Total Maximum Daily Load of Polychlorinated Biphenyls in Back River Oligohaline Tidal Chesapeake Bay Segment, Maryland

FINAL

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Partially Funded by the American Recovery and Reinvestment Act of 2009

Submitted to:

Watershed Protection Division
U.S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

September 2011

EPA Submittal Date: September 30, 2011
EPA Approval Date: October 1, 2012

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List of Abbreviations

Adj-SediBAF	Sediment Bioaccumulation Factor
Adj-tBAF	Adjusted Total Bioaccumulation Factor
ARS	Agricultural Research Service
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BIBI	Benthic Index of Biotic Integrity
BMP	Best Management Practice
BRCCS	Back River Chemical Contaminant Survey
BSAF	Biota-Sediment Accumulation Factor
CBP	Chesapeake Bay Program
CHARM	Comprehensive Harbor Assessment and Regional Modeling Study
CI	Confidence Interval
COMAR	Code of Maryland Regulations
CSF	Cancer Slope Factor
CV	Coefficient of Variation
CWA	Clean Water Act
DEM	Digital Elevation Model
DOC	Dissolved Organic Carbon
ENR	Enhanced Nutrient Removal
EOF	Edge of Field
EOS	Edge of Stream
EPA	U.S. Environmental Protection Agency
ERM	Effects Range Median
FIBI	Fish Index of Biotic Integrity
Ft	Feet
GIS	Geographic Information System
G	Gram
Kg	Kilogram

Km^2	Square Kilometer
Kow	PCB Octanol-Water Partition Coefficient
L	Liter
Lbs	Pounds
LA	Load Allocation
LMA	Lang Management Administration
LRP-MAP	Land Restoration Program Geospatial Database
M^2	Square meter
M^3	Cubic meter
MD 8-Digit	Maryland 8-Digit
MDE	Maryland Department of the Environment
MDL	Maximum Daily Load
Mg	Milligram
MGD	Million Gallons per Day
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer Systems
Ng	Nanogram
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PCB	Polychlorinated Biphenyl
POC	Particulate Organic Carbon
Ppb	Parts per Billion
Ppt	Parts per Trillion
RUSLE2	Revised Universal Soil Loss Equation Version II
SediBAF	Sediment Bioaccumulation Factor
SIC	Standard Industrial Classification
SQG	Sediment Quality Guideline
TMDL	Total Maximum Daily Load
tBAF	Total Bioaccumulation Factor

tPCB	Total PCB
TEL	Threshold Effects Level
TSD	Technical Support Document
TSS	Total Suspended Solids
UMCES	University of Maryland Center for Environmental Science
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VA	Virginia
VCP	Voluntary Cleanup Program
WLA	Waste Load Allocation
WQA	Water Quality Analysis
WQBEL	Water Quality Based Effluent Limit
WQLS	Water Quality Limited Segment
WQS	Water Quality Standard
WWTP	Waste Water Treatment Plant
µg	Microgram

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for Polychlorinated Biphenyls (PCBs) in the Back River Oligohaline Tidal Chesapeake Bay Segment. Section 303(d) of the federal Clean Water Act (CWA) and the EPA's 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 (WQSs). For each WQLS, the State is to either establish a TMDL of the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2011b).

Maryland WQSs specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life (COMAR 2011a). Additionally, the specific designated use of the Back River Oligohaline Tidal Chesapeake Bay Segment is Use II – Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting (COMAR 2011b). The Maryland Department of the Environment (MDE) has identified the waters of the Back River Oligohaline Tidal Chesapeake Bay Segment (Integrated Report Assessment Unit ID: BACOH) on the State's 2010 Integrated Report as impaired by PCBs in both sediment (1998) and fish tissue (2008), sediments (1996), chlordane (1996), zinc (1998), nutrients – nitrogen and phosphorus (1996), and impacts to biological communities (2002) (MDE 2011a). The Back River Oligohaline Tidal Chesapeake Bay Segment is often referred to as the Back River embayment, and therefore, for the purposes of this report, will be referred to as such for simplicity. The TMDL established herein by MDE will address the total PCB (tPCB) listing for the Back River embayment, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. Chlordane and nutrients (nitrogen and phosphorus) TMDLs, and a zinc water quality analysis (WQA) were approved by the EPA in 1999, 2005, and 2004, respectively. Then, in 2010, the Chesapeake Bay nutrient and sediment TMDLs were developed by EPA, which addressed the sediment impairment listing for the embayment. The listing for impacts to biological communities will be addressed at a future date.

