Watershed Report for Biological Impairment of the Double Pipe Creek Basin in Carroll and Frederick Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation

REVISED FINAL

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List of Abbreviations

AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DNR	Maryland Department of Natural Resources
DO	Dissolved Oxygen
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
MH	Mantel-Haenszel Approach
mg/L	Milligrams per liter
MS4	Municipal Separate Storm Sewer System
n	Number
NH_3	Ammonia
NPDES	National Pollution Discharge Elimination System
OP	Orthophosphate
PCB	Polychlorinated Biphenyls
PSU	Primary Sampling Unit
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
µeq/L	Micro equivalent per liter
µS/cm	Micro Siemens per centimeter
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 Double Pipe Creek watershed (basin number 02140304), located in Carroll and Frederick Counties, was identified on the Integrated Report under Category 5 as impaired by nutrients and suspended sediments (1996 listings), fecal bacteria and impacts to biological communities (2002 listings), and polychlorinated biphenyls (PCB) in fish tissue (2008 listing) (MDE 2008). All impairments are listed for non-tidal streams. The 1996 nutrients listing was refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance. Similarly, the 1996 suspended sediment listing was refined in the 2008 Integrated Report to a listing for total suspended solids. A TMDL for sediments was approved by the USEPA in 2009. A TMDL for fecal bacteria to address the 2002 bacteria listing was approved by the USEPA in 2009.

In 2002, the State began listing biological impairments on the Integrated Report. The current Maryland Department of the Environment (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 poor to very poor, and calculating whether this is significant from a reference condition watershed (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 waters of Double Pipe Creek is Use IV-P – *recreational trout waters and public water supply.* One tributary, Bear Branch (and its tributaries) from the stream's confluence with Bennett Creek is designated as Use III-P – *nontidal cold water and public water supply* (COMAR 2009 a,b,c). The Double Pipe Creek 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 Double Pipe Creek watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and which may be reviewed in more detail in the report entitled "Maryland Biological Stressor Identification Process" (MDE 2009). Data suggest that the biological degradation of communities in the Double Pipe Creek watershed is strongly influenced by urban and agricultural land use and its concomitant effects: altered hydrology and elevated levels of sediments, nutrients, and conductivity (a measure of the presence of dissolved salts). The development of landscapes creates broad and interrelated forms of degradation (i.e., hydrological, morphological, and water chemistry) that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between highly urbanized and agricultural 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 Double Pipe Creek watershed can be summarized as follows:

- The BSID process has determined that biological communities in the Double Pipe Creek watershed are likely degraded due to sediment and riparian habitat related stressors. Specifically, altered hydrology and increased runoff from urban and agricultural landscapes have resulted in channel erosion and subsequent elevated suspended sediment in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results confirm that the establishment of a USEPA approved sediment TMDL in 2009 was an appropriate management action to begin addressing the impact these stressor have on the biological communities in the Double Pipe Creek watershed.

- The BSID process has determined that the biological communities in the Double Pipe Creek watershed are likely degraded due to water chemistry related stressors. Specifically, agricultural and urban land use practices have resulted in the potential elevation of nutrient (i.e. TN, OP and TP) inputs in the watershed, which are in turn the probable causes of impacts to biological communities. Due to anthropogenic sources, the watershed is vulnerable to nutrient fluxes (e.g., sediment release, fertilizer application, stormwater) that could be detrimental to the biological community, but phosphorus concentrations may be limiting in the watershed. Therefore, MDE scientists recommend a more intense analysis of all available data to assess the TN:TP ratio of the watershed. BSID results also include low DO and low DO saturation; a moderate increase of phosphorous may lead to increased algal blooms and decreased oxygen concentrations. The BSID results thus confirm the 2008 Category 5 listing for phosphorus levels and suggest that elevated levels are also associated with degraded biological conditions in the Double Pipe Creek 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 2008a). 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 Double Pipe Creek watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Double Pipe Creek Watershed Characterization

2.1 Location

The Double Pipe Creek watershed flows through parts of Carroll and Frederick Counties, Maryland. The stream system empties into the Maryland 8-Digit Upper Monocacy River watershed (see Figure 1). The Double Pipe Creek watershed encompasses approximately 123,400 acres, and lies north, west, and southwest of the Westminster metropolitan area (MDE 2007). The watershed itself consists of two sub-basins, Big Pipe Creek, which makes up 58% of the total watershed area, and Little Pipe Creek, which makes up the remaining 42% of the total watershed area (McCoy and Summers 1992). The watershed is located the Highland 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).

