Watershed Report for Biological Impairment of Upper Chester River Watershed in Kent and Queen Anne's Counties, Maryland

FINAL

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Submitted to:

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
MBSS	Maryland Biological Stream Survey
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
mg/L	Milligrams per liter
MH	Mantel-Haenzel
NPDES	National Pollution Discharge Elimination System
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

Executive Summary

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

The Upper Chester River watershed (basin code 02130510), located in Kent and Queen Anne's Counties, has two different assessment units: non-tidal (8-digit basin) and an estuary portion (Chesapeake Bay segment) in the Integrated Report (IR): The Chesapeake Bay segment related to the Upper Chester River watershed is the Upper Chester River Tidal Fresh segment. All impairments are listed for the tidal fresh portion of the watershed except impacts to biological communities, which is for non-tidal streams. Nitrogen, and phosphorus currently are listed as Category 4a – Impaired, TMDL completed. Millington Wildlife Ponds, located within the Upper Chester River watershed, were also identified on the Maryland Integrated Report as impaired by methylmercury in fish tissue (2004 listing). A TMDL for this listing was completed in 2010. Below, Table E1 identifies the listings associated with this watershed.

Table E1. 2010 Integrated Report Listings for the Upper Chester River Watershed

Watershed	Basin Code	Non-tidal/Tidal	Designated Use	Year listed	Identified Pollutant	Listing Category
Upper Chester River	02130510	Non-tidal	Aquatic Life and Wildlife	2002	Impacts to Biological Communities	5
Upper Chester River Tidal Fresh	CHSTF	Tidal	Seasonal Migratory fish spawning and nursery Subcategory	1996	TN	4a
				1996	TP	4a
			Aquatic Life and Wildlife		Impacts to Estuarine Biological Communities	3
			Open Water Fish and Shellfish	1996	TN	4a
				1996	TP	4a
			Aquatic Life and Wildlife	1996	TSS	5
Upper Chester River Tidal Fresh Duck Neck Beach	CHSTF	Tidal	Water Contact Sports	1996	Enterococcuc	5
Millington Wildlife Ponds	02130510	Impoundment	Fishing	2004	Mercury in Fish Tissue	5

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 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 Designations in the Code of Maryland Regulations (COMAR) for Upper Chester River and its tributaries are Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life) and Use II (Migratory Spawning and Nursery Use: February 1 to May 31, inclusive Shallow Water Submerged Aquatic Vegetation Use: April 1 to October 30, inclusive Application Depth: 0.5 meters, Open Water Fish and Shellfish Use: January 1 to December 31, inclusive Shellfish Harvest). Limits on the Use II is the transect between Travilla Wharf and Marshy Point, and on Andover Branch 900 feet above Rt. 313. All nontidal areas are Use I (COMAR a,b,c,d). The Upper Chester River watershed is not attaining its designated use of protection of aquatic life because of biological impairments. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has a developed 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 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 Upper Chester 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 Upper Chester River watershed's biological communities are strongly influenced by agricultural land use resulting in degradation to stream habitat and increased nutrient pollutant loading.

There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to agricultural landscapes, particularly those streams with agricultural land uses with in the riparian buffer zone, which often results in further increases in contaminant loads from runoff. The results of the BSID process, and the probable causes and sources of the biological impairments of Upper Chester River can be summarized as follows:

- The BSID process has determined that biological communities in Upper Chester River are also likely degraded due to sediment and in-stream habitat related stressors. Specifically, altered habitat, and increased runoff from agricultural landscapes have resulted in changes to stream geomorphology 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 Upper Chester 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 Upper Chester River.

- The BSID process has also determined that biological communities in the Upper Chester River watershed are likely degraded due to anthropogenic channelization of stream segments. MDE considers channelization as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution. Category 4c listings include segments impaired because of stream channelization or the lack of adequate flow. MDE recommends a Category 4c listing for the Upper Chester River watershed based on channelization being present in approximately 59% of degraded stream miles.

- The BSID process has determined that nutrients, specifically total nitrogen, are associated with degradation of biological communities in the Upper Chester River. The BSID analysis uses a case-control, risk-based approach too systematically and objectively determine the predominant cause(s) and source of degraded biological conditions. Currently, there is no scientific consensus on numeric nutrient criteria for non-tidal streams (ICPRB 2011). Nutrients in excess do not act directly as pollutants in aquatic systems but, rather, manifest their negative effects via changes in chemical and biological metrics. For this reason, numeric thresholds or ranges of nutrient concentrations should not, by themselves, be used to list non-tidal stream segments as impaired by nutrients (Category 5). Maryland has thus taken an alternative, multi-faceted 'causal pathway' approach. Under this approach, a stream segment may be listed as impaired by nutrients only when poor biological conditions are demonstrated (via low Indices of Biotic

Integrity or IBIs) in conjunction with (1) high nutrient concentrations, and (2) one or more of the following stressors known to be associated with nutrient over-enrichment and have scientifically defensible regulatory limits: (a) Low dissolved oxygen (DO) concentrations; (b) low or high DO saturation; (c) high pH. Since none of the stressors known to be associated with nutrient over enrichment were identified in the BSID analysis, a Category 5 listing for nutrients is not recommended for Upper Chester River. In the absence of a firm causal pathway as described above, concluding that Upper Chester River is impaired by nutrients could result in unnecessary planning and pollution control implementation costs.

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 2010). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or black water streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy stream, <10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report If a watershed is not determined to differ significantly from the reference condition, the assessment must have an acceptable precision (i.e., margin of error) before the watershed is listed as meeting water quality standards (Category 1 or 2). If the level of precision is not acceptable, the status of the watershed is listed as inconclusive and subsequent monitoring options are considered (Category 3). If a watershed is still considered impaired but has a TMDL that has been completed or submitted to EPA it will be listed as Category 4a.). If the state can demonstrate that watershed impairment is a result of pollution, but not a pollutant the watershed is listed under Category 4c. 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 BSID analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of biological impairment. Identification of stressors responsible for biological impairment was limited to the round two MDDNR MBSS dataset 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 Upper Chester River watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Upper Chester River Watershed Characterization

2.1 Location

The Upper Chester River and its tributaries are part of the Chester River basin that drains to the Chesapeake Bay. The Upper Chester River watershed covers 178 square miles in Maryland and Delaware. About 137 square miles of the Upper Chester River watershed are in Maryland, which includes 82 square miles in Queen Anne's County and 55 square miles in Kent County (see Figure 1). Upper Chester River is approximately 16.9 kilometers (10.5 miles) in length and extends from the headwaters in Delaware downstream to the confluence with Foreman Branch, and the Middle Chester watershed extends from that point downstream to the confluence with Southeast Creek. The upper region of the Upper Chester River Watershed, near the Maryland and Delaware border, consists of uninhabited forests and wetlands, which are part of the Millington Wildlife Management Area. This is an area of approximately 3,800 acres, which drains into Cypress Branch, northeast of Millington. The Upper Chester River watershed is agriculturally diverse and high in the production of corn, wheat and soybean. The watershed area is located in the Coastal region of three distinct eco-regions identified in the MBSS IBI metrics (Southerland et al. 2005) (see Figure 2).

