rowspan="2">3</td></tr>
<tr><td></td><td>TP</td></tr>
<tr><td></td><td>TSS</td><td>2</td></tr>
<tr><td></td><td>Tidal Shellfish Area</td><td>1996</td><td>Fecal Coliform</td><td>4a</td></tr>
</table>

Table E1. 2010 Integrated Report Listings for the West River Watershed (cont'd)

Watershed	Basin Code	Non-tidal/Tidal	Subwatershed	Designated Use	Year listed	Identified Pollutant	Listing Category
Rhode River Mesohaline	RHDMH	Tidal		Fishing	2006	PCB in Fish Tissue	5
				Aquatic Life and Wildlife	2010 assessment	Estuarine Bioassessments	3
				Open-Water Fish and Shellfish Subcategory	1996	TP	5
						TN	
				Seasonal Migratory Fish spawning and nursery Subcategory		TP	3
						TN	
					1996	TSS	5
			Bear Neck Creek	Tidal Shellfish Area	1996	Fecal Coliform	4a
			Parish Creek				
			Cadle Creek				

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 of less than three, and calculating whether this is a significant deviation from reference condition watersheds (i.e., healthy stream, less than 10% stream miles degraded).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the West River watershed's tributaries including Muddy Creek from the confluence with South Fork Muddy Creek to North Fork Muddy Creek, the un-named tributaries to West River near Johns Creek and Lerch Creek, Smith Creek at the confluence to West River, and the West River headwaters are designated as Use I - *water contact recreation, and protection of nontidal warmwater aquatic life*. All other tributaries including the Rhode River and Muddy Creek, from the confluence with Steinlein Branch to the confluence with Boathouse Creek, are designated as Use II - *support of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2010 a, b). The West 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) (Southerland et al. 2005a).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause of reduced biological conditions, thus enabling the Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors, sources of stressors and the biological community, and the likely impact these stressors would have on 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 West River 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 degradation of biological communities in the West River watershed is due to natural conditions that are probably exacerbated by the watershed's agricultural legacy and increasing urban land use and its concomitant effects: altered hydrology and elevated levels of sediments, and inorganic pollutants. Peer-reviewed scientific literature establishes a link between highly agricultural and 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 in the West River watershed can be summarized as follows:

- The BSID process has determined that biological communities in West River watershed are likely degraded due to flow/sediment and in-stream habitat related stressors. Specifically, natural sediment conditions of the Coastal Plain physiographic region that have been exacerbated by anthropogenic sources, have resulted in altered habitat heterogeneity and subsequent elevated suspended sediment in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results confirm the tidal 1996 Category 5 listing for total suspended solids (TSS) as an appropriate management action in the watershed, and links this pollutant to biological conditions in these waters and extend the impairment to the watershed's non-tidal waters. Therefore, the establishment of total suspended solids TMDL in 2010 through the Chesapeake Bay TMDL was an appropriate management action to begin addressing this stressor to the biological communities in the West River watershed. In addition, the BSID results support the identification of the non-tidal portion of this watershed in Category 5 of the Integrated Report as impaired by TSS to begin addressing the impacts of this stressor on the biological communities in the West River.

- The BSID process has also determined that the biological communities in the West River watershed are likely degraded due to inorganic pollutants (i.e., sulfates). Sulfate levels are significantly associated with degraded biological conditions and found in 63% of the stream miles with poor to very poor biological conditions in the West 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 of sulfates for 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 West River watershed.
- There is presently a Category 5 listing for phosphorus in Maryland’s 2008 Integrated Report; this listing is for the tidal portion of the West River watershed. The BSID analysis did not identify any nutrient stressors present and/or nutrient stressors showing a significant association with degraded biological conditions in the non-tidal portion of the West River watershed.

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 2009). 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, less than 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 West River watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 West River Watershed Characterization

2.1 Location

The West River watershed is located on the lower western shore of Maryland in Anne Arundel County (see Figure 1). The West River watershed is comprised of two major tributaries, the West and Rhode Rivers. The drainage area of the Maryland 8-digit watershed is approximately 19,865 acres. The watershed is located in the Coastal Plain region, one of three distinct eco-regions identified in the MDDNR MBSS Index of Biological Integrity (IBI) metrics (Southerland et al. 2005a) (see Figure 2).