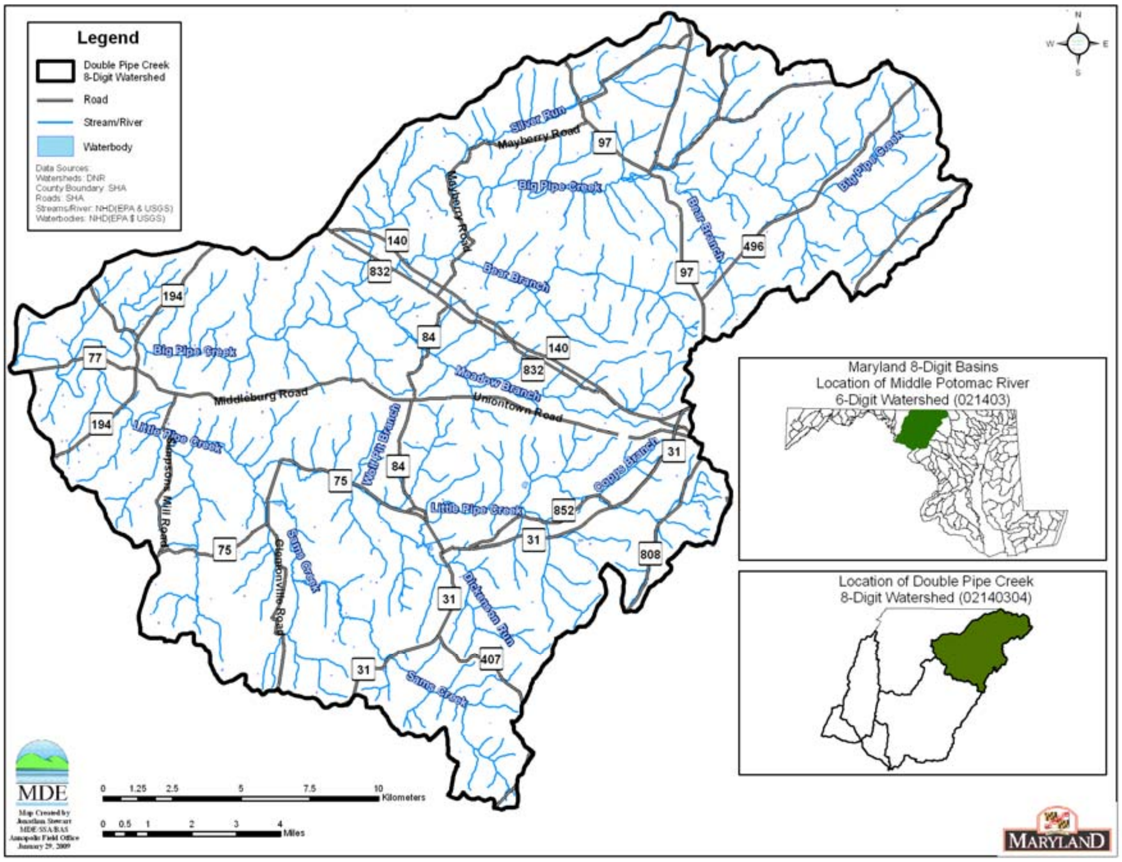

Figure 1. Location Map of the Double Pipe Creek Watershed

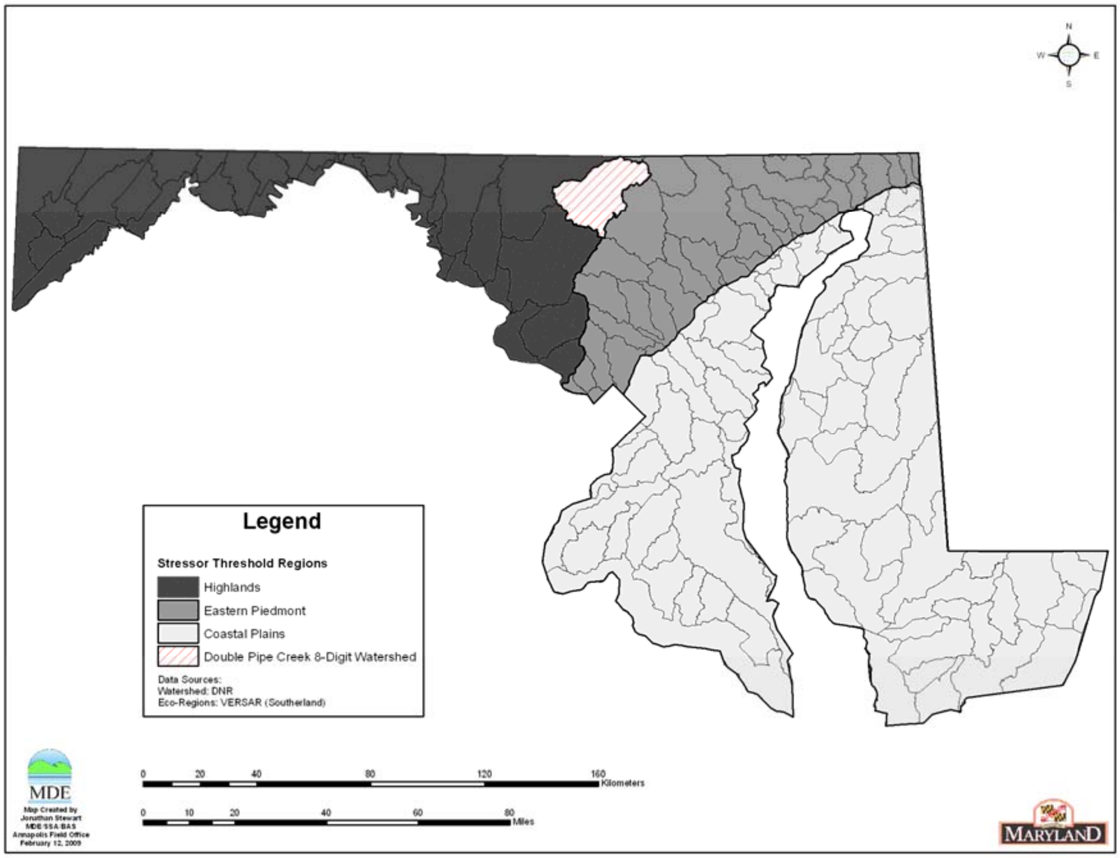

Figure 2. Eco-Region Location Map of the Double Pipe Creek Watershed

2.2 Land Use

The Double Pipe Creek watershed is mostly rural, containing primarily agricultural land use, specifically cropland and livestock/feeding operations (see Figure 3). There are four minor urban areas and one major urban area within the basin. The four minor urban areas include Taneytown, Manchester, Union Bridge, and New Windsor. The one major urban area is the city of Westminster (MDE 2008b). The land use distribution in the watershed is approximately 68% agricultural, 20% forest/herbaceous, and 12% urban (see Figure 4) (MDP 2002).