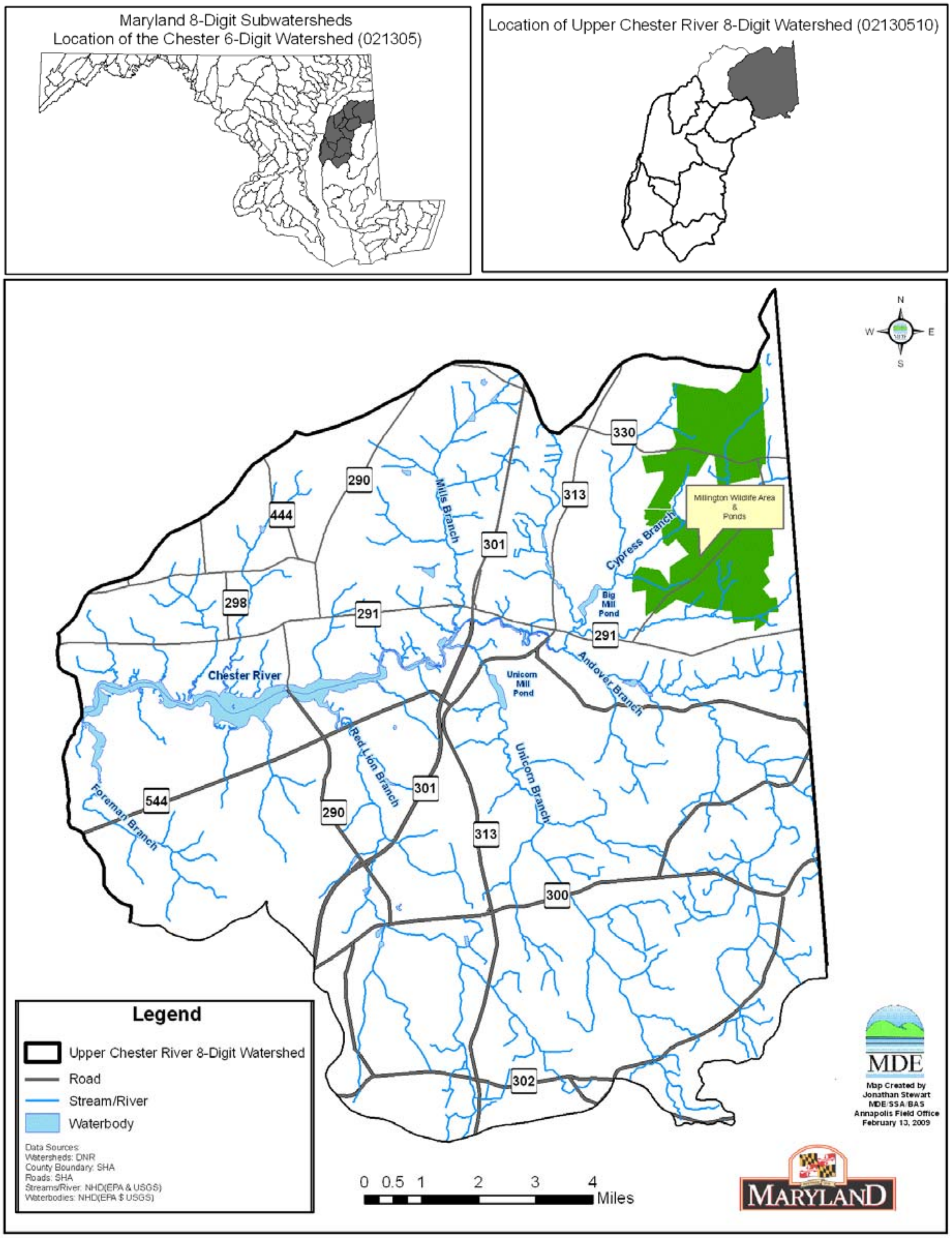

Figure 1. Location Map of the Upper Chester River Watershed

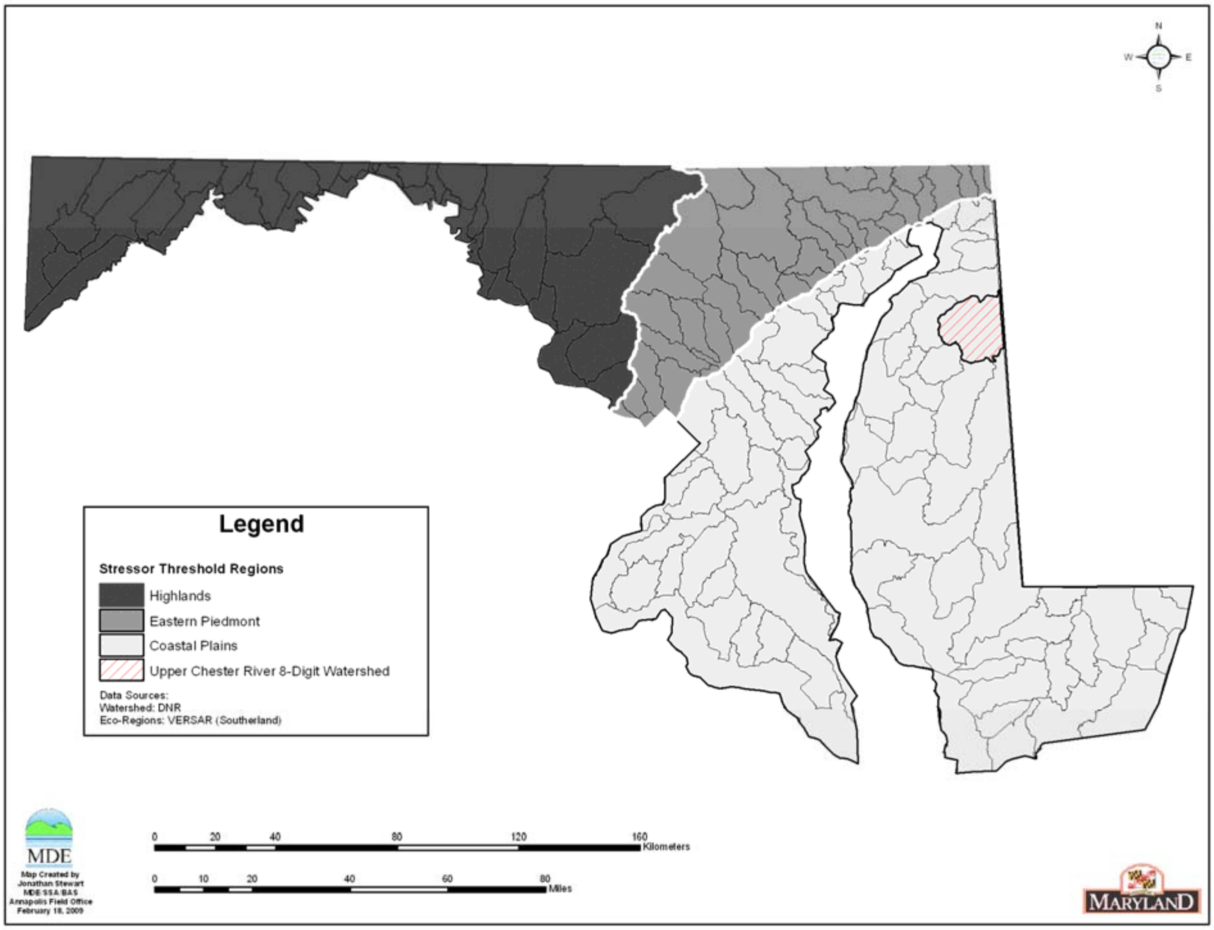

Figure 2. Eco-Region Location Map of Upper Chester River

2.2 Land Use

The distribution of major land use categories in the Upper Chester River watershed based on 2002 data produced by the Maryland Department of Planning (MDP 2002). Agriculture represents roughly two-thirds of the land use in the watershed. Together, forest and shrub account for roughly one-third (see Figure 3). The Upper Chester River watershed is agriculturally diverse and high in crop production of corn, wheat and soybean. The Upper Chester Watershed consists mostly of mixed agriculture 65%, with the remaining land use being forest 30%, urban 3%, and water 2% (see Figure 4) (MDP 2002).