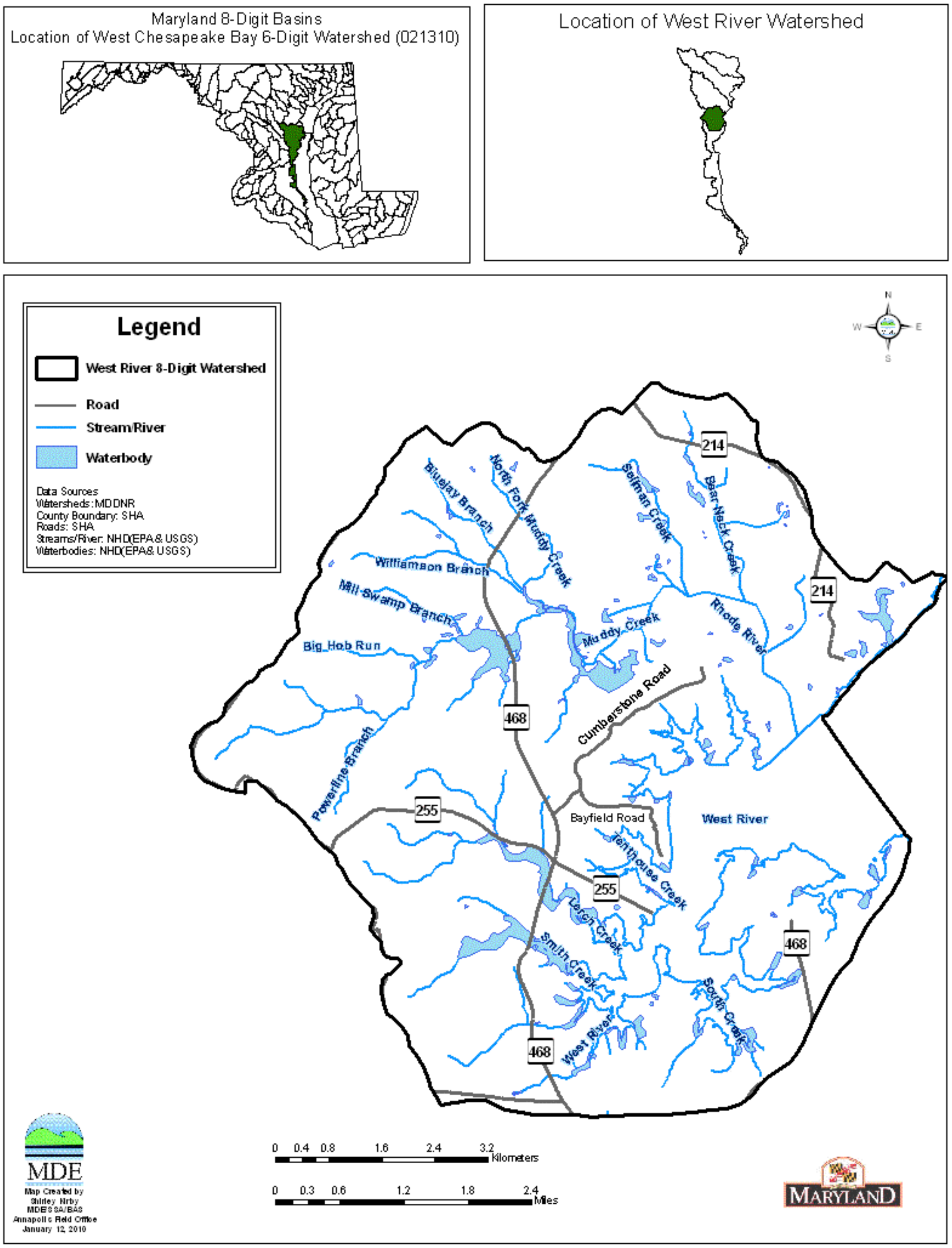

Figure 1. Location Map of the West River Watershed

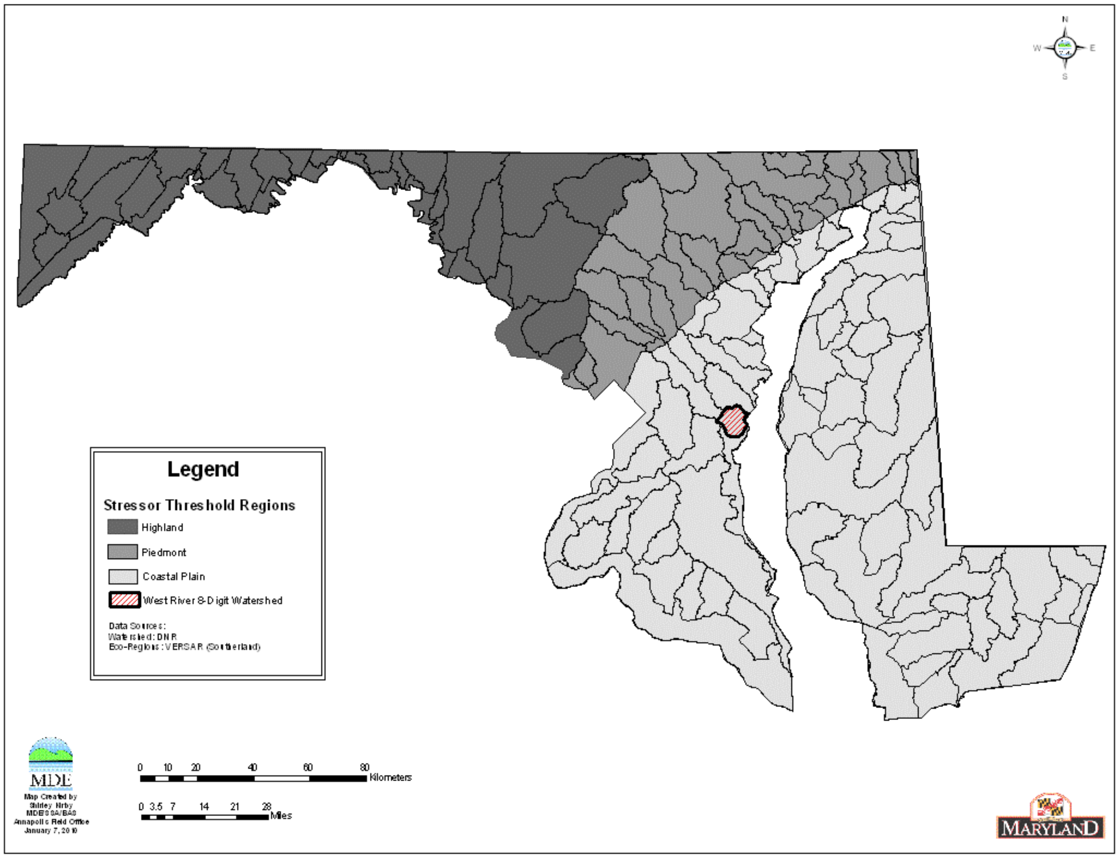

Figure 2. Eco-Region Location Map of the West River Watershed

2.2 Land Use

The West River watershed lies within the Coastal Plain Physiographic Province. The watershed contains primarily forest land use; agricultural land use is secondary (see Figure 3). Urban, specifically residential, land use is also present in the watershed; this includes the towns of Beverly Beach, Galesville, and Shadyside. State and county paved roads, such as routes 214, 255, 468, and 790, interconnect points within the watershed. The Rhode River is one of two major tributaries in the West River watershed, Muddy Creek and Bear Neck Creek are the two tributaries of this river. The Smithsonian Environmental Research Center occupies several acres of the Muddy Creek wetland area, which is located on the northwestern shore of the Rhode River. The Camp Letts YMCA is on a peninsula at the northern end of the Rhode River, northeast of Muddy Creek along Bear Neck Creek. The land use distribution in the watershed is approximately 37% forest/herbaceous, 28% agriculture/pasture, water/wetlands 19%, and 16% urban (see Figure 4) (MDP 2002).