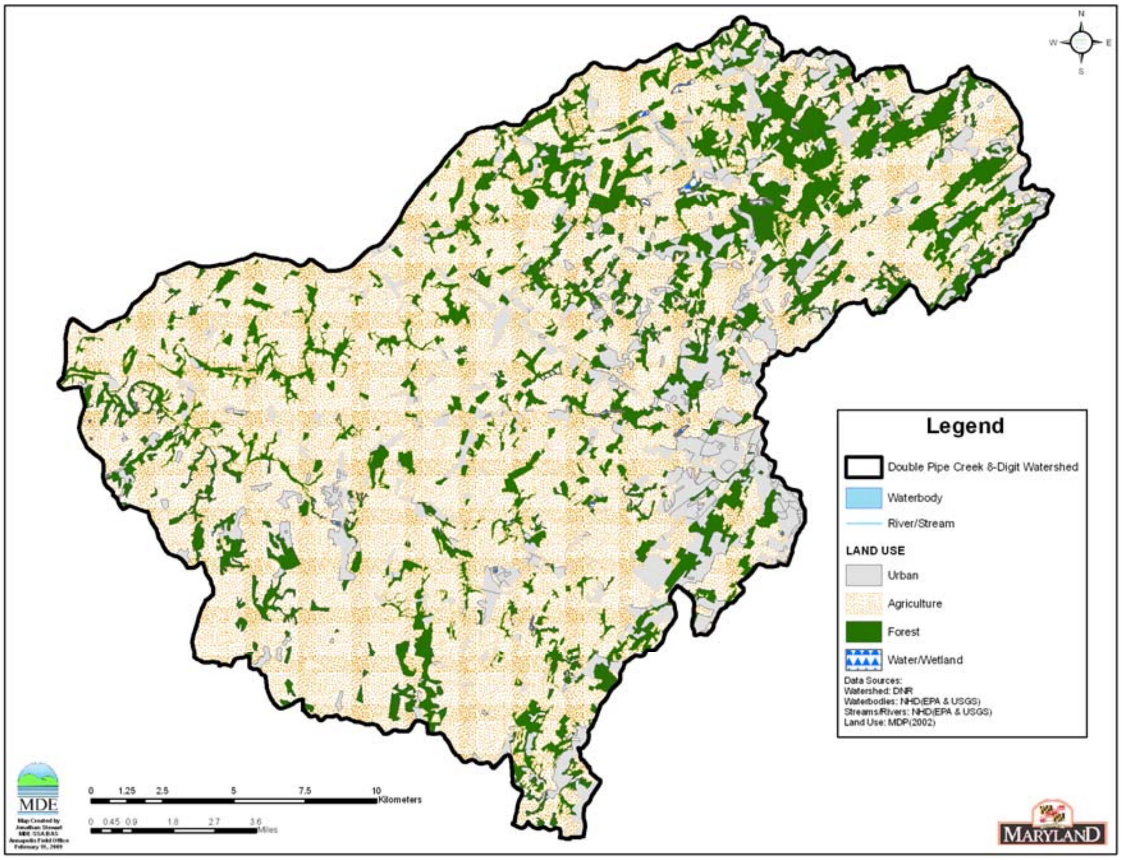

Figure 3. Land Use Map of the Double Pipe Creek Watershed

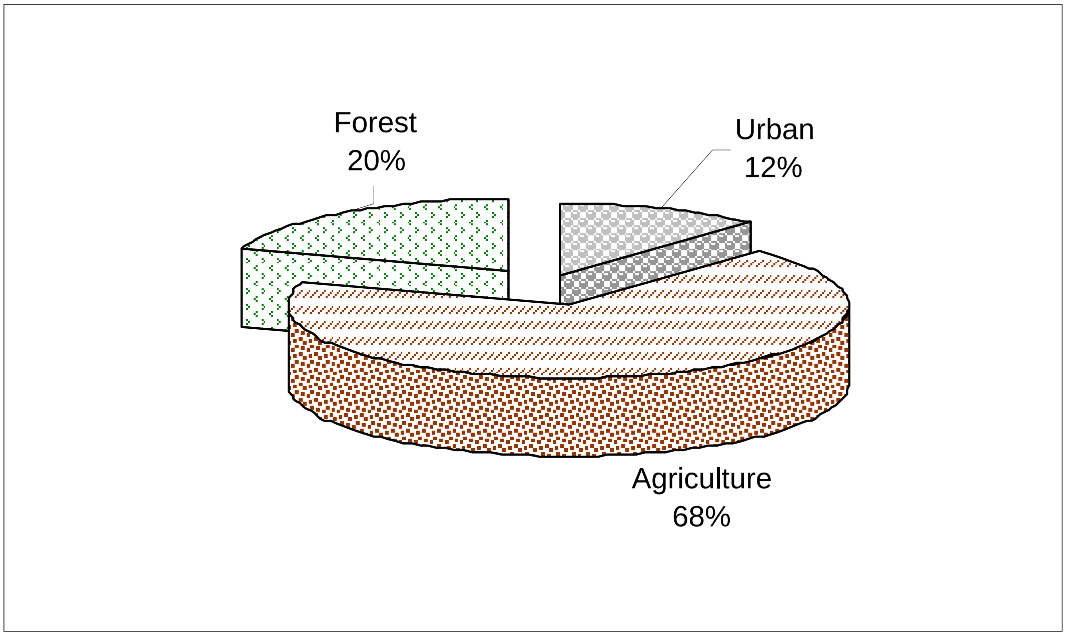

Figure 4. Proportions of Land Use in the Double Pipe Creek Watershed

2.3 Soils/hydrology

The Double Pipe Creek watershed drains in a westerly direction, lies within the north central Piedmont Plateau Physiographic Province and is characterized by gently rolling to steep uplands with streams of average to steep gradients, which feed into the lower valleys of the Piedmont. The predominant soils in the watershed are moderately erodible. Ground water within the project area occurs primarily in fractures and bedding-plane partings of rocks. It may also occur in solutional cavities in limestone and marble (McCoy and Summers 1992).

3.0 Double Pipe Creek Water Quality Characterization

3.1 Integrated Report Impairment Listings

The MDE has identified the waters of Double Pipe Creek on the State's Integrated Report under Category 5 as impaired by nutrients and suspended sediments (1996 listings), fecal bacteria and impacts to biological communities (2002 listings), and PCB in fish tissue (2008 listing) (MDE 2008a). All impairments are listed for non-tidal streams. The 1996 nutrients listing was refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance. Similarly, the 1996 suspended sediment listing was refined in the 2008 Integrated Report to a listing for total suspended solids. A TMDL for sediments was approved by the USEPA in 2009. A TMDL for fecal bacteria to address the 2002 bacteria listing was approved by the USEPA in 2009.

3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the waters of Double Pipe Creek is Use IV-P – *recreational trout waters and public water supply*. One tributary, Bear Branch (and its tributaries) from the stream's confluence with Bennett Creek is designated as Use III-P – *nontidal cold water and public water supply* (COMAR 2009a,b, c). Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

The Double Pipe Creek watershed is listed under Category 5 of the 2008 Integrated Report as impaired for impacts to biological communities. Approximately 65% of stream miles in the Double Pipe Creek watershed are estimated as having fish and/or benthic indices of biological impairment in the very poor to poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data, which include forty-three stations. Twenty-eight of the forty-three 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 sixteen sites; with eleven having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Double Pipe Creek watershed.