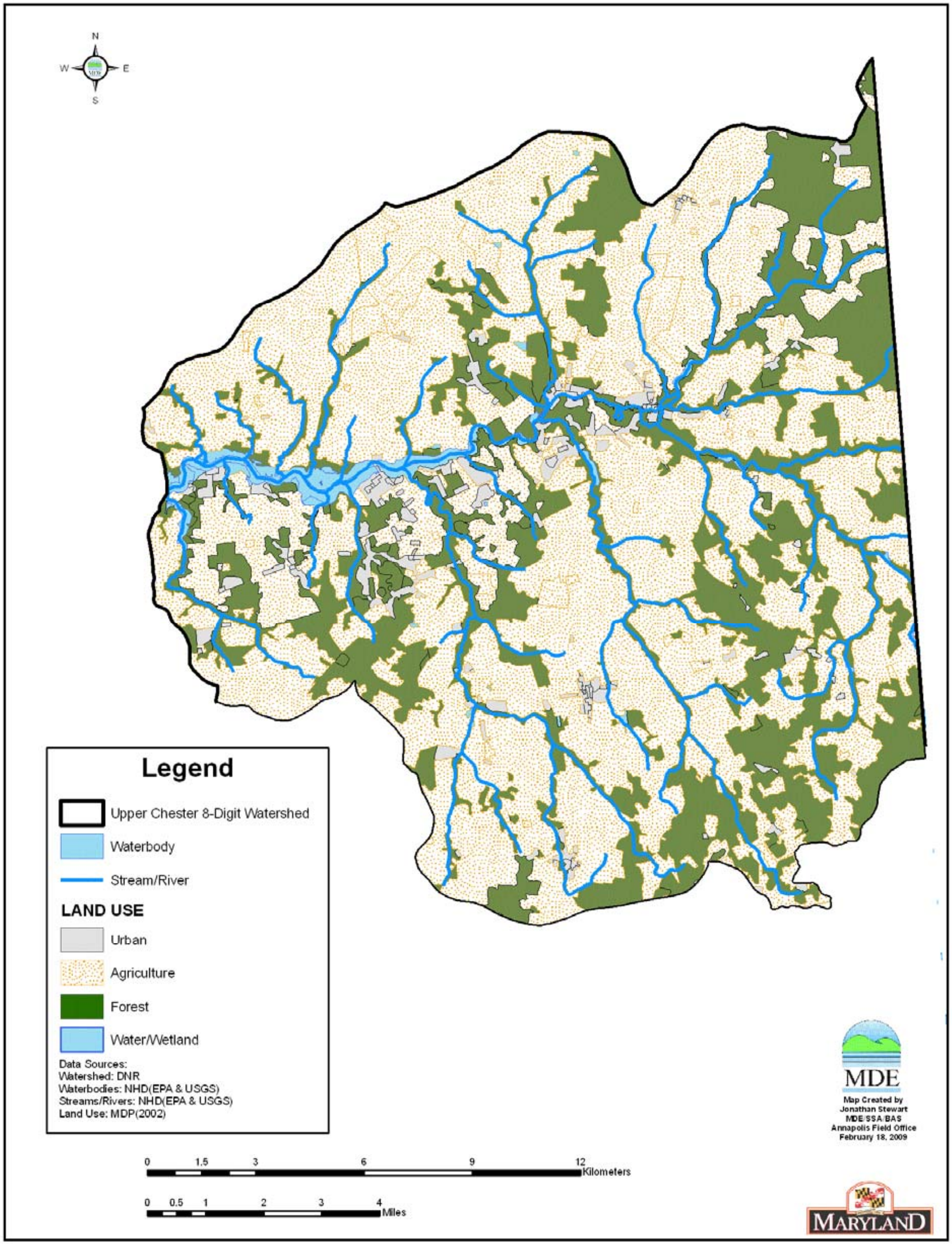

Figure 3. Land Use Map of the Upper Chester River Watershed

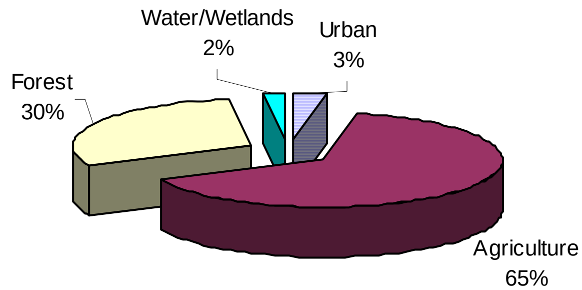

Figure 4. Proportions of Land Use in the Upper Chester River Watershed

2.3 Soils/hydrology

The Upper Chester River watershed lies within the Delmarva Peninsula Region of the Coastal Province physiographic region of Maryland. The Delmarva Peninsula Province encompasses the landmass between the Chesapeake Bay and the Delaware Bay. Wetlands are abundant in the Coastal Plain due to the low topographical relief and high groundwater characteristics of the region. Watershed geology is about 86% Eastern Shore Upland Deposit. The remaining 14% of the watershed includes Lowland Deposits, the Calvert Formation and the Aquia Formation that, together, tend to be in the vicinity of the Chester River mainstem and the mainstems of major tributary streams. About 56% of the watershed is prime agricultural soil. Another 30% of local soils exhibit hydric characteristics that tend to be found in the Upland Deposit geologic area. The remaining 14% of soils includes: Sandy, excessively drained soils, which are generally located along the Chester River mainstem (DNR 2005a).

3.0 Upper Chester River Water Quality Characterization

3.1 Integrated Report Listings

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3.2 Biological Impairment

The Maryland Surface Water Use Designations in the Code of Maryland Regulations (COMAR) for Upper Chester River and its tributaries are Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life) and Use II (Migratory Spawning and Nursery Use: February 1 to May 31, inclusive Shallow Water Submerged Aquatic Vegetation Use: April 1 to October 30, inclusive Application Depth: 0.5 meters, Open Water Fish and Shellfish Use: January 1 to December 31, inclusive Shellfish Harvest). Limits on the Use II is the transect between Travilla Wharf and Marshy Point, and on Andover Branch 900 feet above Rt. 313. All nontidal areas are Use I (COMAR a,b,c,d). 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 Upper Chester River watershed is listed under Category 5 of the 2008 Integrated Report as impaired for evidence of biological impacts. Approximately 20% of stream miles in the Upper Chester 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 thirty-one sites. Ten of the thirty-one sites have 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 ten MBSS sites with seven having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site location for the Upper Chester River watershed.