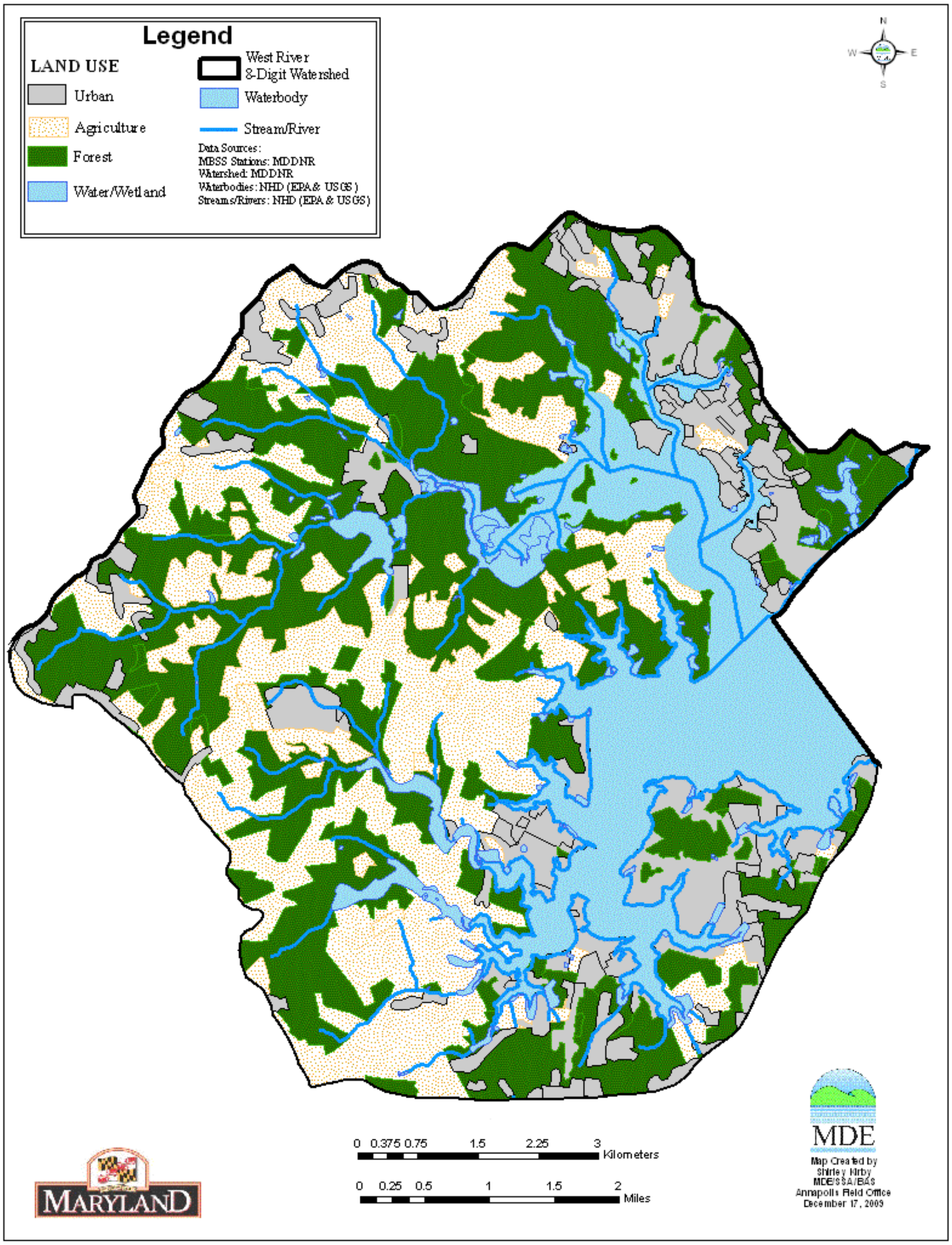

Figure 3. Land Use Map of the West River Watershed

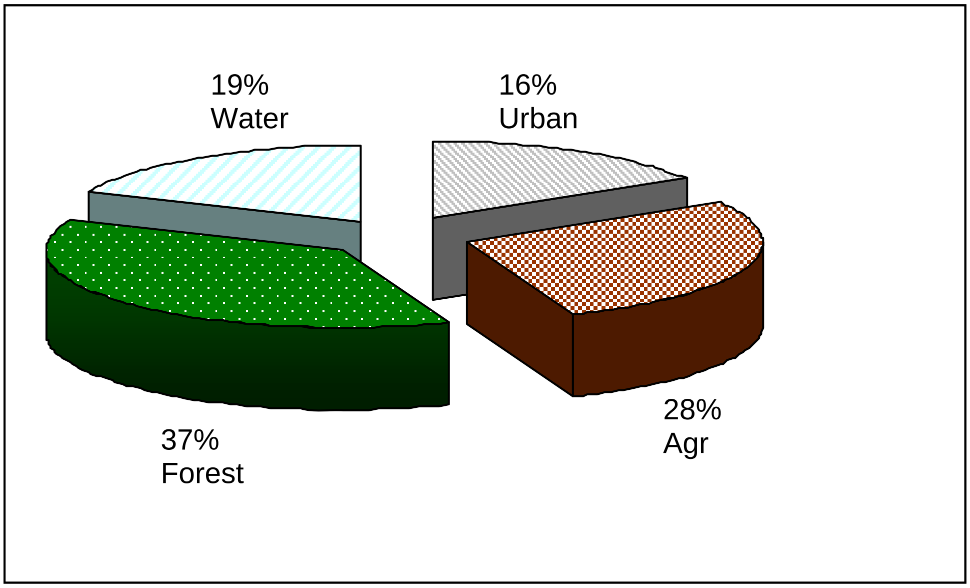

Figure 4. Proportions of Land Use in the West River Watershed

2.3 Soils/hydrology

The West River watershed is in the Coastal Plain Physiographic Province, in Anne Arundel County. There are three soil series in the watershed, Collington, Othello, and Westphalia. These soils consist of unconsolidated deposits of gravel, sand, silt, and clay. The moisture capacity of the soils range from moderately low to high, strongly to extremely acidic, and have a high silt concentration and erosion potential (NRCS 1973). The topography ranges from nearly level to very steep; erosion can easily remove any high spots that develop in these soft, uncemented materials (NRCS 1973; Schmidt 1993).

3.0 West River Watershed Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Maryland Department of the Environment has identified the non-tidal areas of the West River watershed on the State's Integrated Report under Category 5 as impaired by evidence of biological impacts (2002 listings). The West River watershed (basin code 02131004), located in Anne Arundel County, MD is associated with three assessment units in the Integrated Report (IR): non-tidal (8-digit basin) and two estuary portions (Chesapeake Bay segments). The Chesapeake Bay segments related to the West River are the West River and Rhode River Mesohaline. Below is a table identifying the listings associated with this watershed.