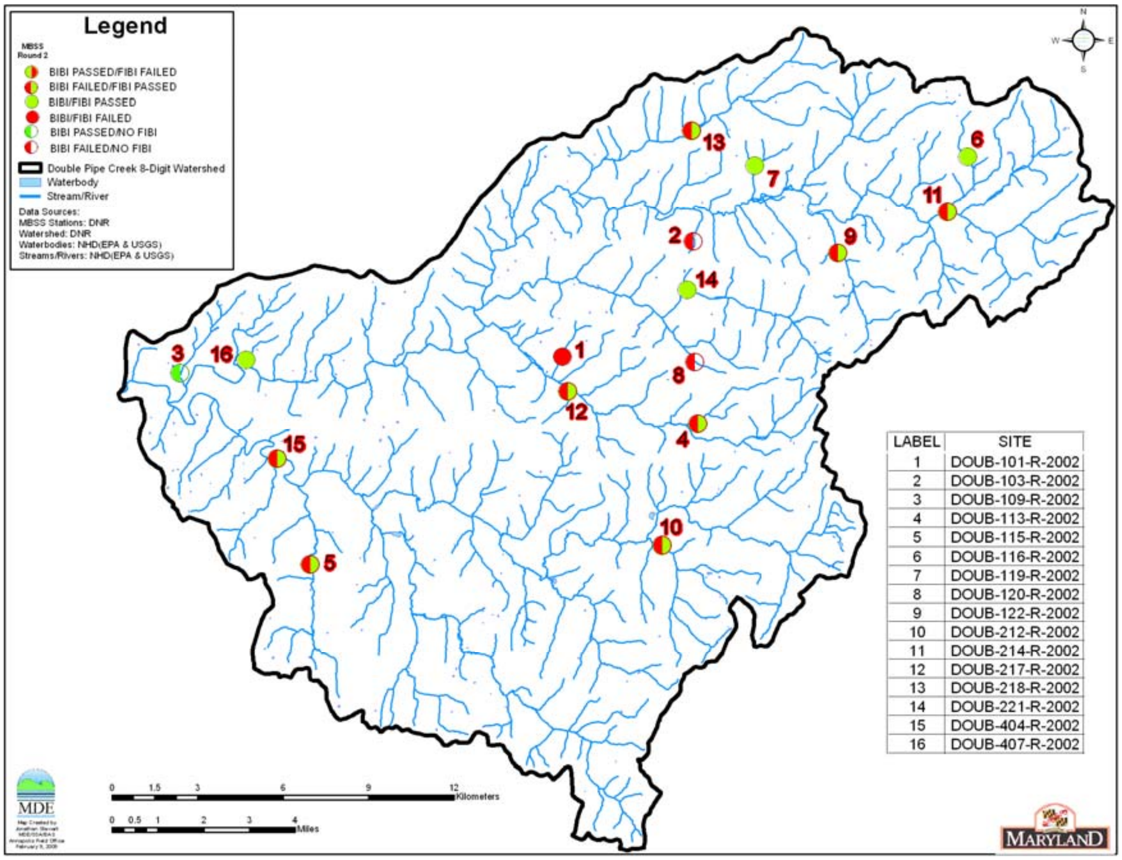

Figure 5. Principal Dataset Sites for the Double Pipe Creek Watershed

4.0 Stressor Identification Results

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

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores 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 very poor to poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and very poor to poor biological conditions and is used to identify potential stressors.

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

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

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

Through the BSID data analysis, MDE identified sediment, instream habitat, riparian habitat and water chemistry parameters, and potential sources significantly associated with degraded fish and/or benthic biological conditions. As shown in Table 1 through Table 3, parameters from the sediment, habitat and water chemistry groups are identified as possible biological stressors in the Double Pipe Creek watershed. Parameters identified as representing possible sources are listed in Table 4 and include various agricultural and urban land use types. A summary of combined AR values for each stressor group is shown in Table 5. A summary of combined AR values for each source group is shown in Table 6.

Table 1. Sediment Biological Stressor Identification Analysis Results for the Double Pipe Creek Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of 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	16	11	80	9%	10%	No	----
	moderate bar formation present	15	11	77	18%	45%	No	----
	bar formation present	16	11	80	82%	89%	No	----
	channel alteration marginal to poor	15	11	77	18%	43%	No	----
	channel alteration poor	15	11	77	9%	10%	No	----
	high embeddedness	15	11	76	27%	3%	Yes	24%
	epifaunal substrate marginal to poor	15	11	77	18%	19%	No	----
	epifaunal substrate poor	15	11	77	18%	3%	Yes	15%
	moderate to severe erosion present	15	11	77	82%	25%	Yes	56%
	severe erosion present	15	11	77	18%	2%	Yes	16%
	poor bank stability index	15	11	77	18%	4%	No	----
	silt clay present	15	11	77	100%	99%	No	----

Table 2. Habitat Biological Stressor Identification Analysis Results for the Double Pipe Creek Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of 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	16	11	80	9%	10%	No	----
	instream habitat structure marginal to poor	15	11	77	36%	22%	No	----
	instream habitat structure poor	15	11	77	9%	2%	No	----
	pool/glide/eddy quality marginal to poor	15	11	77	45%	46%	No	----
	pool/glide/eddy quality poor	15	11	77	18%	6%	No	----
	riffle/run quality marginal to poor	15	11	77	27%	32%	No	----
	riffle/run quality poor	15	11	77	0%	7%	No	----
	velocity/depth diversity marginal to poor	15	11	77	55%	50%	No	----
	velocity/depth diversity poor	15	11	77	9%	8%	No	----
	concrete/gabion present	16	11	80	0%	4%	No	----
	beaver pond present	15	11	77	0%	2%	No	----
Riparian Habitat	no riparian buffer	16	11	80	36%	23%	No	----
	low shading	15	11	77	36%	11%	Yes	24%

Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Double Pipe Creek Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of 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	16	11	159	73%	8%	Yes	65%
	high total dissolved nitrogen	0	0	0	0%	0%	No	----
	ammonia acute with salmonid present	16	11	159	27%	2%	Yes	25%*
	ammonia acute with salmonid absent	16	11	159	18%	1%	Yes	17%*
	ammonia chronic with salmonid present	16	11	159	27%	4%	Yes	23%*
	ammonia chronic with salmonid absent	16	11	159	18%	2%	Yes	16%*
	low lab pH	16	11	159	0%	5%	No	----
	high lab pH	16	11	159	0%	1%	No	----
	low field pH	15	11	154	0%	14%	No	----
	high field pH	15	11	154	0%	0%	No	----
	high total phosphorus	16	11	146	18%	3%	Yes	15%
	high orthophosphate	16	11	159	18%	4%	Yes	14%
	dissolved oxygen < 5mg/l	15	11	154	18%	3%	Yes	16%
	dissolved oxygen < 6mg/l	15	11	154	18%	7%	No	----
	low dissolved oxygen saturation	15	11	138	18%	4%	Yes	15%
	high dissolved oxygen saturation	15	11	138	9%	1%	No	----
	acid neutralizing capacity below chronic level	16	11	159	0%	6%	No	----
	acid neutralizing capacity below episodic level	16	11	159	0%	43%	No	----
	high chlorides	16	11	159	9%	7%	No	----
	high conductivity	16	11	159	18%	4%	Yes	14%
	high sulfates	16	11	159	0%	4%	No	----

*** Due to minimal sampling for ammonia in MBSS data set, To make an accurate determination of acute and chronic ammonia toxicity, MDE reviewed additional data to determine if there is ammonia toxicity impairment in these waters. (See page 20)**

Table 4. Stressor Source Identification Analysis Results for the Double Pipe Creek Watershed