PCBs are a class of man-made, carcinogenic compounds with both acute and chronic toxic effects, which are also bioaccumulative and do not readily breakdown in the natural environment. There are 209 possible chemical arrangements of PCBs known as congeners, which consist of two phenyl groups and one to ten chlorine atoms. The congeners differ in the number and position of chlorine atoms along the phenyl groups. PCBs were manufactured and used for a variety of industrial applications and sold as mixtures under various trade names commonly known as Aroclors (QEA 1999). Sixteen different Aroclor mixtures were produced, each formulated based on a specific chlorine composition by mass. PCBs are a concern to human health, as regular consumption of fish containing elevated levels of PCBs will cause bioaccumulation within the fatty tissues of humans, which can potentially lead to the development of cancer.

Since the Back River embayment was identified as impaired for PCBs in fish tissue, the overall objective of the tPCB TMDL established in this document is to ensure that the "fishing" designated use, which is protective of human health related to the consumption of fish, in the Back River embayment is supported; however, this TMDL will also ensure the protection of all other applicable designated uses within the embayment. This objective was achieved via the use of extensive field observations and a tidal prism model. The model incorporates the influences of freshwater inputs, tidal flushing, and exchanges between the water column and bottom sediments, thereby representing realistic dynamic transport within the Back River embayment.

The tidal prism model is used to:

1. Estimate and predict PCB transport and fate based on observed tPCB concentrations in the water column and bottom sediments of the Back River embayment.
2. Simulate long-term tPCB concentrations in the water column and bottom sediments.
3. Estimate the load reductions necessary to meet the water column and sediment TMDL endpoint tPCB concentrations, which are derived from the Integrated Report fish tissue listing threshold and site specific total Bioaccumulation Factors (tBAFs).
4. Estimate the amount of time necessary for tPCB concentrations within the embayment to reach the water column and sediment TMDL endpoints, given the required load reductions from the individual source sectors and an estimated rate of decline in the tPCB concentrations at the boundary between the embayment and the Chesapeake Bay mainstem.

The CWA, as recently interpreted by the United States District Court, requires TMDLs to be protective of all the designated uses applicable to a particular waterbody (US District Court for the District of Columbia 2011). Within the Back River embayment, these designated uses, as described previously, include “water contact recreation”, “fishing”, “the protection of aquatic life”, and “marine and estuarine aquatic life and shellfish harvesting”. The TMDL presented herein was developed specifically to be protective of the “fishing” designated use, which is protective of human health related to the consumption of fish, since the embayment was identified as impaired for “PCBs in fish tissue” on the Integrated Report. Additionally, the embayment was also identified on the Integrated Report as impaired for PCBs in sediment. This PCB sediment impairment listing was assessed based on sediment concentrations exceeding the sediment quality guideline (SQG) effects-range median (ERM) for PCBs (Buchman 1999). Though the ERM is sufficient for providing an official assessment (i.e., Integrated Report listing purposes) of PCB sediment impairments, since it provides reasonable certainty that concentrations above this threshold do in fact result in toxicity, concentrations below this threshold may still be representative of conditions that adversely impact benthic life, in some instances. Conversely, the SQG Threshold Effects Level (TEL) for PCBs in marine sediments indicates that concentrations below this threshold are highly unlikely to result in toxicity and will therefore be protective of benthic life. Thus, the TEL will be used as a reference for comparison, rather than the ERM, when evaluating the sediment TMDL endpoint tPCB concentration for the Back River embayment.