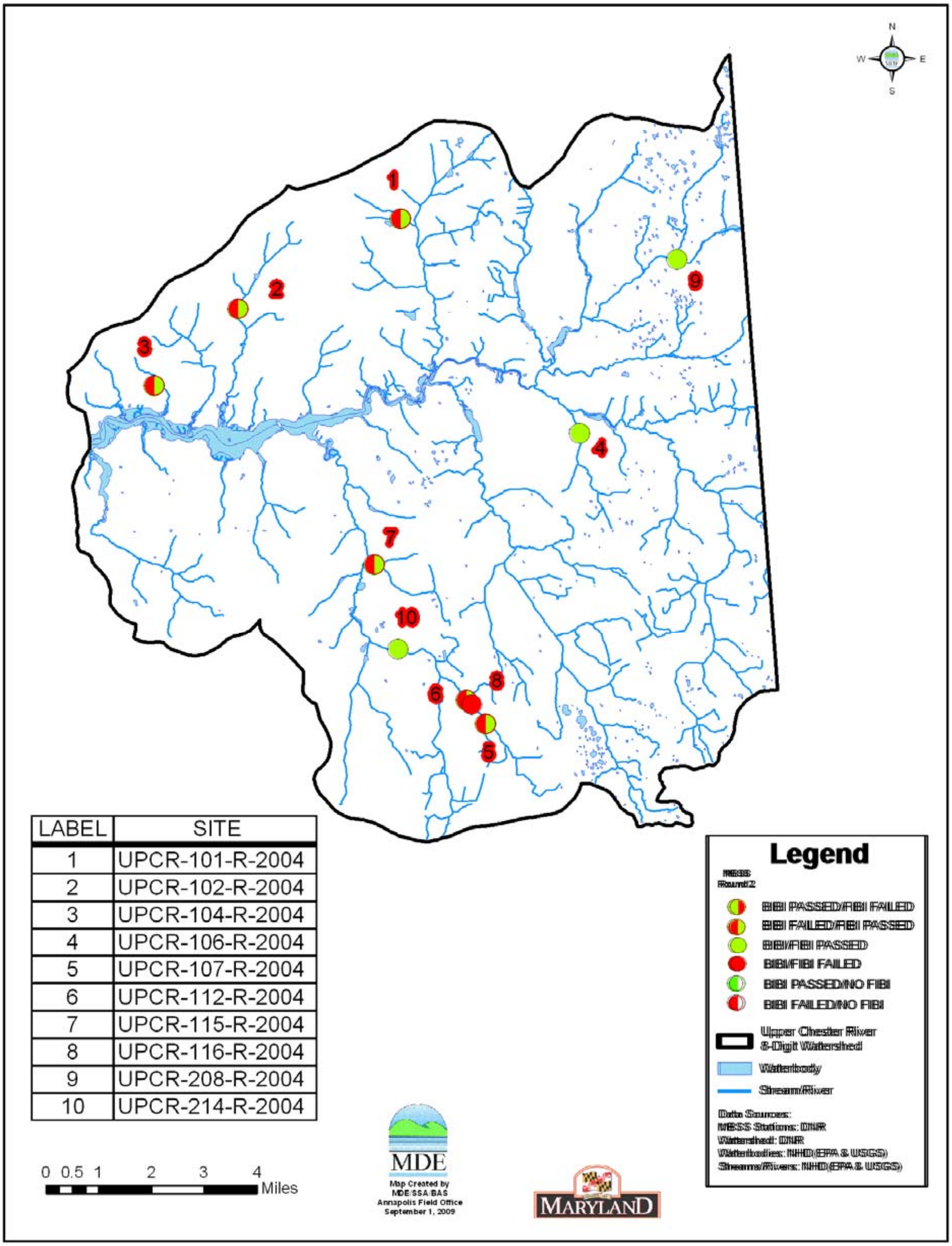

Figure 5. Principal Dataset Sites for the Upper Chester River Watershed

4.0 Stressor Identification Results

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

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores significantly lower than 3.0 (i.e., poor to very poor). The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups – 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-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 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 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 analysis, MDE identified sediment, in-stream habitat, water chemistry parameters, and potential agricultural land use sources as significantly associated with degraded fish and/or benthic biological conditions. As shown in Table 2 through Table 4, parameters from the sediment, in-stream habitat, and water chemistry groups are identified as possible biological stressors in Upper Chester River. Table 5 identifies parameters representing possible sources. Table 6 shows the summary of combined AR values for the stressor groups in the Upper Chester River watershed. Table 7 shows the summary of combined AR values for the source groups in the Upper Chester River watershed.

Table 2. Sediment Biological Stressor Identification Analysis Results for Upper Chester River

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Sediment	extensive bar formation present	10	7	132	0%	23%	No	----
	moderate bar formation present	10	7	132	71%	55%	No	----
	bar formation present	10	7	132	100%	82%	No	----
	channel alteration moderate to poor	10	7	128	86%	62%	No	----
	channel alteration poor	10	7	128	0%	27%	No	----
	high embeddedness	10	7	132	0%	0%	No	----
	epifaunal substrate marginal to poor	10	7	132	71%	45%	No	----
	epifaunal substrate poor	10	7	132	43%	10%	Yes	33%
	moderate to severe erosion present	10	7	132	43%	45%	No	----
	severe erosion present	10	7	132	14%	14%	No	----
	poor bank stability index	10	7	132	29%	23%	No	----
	silt clay present	10	7	132	100%	99%	No	----

Table 3. Habitat Biological Stressor Identification Analysis Results for Upper Chester River

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
In-Stream Habitat	channelization present	10	7	134	71%	13%	Yes	59%
	instream habitat structure marginal to poor	10	7	132	86%	40%	Yes	46%
	instream habitat structure poor	10	7	132	14%	5%	No	----
	pool/glide/eddy quality marginal to poor	10	7	132	43%	45%	No	----
	pool/glide/eddy quality poor	10	7	132	0%	3%	No	----
	riffle/run quality marginal to poor	10	7	132	57%	45%	No	----
	riffle/run quality poor	10	7	132	57%	18%	Yes	39%
	velocity/depth diversity marginal to poor	10	7	132	71%	58%	No	----