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Urban	high impervious surface in watershed	16	11	156	0%	1%	No	----
	high % of high intensity urban in watershed	16	11	159	27%	4%	Yes	23%
	high % of low intensity urban in watershed	16	11	159	27%	8%	Yes	20%
	high % of transportation in watershed	16	11	159	27%	9%	Yes	18%
	high % of high intensity urban in 60m buffer	16	11	159	27%	6%	Yes	22%
	high % of low intensity urban in 60m buffer	16	11	159	9%	7%	No	----
	high % of transportation in 60m buffer	16	11	159	18%	9%	No	----
Sources Agriculture	high % of agriculture in watershed	16	11	159	36%	6%	Yes	31%
	high % of cropland in watershed	16	11	159	0%	6%	No	----
	high % of pasture/hay in watershed	16	11	159	55%	8%	Yes	47%
	high % of agriculture in 60m buffer	16	11	159	55%	6%	Yes	49%
	high % of cropland in 60m buffer	16	11	159	0%	4%	No	----
	high % of pasture/hay in 60m buffer	16	11	159	64%	8%	Yes	56%
Sources Barren	high % of barren land in watershed	16	11	159	0%	7%	No	----
	high % of barren land in 60m buffer	16	11	159	0%	6%	No	----
Sources Anthropogenic	low % of forest in watershed	16	11	159	55%	5%	Yes	50%
	low % of forest in 60m buffer	16	11	159	73%	6%	Yes	67%
Sources Acidity	atmospheric deposition present	16	11	159	0%	39%	No	----
	AMD acid source present	16	11	159	0%	4%	No	----
	organic acid source present	16	11	159	0%	3%	No	----
	agricultural acid source present	16	11	159	0%	1%	No	----

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

Stressor Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Sediment	75%	94%
Instream Habitat	----	
Riparian Habitat	24%	
Water Chemistry	78%	

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

Source Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Urban	32%	77%
Agriculture	58%	
Barren Land	----	
Anthropogenic	68%	
Acidity	----	

<u>Sediment Conditions</u>

BSID analysis results for the Double Pipe Creek watershed identified four sediment parameters that have a statistically significant association with poor to very poor stream biological condition: *high embeddedness, epifaunal substrate (poor), and erosion present (moderate to severe, and severe).*

High embeddedness was identified as significantly associated with degraded biological conditions and found to impact approximately 24% of the stream miles with very poor to poor biological conditions in the Double Pipe Creek watershed. This stressor measures the percentage of fine sediment surrounding gravel, cobble, and boulder particles in the streambed. High embeddedness is a result of excessive sediment deposition. High embeddedness suggests that sediment may interfere with feeding or reproductive processes and result in biological impairment. Although embeddedness is confounded by natural variability (e.g., Coastal Plain streams will naturally have more embeddedness than Highlands streams), embeddedness values higher than reference streams are indicative of anthropogenic sediment inputs from overland flow and/or stream channel erosion.

Epifaunal substrate (poor) was identified as significantly associated with degraded biological conditions and found to impact approximately 15% of the stream miles with very poor to poor biological conditions in the Double Pipe Creek 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. Epifaunal substrates can be impacted by hydrological changes with resultant streambed scouring.

Erosion present (i.e., *erosion severity*) was identified as significantly associated with degraded biological conditions, and found to impact approximately 56% *(moderate to severe* rating) and 16% (*severe* rating) of the stream miles with very poor to poor biological conditions in the Double Pipe Creek watershed. This stressor indicates that stream discharge is frequently exceeding the ability of the channel and/or floodplain to attenuate flow energy, resulting in channel instability, which in turn affects bank stability. Where such conditions are observed, flow energy is considered to have increased in frequency or intensity, accelerating channel and bank erosion. Increased flow energy suggested by this measure is also expected to negatively influence stream biology.

The BSID analysis results include stressors (*high embeddedness*, *epifaunal substrate poor* and *erosion present*) associated with the effects of agricultural and urban land use. The Double Pipe Creek watershed contains a considerable proportion (68%) of agricultural and pasture/hay (livestock) land use within the watershed. Agricultural land use results in increased sediment deposition within the watershed, sediment "pollution" is the number one impairment of streams nationwide Southerland et al. (2005b). Increased inputs of sediments impact riparian and stream channel habitat, and alter flows (Cooper 1993). The MDDNR MBSS documented (i.e., photographed) several examples of livestock access as part of the site habitat assessment in the Double Pipe Creek watershed; livestock trampling of stream banks increases erosion and sedimentation. Livestock trampling affects riparian zones and cattle are also a key mode of sediment transport into stream channels (George et al. 2004).

The watershed also contains urban development (12%); there are several low- to high-intensity urbanized areas (i.e., Manchester, Westminster, Taneytown, Union Bridge and New Windsor) in the watershed which alter natural flow regimes. Altered flow regimes create a less stable stream channel, leading to excessive bank erosion, loss of pool habitat and instream cover, and excessive streambed scour and sediment deposition (Wang et al.

2001). In urbanized areas lawns are frequently and severely mowed, as a result soils can be more easily eroded and transported to streams.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with very poor to poor biological conditions. The combined AR for the sediment stressor group is approximately 75% suggesting these stressors impact a considerable proportion of the degraded stream miles in the Double Pipe Creek watershed (Table 5).

Instream Habitat Conditions

BSID analysis results for the Double Pipe Creek watershed did not identify instream habitat parameters that have statistically significant associations with poor to very poor stream biological condition.

Riparian Habitat Conditions

BSID analysis results for the Double Pipe Creek watershed identified one riparian habitat parameter that has a statistically significant association with poor to very poor stream biological condition: *low shading.*

Low shading was identified as significantly associated with degraded biological conditions and found to impact approximately 24% of the stream miles with very poor to poor biological conditions in the Double Pipe Creek watershed. This stressor indicates the percentage of the stream segment that is shaded, taking duration into account. Solar radiation can increase the temperature of stream segments causing thermal stress on fish and invertebrates. Detrimental impacts include increased temperature of stream segments resulting in thermal stress on fish and invertebrates, and decreased dissolved oxygen due to high instream temperatures and increased bacterial and algal growth.