The water column and sediment TMDL endpoint tPCB concentrations applied within this analysis, which are derived from Maryland’s Integrated Report fish tissue listing threshold tPCB concentration and site specific tBAFs, are lower than 1) EPA’s human health criterion tPCB water column concentration relative to fish consumption, 2) both Maryland’s freshwater and saltwater aquatic life chronic criteria tPCB water column concentrations, and 3) the SQG TEL for PCBs (see Section 3 for further details). This indicates that the TMDL is not only protective of the “fishing” designated use but also the “aquatic life” designated use, specifically the protection of “marine and estuarine aquatic life and shellfish harvesting” (i.e., water column TMDL endpoint tPCB concentration < saltwater chronic criteria), and in particular, it is also protective of benthic aquatic life (i.e., sediment TMDL endpoint tPCB concentration < SQG TEL). Since the sediment TMDL endpoint tPCB concentration applied within the analysis is less than the SQG TEL, this indicates that that the impairment listings for PCBs in sediment for the embayment will be addressed as well. Lastly, the designated use for "water contact recreation" is not associated with any potential human health risks due to PCB exposure. Dermal contact and consumption of water from activities associated with "water contact recreation" are not a significant pathway for the uptake of PCBs. The EPA human health criterion was developed solely based on organism consumption, as drinking water consumption does not pose any risk for cancer development at environmentally relevant levels. The only human health risk associated with PCB exposure is through the consumption of aquatic organisms, which is addressed by the water column and sediment tPCB endpoint concentrations applied within this TMDL developed to be supportive of the "fishing" designated use for the embayment.

As part of this analysis, both point and nonpoint sources of PCBs have been identified throughout the Back River embayment's watershed. Nonpoint sources include direct atmospheric deposition to the embayment, identified contaminated sites, runoff from non-regulated watershed areas, resuspension and diffusion from bottom sediments, and tidal influence from the Chesapeake Bay mainstem. Point sources include a single municipal wastewater treatment plant (WWTP) and National Pollutant Discharge Elimination System (NPDES) regulated stormwater runoff within the embayment's watershed. Model estimated tPCB loads from these point and nonpoint sources represent the baseline conditions for the embayment.

The transport of PCBs from bottom sediments to the water column through resuspension and diffusion could be a major source of PCBs to the system; however, under current conditions, due to elevated particulate PCB concentrations resultant from PCB adsorption to the organic carbon component of suspended sediment, there is a net transport of PCBs to the bottom sediment from the water column through settling and deposition. The estimated baseline load to the bottom sediments from the water column is 11,339.8 grams/year (g/year). Also, the transport of PCBs into the embayment due to tidal influxes from the Chesapeake Bay mainstem could be a major source of PCBs to the system; however, under current conditions, due to elevated PCB water column concentrations within the embayment, there is a net transport of PCBs out of the embayment into the Bay's mainstem (7,262.9 g/year). Thus, through tidal influences, PCBs are being removed from the Back River embayment. Even if resuspension and diffusion from bottom sediment and tidal influences from the Chesapeake Bay mainstem served as sources of PCBs to the water column, their load contribution is resultant from other point and nonpoint source inputs (both historic and current) within the embayment's watershed and the Upper Chesapeake Bay watershed. Thus, these sources are not considered to be directly controllable and will not be considered for reductions under the scope of this TMDL.

The objective of the TMDL established herein is to reduce current PCB loads to the Back River embayment so that the water column and sediment TMDL endpoint tPCB concentratons are achieved. All TMDLs need to be presented as a sum of Wasteload Allocations (WLAs) for the identified point sources, Load Allocations (LAs) for nonpoint source loads generated within the assessment unit, and where applicable, natural background, tributary, and adjacent segment loads. Furthermore, all TMDLs must include a margin of safety (MOS) to account for lack of knowledge and the many uncertainties in the understanding and simulation of water quality parameters in natural systems (i.e., the relationship between modeled loads and water quality) (CFR 2011b). The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection. An explicit MOS of 5% was incorporated into the analysis to account for such uncertainty.