	velocity/depth diversity poor	10	7	132	43%	14%	Yes	29%
	concrete/gabion present	10	7	138	29%	1%	Yes	27%
	beaver pond present	10	7	131	0%	6%	No	----
Riparian Habitat	no riparian buffer	10	7	134	29%	13%	No	----
	low shading	10	7	132	14%	9%	No	----

Table 4. Water Chemistry Biological Stressor Identification Analysis Results for Upper Chester River

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Water Chemistry	high total nitrogen	10	7	208	86%	25%	Yes	61%
	high total dissolved nitrogen	0	0	0	0%	0%	No	----
	ammonia acute with salmonid present	10	7	208	29%	39%	No	----
	ammonia acute with salmonid absent	10	7	208	29%	26%	No	----
	ammonia chronic with salmonid present	10	7	208	86%	67%	No	----
	ammonia chronic with salmonid absent	10	7	208	71%	57%	No	----
	low lab pH	10	7	208	43%	38%	No	----
	high lab pH	10	7	208	0%	0%	No	----
	low field pH	10	7	207	57%	39%	No	----
	high field pH	10	7	207	0%	0%	No	----
	high total phosphorus	10	7	208	14%	3%	No	----
	high orthophosphate	10	7	208	0%	13%	No	----
	dissolved oxygen < 5mg/l	10	7	206	14%	14%	No	----
	dissolved oxygen < 6mg/l	10	7	206	43%	22%	No	----
	low dissolved oxygen saturation	9	7	184	43%	18%	No	----
	high dissolved oxygen saturation	9	7	184	0%	0%	No	----
	acid neutralizing capacity below chronic level	10	7	208	0%	9%	No	----
	acid neutralizing capacity below episodic level	10	7	208	14%	48%	No	----
	high chlorides	10	7	208	0%	6%	No	----
	high conductivity	10	7	208	0%	5%	No	----
	high sulfates	10	7	208	14%	4%	No	----

Table 5. Stressor Source Identification Analysis Results for Upper Chester River

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Urban	high impervious surface in watershed	10	7	214	0%	5%	No	----
	high % of high intensity urban in watershed	10	7	214	0%	9%	No	----
	high % of low intensity urban in watershed	10	7	214	0%	4%	No	----
	high % of transportation in watershed	10	7	214	0%	7%	No	----
	high % of high intensity urban in 60m buffer	10	7	212	0%	7%	No	----
	high % of low intensity urban in 60m buffer	10	7	212	0%	5%	No	----
	high % of transportation in 60m buffer	10	7	212	0%	9%	No	----
Sources Agriculture	high % of agriculture in watershed	10	7	214	43%	18%	No	----
	high % of cropland in watershed	10	7	214	71%	27%	Yes	44%
	high % of pasture/hay in watershed	10	7	214	0%	6%	No	----
	high % of agriculture in 60m buffer	10	7	212	0%	8%	No	----
	high % of cropland in 60m buffer	10	7	212	71%	18%	Yes	54%
	high % of pasture/hay in 60m buffer	10	7	212	0%	8%	No	----
Sources Barren	high % of barren land in watershed	10	7	214	0%	23%	No	----
	high % of barren land in 60m buffer	10	7	212	14%	6%	No	----

Table 5. Stressor Source Identification Analysis Results for Upper Chester River (Cont.)