The Double Pipe Creek watershed contains a considerable proportion (68%) of agricultural and pasture/hay (livestock) land use; to a lesser extent (12%) the watershed also includes urban development. Stream channel shading is reduced or eliminated as forests and other riparian vegetation are replaced with agricultural, livestock industries and urban development (Allan 2004; Kline et al. 2005; Southerland et al. 2005b). Local riparian vegetation is a secondary predictor of stream integrity; the extent of riparian vegetation may affect the volume of pollutants in runoff (Kline et al. 2005; Roth et al. 1996). Anthropogenic replacement of mature riparian vegetation by successional species or crops decreases shading and eliminates the buffer between terrestrial and aquatic components of a drainage basin, resulting in increased inputs of sediments and nutrients (Delong and Brusven 1994). The elimination of riparian vegetation can be a result of extreme overuse by livestock; riparian-aquatic zones are more heavily grazed upon than upland-terrestrial zones (Armour, Duff, and Elmore 1991). Due to low shading, stream segments are also exposed to increased thermal energy, this factor plus increased nutrient input usually results in increased primary productivity (i.e., eutrophication, algal growth), which leads to a decrease in dissolved oxygen, ultimately resulting in the tolerance exceedence of biological communities and a shift in community structure.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with very poor to poor biological conditions. The combined AR for the riparian stressor group is approximately 24% suggesting this stressor impacts a minimal proportion of degraded stream miles in the Double Pipe Creek watershed (Table 5).

Water Chemistry

BSID analysis results for the Double Pipe Creek watershed identified ten water chemistry parameters that have statistically significant association with a very poor to poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters are *high total nitrogen, acute ammonia (with salmonid present and salmonid absent), chronic ammonia (with salmonid present and salmonid absent), high total phosphorus, high orthophosphate, dissolved oxygen (< 5mg/L), low dissolved oxygen saturation, and high conductivity*.

High total nitrogen (TN) concentrations were identified as significantly associated with degraded biological conditions and found to impact approximately 65% of the stream miles with very poor to poor biological conditions in the Double Pipe Creek watershed. This stressor 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 also can lead to increased primary production, which potentially results in species tolerance exceedences of dissolved oxygen and pH levels. Runoff and leaching from agricultural land can generate high in-stream levels of nitrogen.

Ammonia acute concentrations were identified as significantly associated with degraded biological conditions in the Double Pipe Creek watershed, and found to impact approximately 25% (*with salmonid present*) and 17% (*with salmonid absent*) of the stream miles with poor to very poor biological conditions. Acute ammonia toxicity refers to potential exceedences of species tolerance caused by one-time, sudden, high exposure of ammonia. Ammonia acute with salmonid present and absent is a USEPA water quality criterion for ammonia concentrations causing acute toxicity in surface waters where salmonid species of fish are present and absent (USEPA 2006). The ammonia (NH_3) parameter is the measure of the amount of NH_3 in the water column. NH_3 is a nitrogen nutrient species; in excessive amounts it has potential toxic effects on aquatic life. Increased nutrient loads from urban and agricultural development are a source of NH_3. NH_3 is associated with increased primary production, increased pH, increased sunlight exposure, and high water temperature. Increased nutrient loads from urban and agricultural development are a source of NH_3.

Ammonia chronic concentrations were identified as significantly associated with degraded biological conditions in the Double Pipe Creek watershed, and found to impact approximately 23% (*with salmonid present*) and 16% (*with salmonid absent*) of the stream miles with poor to very poor biological conditions. Chronic ammonia toxicity refers to potential exceedences of species tolerance caused by repeated exposure over a long period of time, see USEPA 2006 reference above.

High total phosphorus (TP) concentrations were identified as significantly associated with degraded biological conditions and found to impact approximately 15% of the stream miles with very poor to poor biological conditions in the Double Pipe Creek watershed. This stressor is a measure of the amount of TP in the water column. Phosphorus forms the basis of a very large number of compounds, the most important class of which is the phosphates. Elevated levels of phosphorus can lead to excessive growth of filamentous algae and aquatic plants. Excessive phosphorus input can also lead to increased primary production (accelerating eutrophication), which potentially results in species tolerance exceedences of dissolved oxygen and pH levels. TP input to surface waters typically increases in watersheds where urban and agricultural developments are predominant.

High orthophosphate (OP) concentrations were identified as significantly associated with degraded biological conditions and found to impact approximately 14% of the stream miles with very poor to poor biological conditions in the Double Pipe Creek watershed. This stressor is a measure of the amount of OP in the water column. For every form of life, phosphates play an essential role in all energy-transfer processes such as metabolism and photosynthesis. OP is the most readily available form of phosphorus for uptake by aquatic organisms (see the previous discussion of TP).

Low (< 5mg/L) dissolved oxygen (DO) concentrations were identified as significantly associated with degraded biological conditions and found to impact approximately 16% of the stream miles with very poor to poor biological conditions in the Double Pipe Creek watershed. Low DO concentrations may indicate organic pollution due to excessive oxygen demand and may stress aquatic organisms. The DO threshold value, at which concentrations below 5.0 mg/L may indicate biological degradation, is established by COMAR 2009.

Low (< 60%) *DO saturation* was also identified as significantly associated with degraded biological conditions and found to impact approximately 15% of the stream miles with very poor to poor biological conditions in the Double Pipe Creek watershed. Natural diurnal fluctuations can become exaggerated in streams with excessive primary production. High and low DO saturation accounts for physical solubility limitations of oxygen in water and provides a more targeted assessment of oxygen dynamics than concentration alone. High DO saturation is considered to demonstrate oxygen production associated with high levels of photosynthesis. Low DO saturation is considered to demonstrate high respiration associated with excessive decomposition of organic material.

High conductivity concentrations were identified as significantly associated with degraded biological conditions and found to impact approximately 14% of the stream miles with very poor to poor biological conditions in the Double Pipe Creek watershed. This stressor is a measure of water's ability to conduct electrical current and is directly related to the total dissolved salt content of the water. Most of the total dissolved salts of surface waters are comprised of inorganic compounds or ions such as chloride, sulfate, carbonate, sodium, and phosphate (IDNR 2008). Urban and agricultural runoffs as well as leaking wastewater infrastructure are typical sources of inorganic compounds. High conductivity (i.e., high salt concentrations) readings can be the result of industrial pollution, urban runoff, and water running off of impervious surfaces. Fertilizers (e.g., potassium nitrate) and manure are also a source of salts. Fertilizer salts are soluble; they readily dissolve in water and leach with rainfall, in excess quantities salts can increase instream conductivity.

The BSID analysis results identify several parameters of water chemistry as significant stressors in the Double Pipe Creek watershed; water chemistry is a major determinant of the integrity of surface waters that is strongly influenced by land-use. The agricultural and urban land uses in the Double Pipe Creek watershed are potential sources for elevated levels of TN (65%), TP (15%), OP (14%), NH_3 (acute and chronic with and without salmonid) and conductivity (14%), and decreased oxygen concentration. The three major nutrients in fertilizers and manure are nitrogen, phosphorus, and potassium. In urban areas, excessive fertilization of lawns can be significant contributors of nutrients (Weibel 1969). Livestock waste is one of the primary agricultural sources of NH_3 and TN, and a significant contributor to instream TP (USEPA 2000; USEPA 2009a). In agricultural areas, animal manure is a potential and significant source of nutrients, during the site habitat assessment of the Double Pipe Creek watershed, the MDDNR MBSS documented (i.e., photographed) several examples of livestock access to streams. In surface water, manure's oxygen demand and NH_3 content can result in fish kills and reduced biodiversity (USEPA 2009a). In Wisconsin streams, Wang et al. (2007) found that many macroinvertebrate and fish measures were significantly correlated with phosphorus and nitrogen concentrations, implying that nutrients have direct and/or indirect links with those biological assemblages.