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West River Mesohaline	WSTMH	Tidal		Fishing	2006	PCB in Fish Tissue	5
				Aquatic Life and Wildlife	2010 assessment	Estuarine Bioassessments	3
				Open-Water Fish and Shellfish Subcategory	1996	TN	5
						TP	
				Seasonal Migratory Fish spawning and nursery Subcategory	2010 assessment	TN	3
						TP	
						TSS	2
				Tidal Shellfish Area	1996	Fecal Coliform	4a
Rhode River Mesohaline	RHDMH	Tidal		Fishing	2006	PCB in Fish Tissue	5
				Aquatic Life and Wildlife	2010 assessment	Estuarine Bioassessments	3
				Open-Water Fish and Shellfish Subcategory	1996	TN	5
						TP	
				Seasonal Migratory Fish spawning and nursery Subcategory	2010 assessment	TP	3
						TN	
					1996	TSS	5
			Bear Neck Creek	Tidal Shellfish Area	1996	Fecal Coliform	4a
			Parish Creek				
			Cadle Creek				

3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the West River watershed's tributaries including Muddy Creek (confluence with South Fork Muddy Creek to North Fork Muddy Creek), the un-named tributaries to West River near Johns Creek and Lerch Creek, Smith Creek at the confluence to West River, and the West River headwaters are designated as Use I - *water contact recreation, and protection of nontidal warmwater aquatic life.* All other tributaries including the Rhode River and Muddy Creek, from the confluence with Steinlein Branch to the confluence with Boathouse Creek, are designated as Use II -

support of estuarine and marine aquatic life and shellfish harvesting (COMAR 2010 a, b). 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 West River watershed is listed under Category 5 of the 2008 Integrated Report as impaired for impacts to biological communities. Approximately 57% of stream miles in the West River watershed are estimated as having fish and/or benthic indices of biological impairment in the poor to very poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data, which include seven stations. Four of the seven stations have degraded 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 four sites; all four having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the West River watershed.

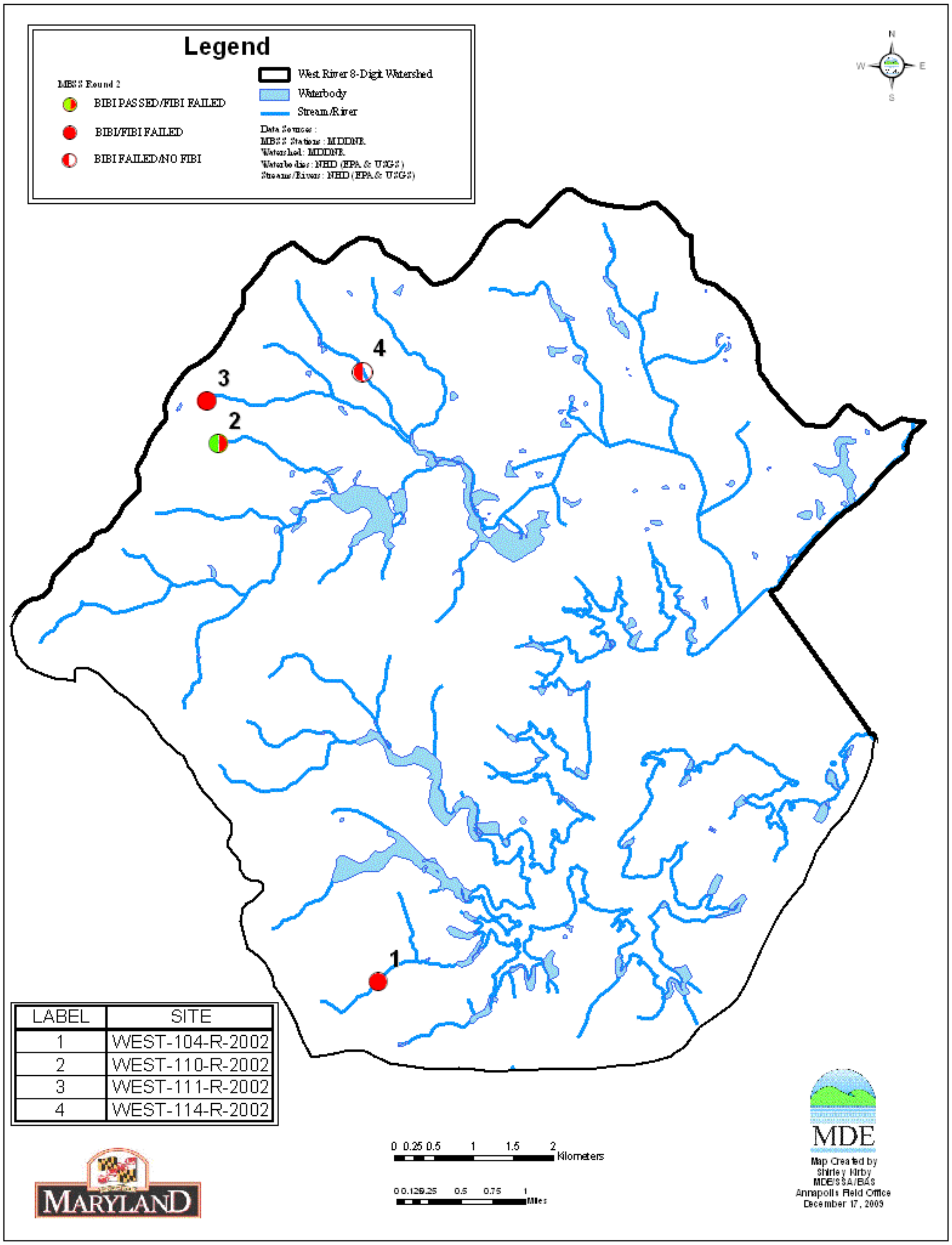

Figure 5. Principal Dataset Sites for the West River Watershed

4.0 Stressor Identification Results

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

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

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

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

Once the AR is calculated for each possible stressor, the AR for groups of stressors is calculated. Similar to the AR calculation for each stressor, the AR calculation for a group of stressors is also summed over the case sites using the individual site characteristics (i.e., stressors present at that site). The only difference is that the absolute risk for the controls at each site is estimated based on the stressor present at the site that has the lowest absolute risk among the controls.

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

Through the BSID data analysis, MDE identified sediment, instream habitat, and water chemistry parameters significantly associated with degraded fish and/or benthic biological conditions. The BSID did not identify potential sources significantly associated with degraded fish and/or benthic biological conditions, Table 2. As shown in Table 3 through Table 5, parameters from the sediment, instream habitat, and water chemistry groups are identified as possible biological stressors in the West River watershed. A summary of combined AR values for each source group is shown in Table 6. A summary of combined AR values for each stressor group is shown in Table 7.

Sources

The BSID stressor source analysis (Table 2) does not identify any land use parameters as potential sources of stressors that may cause negative biological impacts. The combined AR for the source group is approximately 0% suggesting that these sources do not impact the degraded stream miles in West River watershed (Table 6). Land use sources may not be significantly associated with poor to very poor biological conditions, but the presence of agricultural and urban development in the watershed probably exacerbates naturally occurring conditions (e.g., drought, soil properties) and possibly contributes to degradative effects in the watershed, see discussion section.