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher 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 Anthropogenic	low % of forest in watershed	10	7	214	0%	5%	No	----
	low % of forest in 60m buffer	10	7	212	0%	5%	No	----
Sources Acidity	atmospheric deposition present	10	7	208	0%	40%	No	----
	AMD acid source present	10	7	208	0%	0%	No	----
	organic acid source present	10	7	208	0%	6%	No	----
	agricultural acid source present	10	7	208	14%	7%	No	----

Table 6. Summary Combined AR Values for Stressor Groups for Upper Chester River Watershed

Stressor Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (AR)	
Sediment	33%	86%
In-Stream Habitat	74%	
Riparian Habitat	----	
Water Chemistry	61%	

Table 7. Summary of Combined AR Values for Source Groups for the Upper Chester River Watershed

Source Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (AR)	
Urban	----	79%
Agriculture	79%	
Barren Land	----	
Lack of Forest	----	
Acidity	----	

Sediment Conditions

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

Epifaunal substrate (poor) was identified as significantly associated with degraded biological conditions in the Upper Chester River, and found to impact approximately 33% of the stream miles with poor to very poor biological conditions. Epifaunal substrate is a visual observation of the abundance, variety, and stability of substrates that offer the potential for full colonization by benthic macroinvertebrates. The varied habitat types such as cobble, woody debris, aquatic vegetation, undercut banks, and other commonly productive surfaces provide valuable habitat for benthic macroinvertebrates. Epifaunal substrate is confounded by natural variability (i.e., streams will naturally have more or less available productive substrate). Greater availability of productive substrate increases the potential for full colonization; conversely, less availability of productive substrate decreases or inhibits colonization by benthic macroinvertebrates. Epifaunal substrate conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, where stable substrate is lacking, or particles are over 75% surrounded by fine sediment and/or flocculent material; and 2) marginal to poor, where large boulders and/or bedrock are prevalent and cobble, woody debris, or other preferred surfaces are uncommon.

The BSID results for the Upper Chester River indicated poor epifaunal substrate as a significant stressor in the watershed. Many agricultural practices result in increased loads of fine-grained (i.e. sands, silts and clay particles < 2 mm) sediments to stream substrates. Fine-grained sediments are considered a major non-point source of pollution in rivers of the United States, and agricultural sources include runoff from tilled landscapes and bank erosion (Waters 1995 and Wood 1997). The United States Department of Agriculture (1997) estimates that 60 percent of total sediments reaching surface waters comes from irrigated and non-irrigated agricultural fields. Fine sediment can influence stream ecosystems by clogging sediment interstices, and can subsequently change hydraulics (Schälchli 1992) and biological function (Boulton et al. 1998) resulting poor biological conditions.

Many of the streams in the Upper Chester River watershed have been converted to agricultural drainage ditches, which greatly reduces the ecological health of the stream system. Water running from the fields into the streams has the potential to reach high velocities, especially during late fall, winter, and early spring when there is very little plant growth in the fields. The high velocity flow over the terrain can potentially scour away large amounts of topsoil from the fields along with material from the stream banks. This scouring results in large amounts of sediment pollution in the stream, potentially reducing biodiversity (DNR 2005b).

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the sediment stressor group is approximately 33 % suggesting these stressors impacts a moderate proportion of the degraded stream miles in Upper Chester River (Table 6).

In-stream Habitat Conditions

BSID analysis results for Upper Chester River identified five in-stream habitat parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters are *channelization present, concrete/gabion present, in-stream habitat structure (marginal to poor), riffle/run quality (poor),* and *velocity/depth diversity (poor).*

Channelization present was identified as significantly associated with degraded biological conditions in the Upper Chester River watershed, and found in 59% of the stream miles with poor to very poor biological conditions. This stressor measures the presence/absence of channelization in stream banks. 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. Natural channels have diverse habitats with varying water velocities as the morphology changes between riffles and pools. The diverse nature of natural channels provides slow water refugia during high flow and many resting areas. With less structural diversity, channelized systems have minimal resting areas and organisms are easily swept away during high flows. In low flow periods, natural channels have sufficient water depth to support fish and aquatic species during the dry season; where as, channelized streams often have insufficient depth to sustain diverse aquatic life (Bolton and Shellberg 2001). Historically many streams in the Coastal Plain were channelized to improve drainage of croplands. The water table in the basin before ditching was close to the surface and interfered with agricultural practices; subsequent ditching lowered the groundwater table (Maguire et al 2009). Channelization has changed many streams into straight shallow ditches with severely depressed biodiversity. Effects of channelization include loss of stream habitat, loss of aquatic productivity, increased streambed and bank erosion, and a reduction of ground water levels.

Concrete/gabion present was identified as significantly associated with degraded biological conditions in the Upper Chester River watershed, and found to impact approximately 27% of the stream miles with poor to very poor biological conditions. The presence of concrete/gabion present in a stream inhibits the heterogeneity of stream morphology needed for colonization, abundance, and diversity of fish and benthic communities. Concrete channelization increases flow and provides a homogeneous substrate, conditions which are detrimental to biological communities.

In-stream habitat structure (marginal to poor) was identified as significantly associated with degraded biological conditions in the Upper Chester River, and found to impact approximately 46% of the stream miles with poor to very poor biological conditions. In-stream habitat is a visual rating based on the perceived value of habitat within the stream channel to the fish community. Multiple habitat types, varied particle sizes, and uneven stream bottoms provide valuable habitat for fish. High in-stream habitat scores are evidence of the lack of sediment deposition. In-stream habitat is confounded by natural variability (i.e., some streams will naturally have more or less in-stream habitat). Low in-stream habitat values can be caused by high flows that collapse undercut banks and by sediment inputs that fill pools and other fish habitats. In-stream habitat conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, which is defined as less than 10% stable habit where lack of habitat is obvious; and 2) marginal to poor, where there is a 10-30% mix of stable habitat but habitat availability is less than desirable.

Riffle/run quality (poor) was identified as significantly associated with degraded biological conditions in the Upper Chester River watershed, and found to impact approximately 39% of the stream miles with poor to very poor biological conditions. Riffle/run quality is a visual observation and quantitative measurement based on the depth, complexity, and functional importance of riffle/run habitat within the stream segment. An increase in the heterogeneity of riffle/run habitat within the stream segment likely increases the abundance and diversity of fish species, while a decrease in heterogeneity likely decreases abundance and diversity. Riffle/run quality conditions indicating biological degradation are set at two levels: 1) poor, defined as riffle/run depths < 1 cm or riffle/run substrates concreted; and 2) marginal to poor, defined as riffle/run depths generally 1 – 5 cm with a primarily single current velocity. The presence of a well-developed riffle/run system is indicative of different types of habitat within a stream reach, and thereby an assumed higher biodiversity of organisms (Richards, Host, and Arthur 1993). Because stream organisms are highly specialized in many cases, a diverse array of habitat typically leads to a diverse array of macroinvertebrates (Karr 1997). The Upper Chester River watershed is located in the Coastal Plain eco-region and streams in this region have low gradients and low flows. Often in low gradient, sand bottom streams pool development is possible; however, any riffles that develop will be unstable and are typically low quality habitat.