The BSID results demonstrate that phosphorus concentrations are less of an impact on stream miles with very poor to poor biological conditions in the Double Pipe Creek watershed, therefore phosphorus may be a limiting nutrient in the watershed (Allan 1996). Due to anthropogenic sources, the watershed is vulnerable to nutrient fluxes (e.g., stormwater) that could be detrimental to the biological community, additional analysis of available data (i.e., TN:TP ratio) is necessary to confirm if phosphorus concentrations are limiting in the watershed. There are several permits for surface water discharges in the Double Pipe Creek watershed that include concentrated animal feeding operations and stormwater associated with industrial activities (MDE 2007). Both sewer and septic systems service the Double Pipe Creek; wastewater collected is treated at the Westminster Treatment Plant (WWTP), the New Windsor WWTP, and the Union Bridge

WWTP, all which discharge into Little Pipe Creek (MDE 2007). Nutrient and suspended solid loads from any wastewater treatment facility is dependent on discharge volume, level of treatment process, and sophistication of the processes and equipment.

Identification of NH_3 toxicity by the BSID analysis is indicative of degradation to water quality due to nutrient loading in the Double Pipe Creek watershed. Under natural conditions, nitrate and nitrite occur in moderate concentrations and are not generally harmful to most aquatic life, but NH_3 is highly toxic to aquatic organisms. There are sixteen MBSS stations in the Double Pipe Creek watershed and minimal sampling for ammonia was conducted (onetime sample) at each station. Acute ammonia toxicity refers to potential exceedences of species tolerance caused by a one-time, sudden, high exposure of ammonia. However, chronic ammonia toxicity refers to potential exceedences of species tolerance caused by repeated exposure over a long period of time. To make an accurate determination of acute and chronic ammonia toxicity, MDE reviewed additional data to determine if there is ammonia toxicity impairment in these waters. During the years of 2001, 2002, 2003, 2004, 2005, and 2008, MDE collected five hundred and ninety-three water quality samples from the Double Pipe Creek watershed. Samples were collected at thirty stations through out the watershed, with most stations being sampled monthly for approximately a year. None of the samples showed exceedances of any of the four USEPA and MDE criteria for ammonia: acute criterion when salmonid fish are present, acute criterion when salmonid fish are absent, chronic criterion when early life stages are present or chronic criterion when early life stages are absent (USEPA 2006). Due to these results from the MDE water quality data analysis, it was determined that ammonia toxicity is not a problem in the Double Pipe Creek watershed.

The BSID analysis also identified low DO and low DO saturation as significantly associated with degraded biology in the Double Pipe Creek watershed. The BSID primary dataset includes sixteen stations; two stations had low DO and/or low DO saturation. The watershed was sampled in 2002 by MDDNR; this was a severe drought year (Prochaska 2005). The low DO and low DO saturation results may be associated with low precipitation. Drought conditions and the decomposition of leaf litter, grass clippings, sewage, and runoff from feedlots can contribute to low DO concentrations.

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

Sources

All fifteen stressor parameters, identified in Tables 1-3, that are significantly associated with biological degradation in the Double Pipe Creek watershed BSID analysis are representative of impacts from agricultural and urban landscapes. As the result of a ten year study in the watershed, Sanders et al. (1992) identified several best management programs for the Double Pipe Creek watershed to address water quality impairments including fertilizer management, permanent vegetated land cover, animal waste control facilities, grazing land protection, stream protection systems, sediment retention, and erosion and water control structures.

The BSID analysis identified agricultural and pasture/hay land use as significant not only in the watershed but also in the riparian buffer zone. The agricultural land use (68%) within the Double Pipe Creek watershed consists mostly of pasture /hay, row crop, and dairy production. Based on literature review, Allan (2004) reported declines in water quality, habitat, and biological assemblages as the extent of agricultural land increases within catchments; also streams draining agricultural lands support fewer species of sensitive benthic and fish taxa than streams draining forested catchments. Agricultural land use degrades streams by increasing nonpoint inputs of pollutants, impacting riparian and stream channel habitat, and altering flows. Storm event flows commonly increase in magnitude and frequency, especially where runoff is enhanced due to drainage ditches, subsurface drains, and loss of wetland area (Allan 2004). Agricultural land use is an important source of pollution when rainfall carries sediment, fertilizers, manure, and pesticides into streams; which are potential sources for the elevated levels of TN, OP, NH_3, and conductivity. 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).

The BSID analysis also identified urban land use as significant not only in the watershed but also in the riparian buffer zone; land use analysis indicates that urban development comprises 12% of the watershed. Wang et al. (2001) reported that even under best-case urban development scenarios, stream fish communities decline substantially in quality even while a watershed remains largely rural in character. The watershed contains several urban centers including Manchester, Westminster, Taneytown, Union Bridge and New Windsor. The scientific community (Booth 1991; Meyer et al. 2005; Southerland et al. 2005b) has consistently identified negative impacts to biological conditions as a result of increased urbanization. The consequences of urbanization include loss of large woody debris, increased erosion, and channel destabilization; the most critical of these environmental changes are those that alter the watershed’s hydrologic regime. A number of systematic and predictable environmental responses have been noted in streams affected by urbanization, and this consistent sequence of effects has been termed “urban stream syndrome” (Meyer et al. 2005). Symptoms of urban stream syndrome include flashier hydrographs, altered habitat conditions, degradation of water quality, and reduced biotic richness, with increased dominance of species tolerant to anthropogenic (and natural) stressors. Overall urban development causes an increase in contaminant loads from point and nonpoint sources by adding sediments, nutrients, road salts, toxics, petroleum products, and inorganic pollutants to surface and ground waters.

Both agricultural and urban land uses are sources that are associated with detrimental changes to the Double Pipe Creek watershed. These effects include altered hydrology, increased nutrients and sediment deposition, and decreased dissolved oxygen concentrations, which result in a shift of fish and benthic macroinvertebrate community structure in the watershed.

The BSID source analysis (Table 4) identifies various types of agricultural and urban land uses as potential sources of stressors that may cause negative biological impacts. The combined AR for the sources group is approximately 77% suggesting that these causal sources impact a substantial proportion of the degraded stream miles in Double Pipe Creek watershed (Table 6).