Table 2. Stressor Source Identification Analysis Results for the West River 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 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 - Urban	high impervious surface in watershed	4	3	214	0%	5%	No	----
	high % of high intensity urban in watershed	4	3	214	0%	9%	No	----
	high % of low intensity urban in watershed	4	3	214	0%	4%	No	----
	high % of transportation in watershed	4	3	214	33%	7%	No	----
	high % of high intensity urban in 60m buffer	3	3	212	0%	7%	No	----
	high % of low intensity urban in 60m buffer	3	3	212	0%	5%	No	----
	high % of transportation in 60m buffer	3	3	212	0%	9%	No	----
Sources - Agriculture	high % of agriculture in watershed	4	3	214	0%	18%	No	----
	high % of cropland in watershed	4	3	214	0%	27%	No	----
	high % of pasture/hay in watershed	4	3	214	0%	6%	No	----
	high % of agriculture in 60m buffer	3	3	212	0%	8%	No	----
	high % of cropland in 60m buffer	3	3	212	0%	18%	No	----
	high % of pasture/hay in 60m buffer	3	3	212	0%	8%	No	----
Sources - Barren	high % of barren land in watershed	4	3	214	0%	23%	No	----
	high % of barren land in 60m buffer	3	3	212	0%	6%	No	----
Sources - Anthropogenic	low % of forest in watershed	4	3	214	0%	5%	No	----
	low % of forest in 60m buffer	3	3	212	0%	5%	No	----
Sources - Acidity	atmospheric deposition present	4	3	208	0%	40%	No	----
	AMD acid source present	4	3	208	0%	0%	No	----
	organic acid source present	4	3	208	0%	6%	No	----
	agricultural acid source present	4	3	208	0%	7%	No	----

Table 3. Sediment Biological Stressor Identification Analysis Results for the West River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor 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 that odds or 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	3	2	132	50%	23%	No	----
	moderate bar formation present	3	2	132	50%	55%	No	----
	bar formation present	3	2	132	100%	82%	No	----
	channel alteration moderate to poor	3	2	128	50%	62%	No	----
	channel alteration poor	3	2	128	50%	27%	No	----
	high embeddedness	3	2	132	0%	0%	No	----
	epifaunal substrate marginal to poor	3	2	132	100%	45%	No	----
	epifaunal substrate poor	3	2	132	100%	10%	Yes	90%
	moderate to severe erosion present	3	2	132	50%	45%	No	----
	severe erosion present	3	2	132	0%	14%	No	----
	poor bank stability index	3	2	132	50%	23%	No	----
	silt clay present	3	2	132	100%	99%	No	----

Table 4. Habitat Biological Stressor Identification Analysis Results for the West River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor 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 that odds or 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	4	3	134	0%	13%	No	----
	instream habitat structure marginal to poor	3	2	132	100%	40%	No	----
	instream habitat structure poor	3	2	132	0%	5%	No	----
	pool/glide/eddy quality marginal to poor	3	2	132	100%	45%	No	----
	pool/glide/eddy quality poor	3	2	132	50%	3%	Yes	47%
	riffle/run quality marginal to poor	3	2	132	100%	45%	No	----
	riffle/run quality poor	3	2	132	50%	18%	No	----
	velocity/depth diversity marginal to poor	3	2	132	100%	58%	No	----
	velocity/depth diversity poor	3	2	132	100%	14%	Yes	86%
	concrete/gabion present	4	3	138	0%	1%	No	----
	beaver pond present	3	2	131	0%	6%	No	----
Riparian Habitat	no riparian buffer	4	3	134	0%	13%	No	----
	low shading	3	2	132	0%	9%	No	----

Table 5. Water Chemistry Biological Stressor Identification Analysis Results for the West River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor 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 that odds or 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	4	3	208	0%	25%	No	----
	high total dissolved nitrogen	0	0	0	0%	0%	No	----
	ammonia acute with salmonid present	4	3	208	33%	39%	No	----
	ammonia acute with salmonid absent	4	3	208	33%	26%	No	----
	ammonia chronic with salmonid present	4	3	208	100%	67%	No	----
	ammonia chronic with salmonid absent	4	3	208	67%	57%	No	----
	low lab pH	4	3	208	0%	38%	No	----
	high lab pH	4	3	208	0%	0%	No	----
	low field pH	3	2	207	0%	39%	No	----
	high field pH	3	2	207	0%	0%	No	----
	high total phosphorus	4	3	208	0%	3%	No	----
	high orthophosphate	4	3	208	0%	13%	No	----
	dissolved oxygen < 5mg/l	3	2	206	50%	14%	No	----
	dissolved oxygen < 6mg/l	3	2	206	50%	22%	No	----
	low dissolved oxygen saturation	3	2	184	50%	18%	No	----
	high dissolved oxygen saturation	3	2	184	0%	0%	No	----
	acid neutralizing capacity below chronic level	4	3	208	0%	9%	No	----
	acid neutralizing capacity below episodic level	4	3	208	0%	48%	No	----
	high chlorides	4	3	208	0%	6%	No	----
	high conductivity	4	3	208	0%	5%	No	----
	high sulfates	4	3	208	67%	4%	Yes	63%

Table 6. Summary of Combined Attributable Risk Values for Source Groups in the West River 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	----	----
Agriculture	----	
Barren Land	----	
Anthropogenic	----	
Acidity	----	

Table 7. Summary of Combined Attributable Risk Values for Stressor Groups in the West River 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	90%	94%
In-Stream Habitat	92%	
Riparian Habitat	----	
Water Chemistry	63%	

<u>Sediment Conditions</u>

BSID analysis results for the West River watershed identified one sediment parameter that has a statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community): *epifaunal substrate (poor).*

Epifaunal substrate (poor) was identified as significantly associated with degraded biological conditions and found to impact approximately 90% of the stream miles with poor to very poor biological conditions in the West River watershed. This stressor measures the abundance, variety, and stability of substrates that offer the potential for full colonization by benthic macroinvertebrates. Greater availability of productive substrate increases the potential for full colonization; conversely, less availability of productive substrate decreases or inhibits colonization by benthic macroinvertebrates. The epifaunal substrate category is rated based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. High epifaunal substrate scores are evidence of the lack of sediment deposition. However, epifaunal substrate is confounded by natural variability, i.e., some streams will naturally have different kinds of epifaunal substrate (Southerland 2005b).