Velocity/depth diversity (poor) was identified as significantly associated with degraded biological conditions in the Upper Chester River watershed, and found to impact approximately 29% of the stream miles with poor to very poor biological conditions. Velocity/depth diversity is a visual observation and quantitative measurement based on the variety of velocity/depth regimes present at a site (i.e., slow-shallow, slow-deep, fast-shallow, and fast-deep). Like pool quality and riffle quality, the increase in the number of different velocity/depth regimes likely increases the abundance and diversity of fish species within the stream segment. The decrease in the number of different velocity/depth regimes likely decreases the abundance and diversity of fish species within the stream segment. The marginal or poor diversity categories could identify the absence of available habitat to sustain a diverse aquatic community. This measure may reflect natural conditions (e.g., bedrock), anthropogenic conditions (e.g., widened channels, dams, channel dredging, etc.), or excessive erosional conditions (e.g., bar formation, entrenchment, etc.). Poor velocity/depth diversity conditions are defined as the stream segment being dominated by one velocity/depth regime. Velocity is one of the critical variables that controls the presence and number of species (Gore 1978). Many invertebrates depend on certain velocity ranges for either feeding or breathing (Brookes 1988). Again, since the Upper Chester River is located in the Coastal Plain eco-region and streams in this region typically have low gradients and low flows, velocity/depth diversities would not typically be considered optimal.

Agricultural land use in watersheds often results in alterations of stream geomorphic structure. Such disturbances lead to increased fine sediment input to the stream along with direct changes in channel structure. Channelization and siltation often eliminate natural riffle-pool complexes and loss of stable diverse substrates. Loss of quality in-stream habitats, riffle/runs, and velocity/depth diversities are serious habitat related problems in the Upper Chester River. A wide variety and/or abundance of stable substrates in a stream provide macroinvertebrates and fish with a large number of niches, thus increasing habitat diversity. As the variety and abundance of substrates decreases, habitat structure becomes monotonous, diversity decreases, and potential for recovery following disturbances decreases. As the physical habitat changes, increased stress is placed on aquatic organisms. These stresses, depending on the tolerance of the species and individuals, may limit growth, abundance, reproduction and survival (Lynch et al. 1977).

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the in-stream habitat stressor group is approximately 74 % suggesting these stressors impact a considerable proportion of the degraded stream miles in Upper Chester River (Table 6).

Riparian Habitat Conditions

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

Water Chemistry

BSID analysis results for Upper Chester River identified one water chemistry parameter that has statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community). This parameter is *high total nitrogen.*

High total nitrogen concentration was identified as significantly associated with degraded biological conditions in Upper Chester River and found in approximately 61% of the stream miles with poor to very poor biological conditions. Total nitrogen (TN) is a measure of the amount of TN in the water column. TN is comprised of organic nitrogen, ammonia nitrogen, nitrite and nitrate. Nitrogen plays a crucial role in primary production. Elevated levels of nitrogen can lead to excessive growth of filamentous algae and aquatic plants. Excessive nitrogen input can also lead to increased primary production, which potentially results in species tolerance exceedances of dissolved oxygen and pH levels. Runoff and leaching from fertilizers applied to agricultural lands and groundwater infiltration can generate elevated levels of nitrogen in surface waters.

Groundwater transports a large amount of nitrogen to streams in the Chesapeake Bay watershed. Nitrogen reaches the land surface in rainfall or through fertilizer application associated with agricultural and suburban land uses. Once on the land surface, some of the nitrogen infiltrates into the underlying soil and groundwater. Once in the groundwater, nitrogen generally is converted to nitrate and moves through the aquifer. Much of the nitrate is discharged into streams and contributes to the total nitrogen load in a stream (USGS 2009). Of the major nitrogen sources (atmospheric, urban, and agricultural) in a watershed, multiple studies (Ator and Ferrari, 1997; Lindsey et al., 1997, Shedlock et al., 1999) have shown that agricultural land use has the greatest impact on nitrogen concentrations in groundwater. Many streams in the Upper Chester River Watershed were ditched to improve drainage of croplands. The water table in the basin is fairly close to the surface and interfered with agricultural practices, subsequent ditching lowered the groundwater table increasing transport of groundwater to the surface waters. Increased leeching of groundwater into surface waters of the Upper Chester River watershed is a potential source of elevated TN.

Water chemistry is another major determinant of the integrity of surface waters that is strongly influenced by land-use. Agricultural land uses comprise sixty-five percent of the Upper Chester River watershed. Agricultural land uses within the watershed as well as within the sixty-meter riparian zone were found to be significantly associated with poor to very poor biological conditions in the watershed. Developed landscapes, particularly the proportion of agriculture in the catchments and the riparian zone, often results in increased nutrients loads to surface waters.

Point source discharges are also a potential source of nutrients to surface waters. There are three minor municipal and two industrial discharges in the Upper Chester River watershed. Nutrient loads from any wastewater treatment facility are dependent on discharge volume, level of treatment process, and sophistication of the processes and equipment.

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 61 % suggesting these stressors impacts a considerable proportion of the degraded stream miles in Upper Chester River (Table 6).

Sources

All seven stressor parameters, identified in Tables 1-3, that are significantly associated with biological degradation in the Upper Chester River watershed BSID analysis are representative of impacts from agricultural landscapes. The watershed and riparian buffer zones of Upper Chester River contains a significant amount of agricultural land uses, which consist mostly of cropland. Numerous studies have documented declines in water quality, habitat, and biological assemblages as the extent of agricultural land increases within catchments (Roth et al. 1996 & Wang et al. 1997). Researchers commonly report that streams draining agricultural lands support fewer species of sensitive insect and fish taxa than streams draining forested catchments (Wang et al. 1997). Large-scale and long-term agricultural disturbances in a watershed can limit the recovery of stream diversity for many decades (Harding et al. 1998). Also, macroinvertebrate community richness usually does not vary by more than three families in streams affected by intensive agriculture (Delong and Brusven 1998).