Summary

The BSID analysis results suggest that degraded biological communities in the Double Pipe Creek watershed are a result of increased urban and agricultural land uses causing alteration to hydrology, increased sedimentation, loss of available habitat, increased nutrients and decreased dissolved oxygen, resulting in an unstable stream ecosystem with degraded biological communities. High proportions of these land uses also typically results in increased contaminant loads from point and nonpoint sources by adding sediments and nutrients to surface waters, resulting in levels of nutrients that can potentially be toxic to aquatic organisms. Alterations to the hydrologic regime, physical habitat, and water chemistry have all combined to degrade the Double Pipe Creek watershed, leading to a loss of diversity in the biological community. The combined AR for all the stressors is approximately 94%, suggesting that altered hydrology/sediment, habitat, and water chemistry stressors adequately account for the biological impairment in the Double Pipe Creek 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 Double Pipe Creek 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 2009b). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 6 illustrates the final casual model for the Double Pipe Creek watershed, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

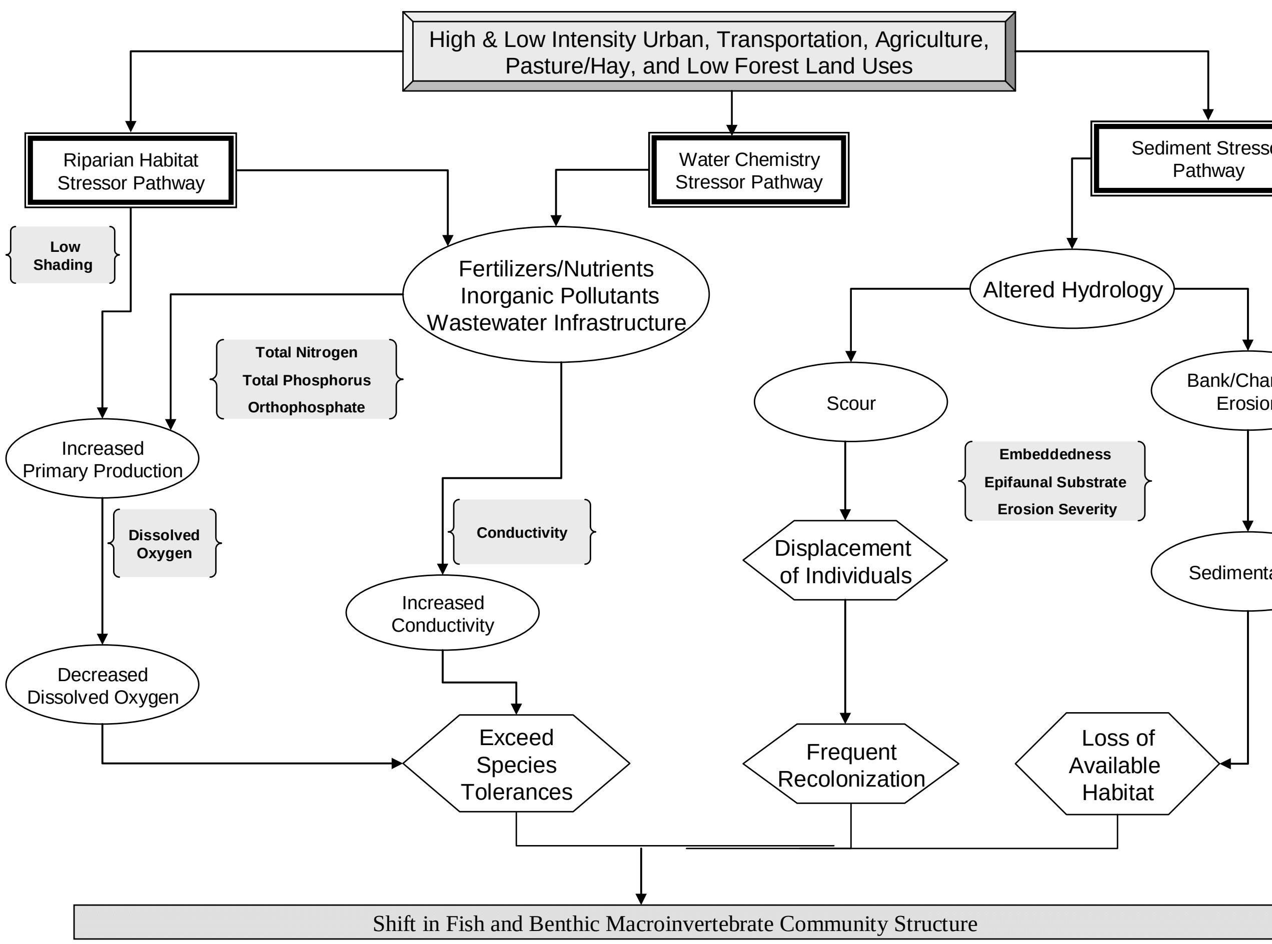

Figure 6. Final Causal Model for the Double Pipe Creek Watershed

5.0 Conclusions

Data suggest that the Double Pipe Creek watershed's biological communities are strongly influenced by urban and agricultural land use, which alters the hydrologic regime resulting in increased erosion, sediment, and nutrient pollutant loading. There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to urban and agricultural 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 Double Pipe Creek are summarized as follows:

- The BSID process has determined that biological communities in the Double Pipe Creek watershed are likely degraded due to sediment and riparian habitat related stressors. Specifically, altered hydrology and increased runoff from urban and agricultural landscapes have resulted in channel erosion and subsequent elevated suspended sediment in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results confirm that the establishment of a USEPA approved sediment TMDL in 2009 was an appropriate management action to begin addressing the impact these stressor have on the biological communities in the Double Pipe Creek watershed.

- The BSID process has determined that the biological communities in the Double Pipe Creek watershed are likely degraded due to water chemistry related stressors. Specifically, agricultural and urban land use practices have resulted in the potential elevation of nutrient (i.e. TN, OP and TP) inputs in the watershed, which are in turn the probable causes of impacts to biological communities. Due to anthropogenic sources, the watershed is vulnerable to nutrient fluxes (e.g., sediment release, fertilizer application, stormwater) that could be detrimental to the biological community, but phosphorus concentrations may be limiting in the watershed. Therefore, MDE scientists recommend a more intense analysis of all available data to assess the TN:TP ratio of the watershed. BSID results also include low DO and low DO saturation; a moderate increase of phosphorous may lead to increased algal blooms and decreased oxygen concentrations. The BSID results thus confirm the 2008 Category 5 listing for phosphorus levels and suggest that elevated levels are also associated with degraded biological conditions in the Double Pipe Creek watershed.

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