Coastal Plain regions do not have the required characteristics to exhibit optimal scores for the epifaunal substrate category because they naturally have a higher percentage of sediment loading than other physiographic regions. The West River watershed is located in Anne Arundel County in the mid-Atlantic Coastal Plain; the soils (i.e., Collington, Othello, and Westphalia) have a silt loam and sand consistency, and are highly erodible. All of the major streams in this region are normally sluggish, and many have large accumulations of silt (NRCS 1973).

Sediment pollution in the West River watershed has resulted in the exceedance of species tolerances and subsequent trophic alteration (e.g., shift to more silt-tolerant species). Consequently, an impaired biological community with poor IBI scores is observed. Agricultural and urban land use sources were not identified as significantly associated with degraded stream miles in the West River watershed, but both of these source groups may result in an exacerbation of the naturally occurring conditions in the watershed.

The combined AR is used to measure the extent of stressor impact of degraded stream miles, poor to very poor biological conditions. The combined AR for the sediment stressor group is approximately 90%, suggesting that this stressor group impacts a substantial proportion of the degraded stream miles in the West River watershed (Table 7).

Instream Habitat Conditions

BSID analysis results for the West River watershed identified two instream habitat parameters that have a statistically significant association with poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community): *pool/glide/eddy quality (poor)* and *velocity/depth diversity (poor)*.

Pool/glide/eddy quality (poor) was identified as significantly associated with degraded biological conditions and found to impact approximately 47% of the stream miles with poor to very poor biological conditions in the West River watershed. Pool/glide/eddy quality is a visual observation and quantitative measurement of the variety and spatial complexity of slow or still water habitat and cover within a stream segment referred to as pool/glide/eddy. Stream morphology complexity directly increases the diversity and abundance of fish species found within the stream segment. The increase in heterogeneous habitat such as a variety in depths of pools, slow moving water, and complex covers likely provide valuable habitat for fish species; conversely, a lack of heterogeneity within the pool/glide/eddy habitat decreases valuable habitat for fish species.

Velocity/depth diversity (poor) was identified as significantly associated with degraded biological conditions and found to impact approximately 86% of the stream miles with poor to very poor biological conditions in the West River watershed. Velocity/depth diversity is a visual observation including quantitative measurements based on the variety of velocity/depth regimes present at a site (i.e., slow-shallow, slow-deep, fast-shallow, and fast-deep). An increase in the number of different velocity/depth regimes likely increases the abundance and diversity of fish species within the stream segment. The decrease in the number of different velocity/depth regimes likely decreases the abundance and diversity of fish species within the stream segment. The 'poor' diversity categories could identify the absence of available habitat to sustain a diverse aquatic community. This measure may reflect natural conditions (e.g., bedrock), anthropogenic conditions (e.g., widened channels, dams, channel dredging, etc.), or excessive erosional conditions.

Both of the instream habitat stressors identified, *pool/glide/eddy quality (poor) and velocity/depth diversity (poor)*, are intricately linked with habitat heterogeneity. 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 altered streams. Stream morphology complexity directly increases the diversity and abundance of fish species found within the stream segment. The increase in heterogeneous habitat such as a variety in depths of pools, slow moving water, and complex covers likely provide valuable habitat for fish species; conversely, a lack of heterogeneity within the pool/glide/eddy habitat decreases valuable habitat for fish species. A lack of varying velocities and depth may reflect a combination of natural conditions, anthropogenic conditions, or excessive erosional conditions.

The combination of the altered flow regime and increased sediment in the West River watershed has resulted in loss of available habitat and an unstable stream ecosystem, characterized by a continuous sediment deposition that smothers instream biological communities. Consequently, an impaired biological community with poor IBI scores is observed. Agricultural and urban land use sources were not identified as significantly associated with degraded stream miles in the West River watershed, but both of these source groups may be associated with significant channel and streambed alteration.

The combined AR is used to measure the extent of stressor impact of degraded stream miles, poor to very poor biological conditions. The combined AR for the instream habitat stressor group is approximately 92% suggesting that this stressor group impacts a substantial proportion of the degraded stream miles in the West River (Table 7).

Riparian Habitat Conditions

BSID analysis results for the West River watershed did not identify riparian habitat parameters that have statistically significant associations with poor to very poor stream biological condition.

Water Chemistry

BSID analysis results for the West River watershed identified one water chemistry parameter that has a statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community): *high sulfates.*

High sulfates concentration was identified as significantly associated with degraded biological conditions and found to impact approximately 63% of the stream miles with poor to very poor biological conditions in the West River watershed. Sulfates can play a critical role in the elevation of conductivity. Other detrimental impacts of elevated sulfates are their ability to form strong acids, which can lead to changes of pH levels in surface waters. Sulfate loads to surface waters can be naturally occurring or originate from urban runoff, agricultural runoff, acid mine drainage, atmospheric deposition, and wastewater dischargers. When naturally occurring, they are often the result of the breakdown of leaves that fall into a stream, of water passing through rock or soil containing gypsum and other common minerals.

The Coastal Plain region has a legacy of high sulfate concentrations due to natural conditions (e.g., wetlands), atmospheric deposition, and agricultural practices. Due to the relatively recent expansion of suburban development in the West River watershed, a corridor between Annapolis and Washington, D.C., soils are often disturbed by construction activities. When these local soils are excavated too deeply, they can give rise to severe active acid sulfate soil problems if the underlying un-oxidized zone of the soil-geologic column that still contains sulfide minerals is exposed (MAPSS 2006). 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. Due to the relatively close proximity of Baltimore City's industrial facilities, atmospheric deposition of sulfates may be associated with poor to very poor biological stream conditions in the watershed. Mid-Atlantic streams whose sulfate concentrations are less than 300 μeq/L most likely receive a majority of their sulfate and possibly their entire sulfate load, from the atmosphere (Herlihy, Kaufman, and Mitch 1991). There are several National Pollutant Discharge Elimination System (NPDES) permitted discharge facilities in the West River watershed. NPDES permitting enforcement does not require sulfate testing; therefore data was not available to verify/identify sulfate as a specific pollutant in this watershed.

The National Atmospheric Deposition Program (NADP) monitors sulfate deposition in the United States. Figure 6 illustrates sulfate deposition at the Wye, Queen Anne County monitoring location (MD13) (NADP 2010). This trend line emulates a decreasing trend in sulfate deposition in the continental United States. Although sulfate deposition is generally decreasing, sulfates are still present in the sediment and can be released by natural and anthropogenic conditions. Due to the anoxic conditions caused by the 2002 drought, sulfates were probably released from the depositional sediments, and/or aeration of previously submerged wetland soils, which caused re-oxidation of stored sulfides to sulfate in the watershed (Eimers and Dillon 2002). Two of four sites in the BSID principal dataset have acid neutralizing capacity (ANC) results that are just above the threshold limit of 200, at 209 and 220 µeq/L; these stations also have higher sulfate concentration results than the other two stations. The soils of the West River watershed are strongly to extremely acidic, the intermittent release of depositional sulfates exacerbates this naturally occurring condition. During baseflow conditions an ANC of 50-200 µeq/L indicates that a stream is vulnerable to episodic acidification, the MDDNR (2000-2004 data) found that 50% of the Lower Western Shore streams were affected by acidic deposition (Southerland 2005b).