The BSID analysis identified cropland in the riparian buffer zone as having significant association (92%) with poor to very poor biological conditions in the watershed. Cropland within the riparian buffer often results in increased inputs of nutrients to surface waters. Forested riparian zones were found to retain 86% of the nitrogen reaching them in runoff, while nearby cropland retained only 8% in a coastal plains basin (Peterjohn and Correll 1984). The agricultural land uses in the Upper Chester River watershed are potential sources for the elevated levels of TN.

The BSID source analysis (Table 5) identifies cropland in watershed and within riparian buffer zones as potential sources of stressors that may cause negative biological impacts. The combined AR for this source group is approximately 79% suggesting that agricultural land uses potentially impacts a substantial proportion of the degraded stream miles in Upper Chester River (Table 7).

Summary

The BSID analysis results suggest that degraded biological communities in the Upper Chester River watershed are a result of anthropogenic and natural alterations to the in-stream habitat conditions, which have lead to loss of available habitat and diversity in the biological community. Significant anthropogenic changes of natural stream channels within the watershed, health and diversity of biological communities are severely impacted. The stressors c*hannelization present* was identified as significantly associated with degraded biological conditions, and found to impact approximately 59% of the stream miles with poor to very poor biological conditions in the Upper Chester River watershed. Also, increased agricultural land use is causing an increase in contaminant loads from nonpoint sources by adding nitrogen to surface waters. The combined AR for the sediment, in-stream habitat, and water chemistry stressors is approximately 86%, suggesting that these stressors adequately account for the biological impairment in Upper Chester River (Table 6).

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.

<u>Final Causal Model for Upper Chester River</u>

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 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 causal model for Upper Chester River, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

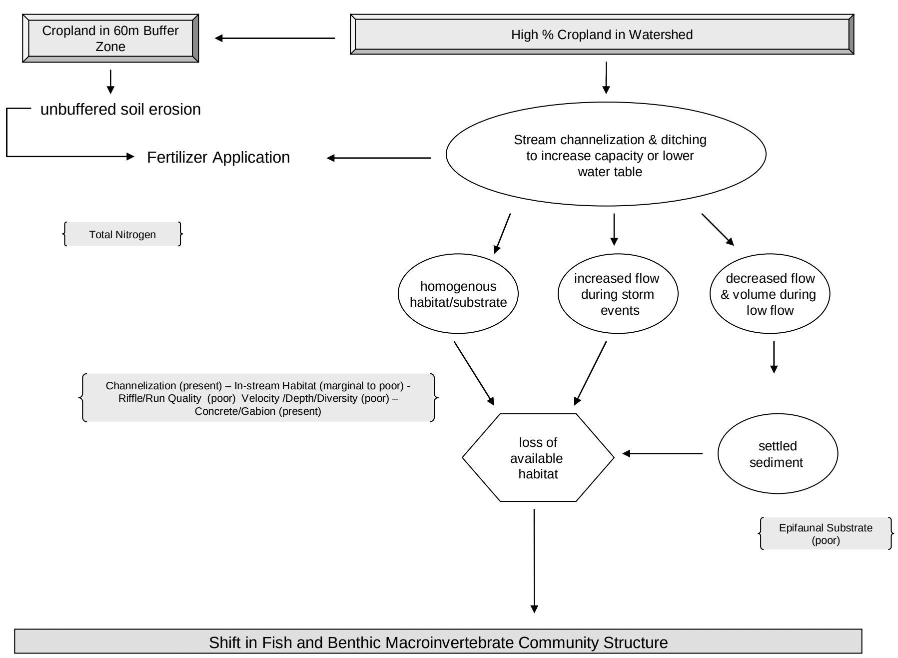

Figure 6. Final Causal Model for the Upper Chester River Watershed

5.0 Conclusions

Data suggest that the Upper Chester River watershed's biological communities are strongly influenced by agricultural land use resulting in increased nutrient pollutant and sediment loading. There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to agricultural landscapes, particularly those landscapes with agricultural land uses with in the riparian buffer zone, which often results in even larger contaminant loads from runoff. Based upon the results of the BSID process, the probable causes and sources of the biological impairments of Upper Chester River are summarized as follows:

- The BSID process has determined that biological communities in Upper Chester River are also likely degraded due to sediment and in-stream habitat related stressors. Specifically, altered habitat, and increased runoff from agricultural landscapes have resulted in changes to stream geomorphology 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 Upper Chester 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 Upper Chester River.

- The BSID process has also determined that biological communities in the Upper Chester River watershed are likely degraded due to anthropogenic channelization of stream segments. MDE considers channelization as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution. Category 4c listings include segments impaired because of stream channelization or the lack of adequate flow. MDE recommends a Category 4c listing for the Upper Chester River watershed based on channelization being present in approximately 59% of degraded stream miles.

- The BSID process has determined that nutrients, specifically total nitrogen, are associated with degradation of biological communities in the Upper Chester River. The BSID analysis uses a case-control, risk-based approach too systematically and objectively determine the predominant cause(s) and source of degraded biological conditions. Currently, there is no scientific consensus on numeric nutrient criteria for non-tidal streams (ICPRB 2011). Nutrients in excess do not act directly as pollutants in aquatic systems but, rather, manifest their negative effects via changes in chemical and biological metrics. For this reason, numeric thresholds or ranges of nutrient concentrations should not, by themselves, be used to list non-tidal stream segments as impaired by nutrients (Category 5). Maryland has thus taken an alternative, multi-faceted 'causal pathway' approach. Under this approach, a stream segment may be listed as impaired by nutrients only when poor biological conditions are demonstrated (via low Indices of Biotic Integrity or IBIs) in conjunction with (1) high nutrient concentrations, and (2) one or more of the following stressors known to be associated with nutrient over-enrichment and have scientifically defensible regulatory limits: (a) Low dissolved oxygen (DO) concentrations; (b) low or high DO saturation; (c) high pH. Since none of the stressors known to be associated with nutrient over enrichment were identified in the BSID analysis, a Category 5 listing for nutrients is not recommended for Upper Chester River. In the absence of a firm causal pathway as described above, concluding that Upper Chester River is impaired by nutrients could result in unnecessary planning and pollution control implementation costs.

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