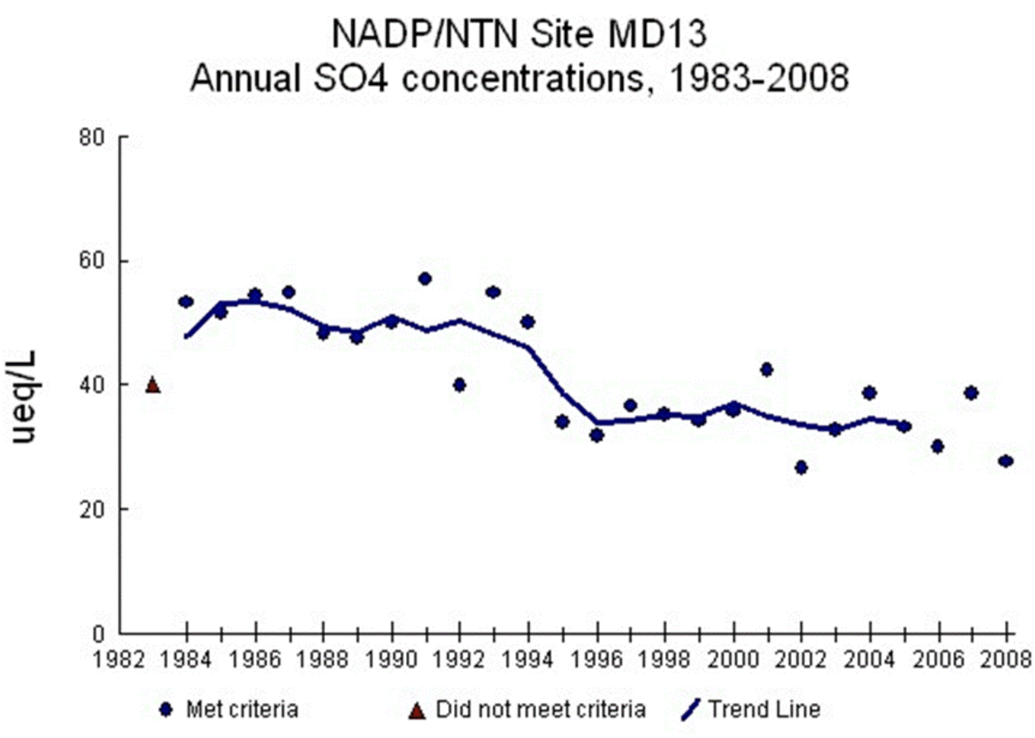

Figure 6. 1983-2008 Sulfate Deposition Trend at Wye, Queen Anne County, Maryland (MD13).

Excess sulfates in the West River watershed has resulted in the exceedance of species tolerances and subsequent trophic alteration. Consequently, an impaired biological community with poor IBI scores is observed. Agricultural and urban land use sources were not identified as significantly associated with degraded stream miles in the West River watershed, but both of these source groups may be associated with an increase of sulfates.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the water chemistry stressor group is approximately 63% suggesting this stressor impacts a considerable proportion of the degraded stream miles in the West River watershed (Table 7).

Discussion

The BSID results did not identify land use sources as significant in the West River watershed. Due to this lack of anthropogenic association, MDE scientists conducted a brief field reconnaissance and contacted Christopher Trumbauer, because of his extensive knowledge of the watershed as the current West/Rhode Riverkeeper, to discuss possible land use sources. The combination of natural characteristics (i.e., normally little freshwater input, very little flushing/stormwater driven flows, nutrient pulses, high erosion capacity) and land use sources (i.e., agricultural legacy and increasing urbanization) may be contributing to biological degradation (WRRI 2010; CWP 2009). The 2009 Attorney General's environmental audit states that poor water quality in the West River watershed is the combined result of runoff from agriculture, construction, and stormwater (MAGO 2009).

The primary dataset in the BSID analysis contain headwater (i.e., first-order) streams; these streams do not typically support biologically diverse and/or sustainable communities (Vannote et al. 1980). Therefore the biological communities of these streams are more vulnerable to intermittent and/or an extended duration of natural and anthropogenic land use alterations, and their associated stressors. The West River watershed is in the Coastal Plain physiographic region, this region is naturally impacted by sediment deposition due to the region's soil and hydrology, and under normal conditions the watershed receives low freshwater input. During baseline conditions there is very little flushing except stormwater flow, subsequently there are usually episodic pulses of nutrients and sediments occurring in the watershed (WRRI 2010).

Natural hydrological variability may play a significant role in the degradation of biological communities in the West River watershed. All the physiographic regions of Maryland were affected by the drought of 2001-2002; the western shore Coastal Plain region had a dramatic response with very low flows and standing pools (Prochaska 2005). During this time, the fish and benthic macroinvertebrate communities experienced drastic changes in water quality, and a reduction in the quantity and quality of available physical habitat. The West River watershed primary dataset contains four sites and was sampled in 2002; during the summer sampling index period the MDDNR MBSS noted very little flow/water in three of the streams and one stream was dry.

Historically the West River watershed's predominant land use was agricultural; tobacco was the leading cash crop (NRCS 1973). Since 1973 the region has becomes more urbanized and farming has declined in economic importance; currently agricultural land use comprises 28% of the watershed. The farms in the watershed are horse, crop, and sod. Sod farmers fertilize fields by injecting sludge into the soil; creeks running through or near these farms reportedly have extremely high sediment levels (MAGO 2009). Agricultural land use results in increased sediment deposition within a watershed; sediment "pollution" is the number one impairment of streams nationwide and sediments can depress populations of invertebrates and fishes, increasing the dominance of silt-tolerant species (Southerland et al. 2005b). Streams in highly agricultural landscapes tend to have poor habitat quality, reflected in declines in habitat indexes and bank stability, as well as greater deposition of sediments on and within the streambed (Roth et al. 1996; Wang et al. 1997). Due to low flow conditions, pollutants settle in the stream; during high flow periods (i.e., snowmelt, stormwater) sediment and nutrients are transported downstream.

The West River watershed is 37% forested, but according to Wang et al. 2001, even under the best-case urban development scenarios, stream fish communities will decline substantially in quality even while a watershed remains largely rural in character. Urban land use comprises 16% of the watershed; urban land development can cause an increase in contaminant loads from point and non-point sources (e.g., lawn fertilizers, failing septic systems) by adding sediments and inorganic pollutants to surface waters. The MDDNR MBSS noted a dump approximately 900 meters (downstream) from one of the watershed sampling sites. The effects of increased transportation in the watershed may also be related to degraded stream miles, and altered stream hydrology, in the watershed. State and county paved roads, such as Routes 214 and 468, interconnect points within the region and are heavily traveled. Roads tend to capture and export more stormwater pollutants than other land covers; as rainfall amounts become larger, previously pervious areas in most residential landscapes become more significant sources of runoff, including sediment (NRC 2008). In watersheds already experiencing anthropogenic stress, hydrologic variability is exacerbated by urbanization, which increases the amount of impervious surface in a basin and causes higher overland flows to streams, especially during storm events (Southerland et al. 2005b).

<ins>Summary</ins>

The BSID analysis results identified stressors (i.e., sediment, instream habitat, water chemistry) but there were no anthropogenic sources identified as associated with poor to very poor stream biological conditions. This may suggest that degraded biological communities in the West River watershed are only a result of naturally occurring conditions, e.g., Coastal Plain soil and hydrology characteristics, and the release of depositional sulfates by 2002 drought conditions. However, these naturally occurring conditions may also be exacerbated by the watershed's agricultural legacy and increasing urban land use. Due to such factors, an unstable stream ecosystem is created, often resulting in a loss of available habitat from sedimentation (i.e., decreased habitat heterogeneity) and subsequent loss of sensitive taxa. Altered flow regimes, as a result of agriculture and urbanization, allow for greater flooding that creates a less stable stream channel leading to excessive bank erosion, loss of pool habitat and instream cover, and sediment deposition (Wang et al. 2001). All of these impacts have resulted in a shift in fish and benthic macroinvertebrate community structure in the West River watershed. The combined AR for all the stressors is approximately 94%, suggesting that altered hydrology/sediment, instream habitat and water chemistry stressors adequately account for the biological impairment in the West River watershed.

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 West River Watershed

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr 1991; USEPA 2010). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 7 illustrates the final casual model for the West River watershed, with pathways to show the watershed's probable stressors as indicated by the BSID analysis.

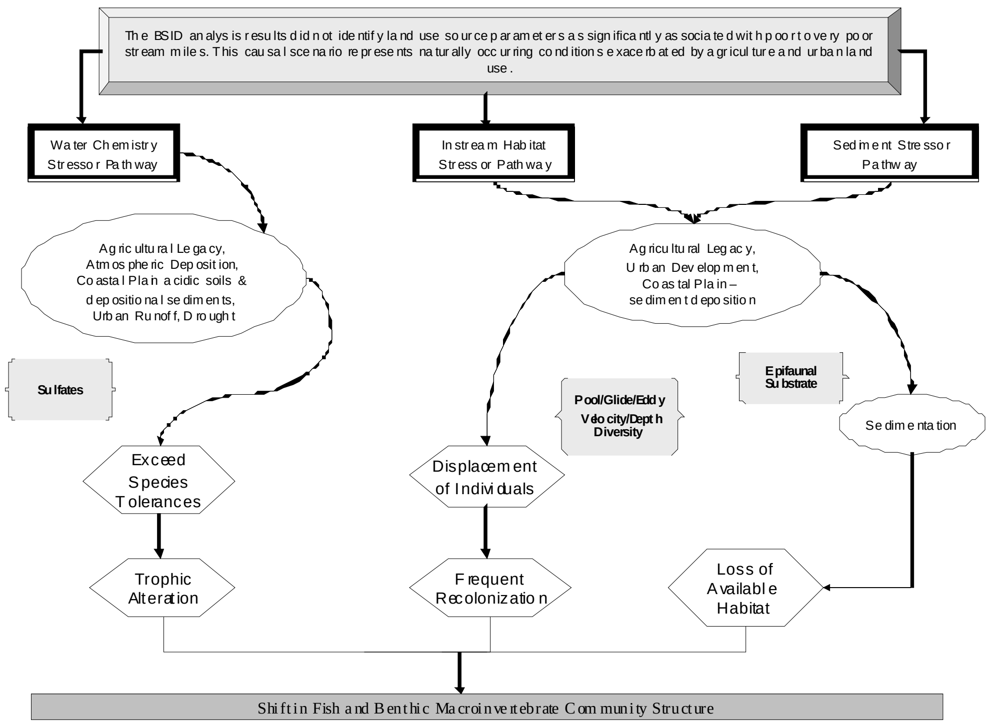

Figure 7. Final Causal Model for the West River Watershed

5.0 Conclusions

Data suggest that the West River watershed's biological communities are influenced by naturally occurring conditions that may be exacerbated by the watershed's legacy of agricultural land use, increasing urban land use and the 2002 drought. These land uses alter the hydrologic regime of a watershed resulting in increased 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 agricultural and 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 West River watershed are summarized as follows:

- The BSID process has determined that biological communities in West River watershed are likely degraded due to flow/sediment and in-stream habitat related stressors. Specifically, natural sediment conditions of the Coastal Plain physiographic region that have been exacerbated by anthropogenic sources, have resulted in altered habitat heterogeneity and subsequent elevated suspended sediment in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results confirm the tidal 1996 Category 5 listing for total suspended solids (TSS) as an appropriate management action in the watershed, and links this pollutant to biological conditions in these waters and extend the impairment to the watershed's non-tidal waters. Therefore, the establishment of total suspended solids TMDL in 2010 through the Chesapeake Bay TMDL was an appropriate management action to begin addressing this stressor to the biological communities in the West River watershed. In addition, the BSID results support the identification of the non-tidal portion of this watershed in Category 5 of the Integrated Report as impaired by TSS to begin addressing the impacts of this stressor on the biological communities in the West River.

- The BSID process has also determined that the biological communities in the West River watershed are likely degraded due to inorganic pollutants (i.e., sulfates). Sulfate levels are significantly associated with degraded biological conditions and found in 63% of the stream miles with poor to very poor biological conditions in the West 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 of sulfates for 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 West River watershed.

- There is presently a Category 5 listing for phosphorus in Maryland's 2010 Integrated Report; this listing is for the tidal portion of the West River watershed. The BSID analysis did not identify any nutrient stressors present and/or nutrient stressors showing a significant association with degraded biological conditions in the non-tidal portion of the West River watershed.

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