A summary of the baseline conditions and TMDL for the Back River embayment is presented in Table ES-1. Additionally, the baseline loads and TMDL allocations only consider current sources of PCBs to the embayment that are deemed to be directly controllable, positive net loads (i.e., reducible loads), and therefore do not include resuspension and diffusion from bottom sediments and the tidal influence of the Chesapeake Bay mainstem. When implemented, this TMDL will ensure that the resulting tPCB loads are at levels supportive of the “fishing” designated use in the Back River embayment.

The water quality model developed for simulating ambient sediment and water column tPCB concentrations within the Back River embayment was used to determine the specific load reductions for each reducible source category that would result in simulated tPCB concentrations in the sediment and water column that meet the TMDL endpoints. The results of this scenario establish the load reductions per reducible source category and the associated WLAs and LAs necessary to achieve the TMDL, except for certain reducible source sector loads, described as follows. Loads from contaminated sites were not reduced from their baseline loads, since they have already undergone some degree of remediation and their baseline loads constitute a relatively small percentage of the Total Baseline Load to the embayment (1.4%). The WLA for municipal WWTPs is assigned based on the water column TMDL endpoint and the facility design flow. The TMDL modeling scenario was used to develop the load reductions, WLAs, and LAs for the non-regulated watershed runoff, NPDES regulated stormwater, and atmospheric deposition source categories. The resultant TMDL scenario requires a 52.5 % reduction for all watershed sources (i.e., non-regulated watershed runoff and NPDES regulated stormwater), with slight variations in the regulated stormwater due to the locations of contaminated sites, and a 40.3% reduction for atmospheric deposition, in order to achieve the sediment and water column TMDL endpoint tPCB concentrations. A smaller reduction for atmospheric deposition is required since it has less of an impact on water quality than the watershed land sources.

Table ES-1: Summary of Baseline tPCB Baseline Loads, TMDL Allocations, Load Reductions, and Maximum Daily Loads (MDLs) in the Back River Embayment

Source	Baseline Load (g/year)	Percent of Total Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Direct Atmospheric Deposition	267.8	29.0	160.0	40.3	1.09
Non-regulated Watershed Runoff	65.7	7.1	31.2	52.5	0.21
Contaminated Sites	12.8	1.4	12.8	0.0	0.09
Nonpoint Sources/LAs	***346.3***	***37.5***	***204.0***	***41.1***	***1.39***
WWTP	133.2	14.4	48.5	63.6	0.41
NPDES Regulated Stormwater[1]					
Baltimore County	273.7	29.7	127.6	53.4	0.87
Baltimore City	169.9	18.4	82.3	51.6	0.56
Point Sources/WLAs	***576.8***	***62.5***	***258.4***	***55.2***	***1.84***
MOS (5%)	**-**	**-**	***24.3***	**-**	***0.17***
Total	**923.1**	**100.0**	**486.7**	**47.3**	**3.40**

Notes: [1] Load per jurisdiction applies to all NPDES stormwater dischargers within the jurisdiction's portion of the watershed draining to the Back River embayment. These dischargers are identified in Appendix J.

Federal regulations require that TMDL analysis take into account the impact of critical conditions and seasonality on water quality (CFR 2011b). The intent of these requirements is to ensure that load reductions required by this TMDL, when implemented, will produce water quality conditions supportive of the designated use at all times. Given that 1) at the observed concentrations, acute conditions are not a concern, and 2) since PCB levels in fish tissue become elevated due to long-term exposure, the selection of the average annual tPCB water column and sediment concentrations for comparison to the TMDL endpoints adequately considers the impact of seasonal variations and critical conditions on the "fishing" designated use in the Back River embayment. Thus, the TMDL for the Back River embayment implicitly accounts for seasonal variations as well as critical conditions.

Under current conditions, there is a net transport of PCBs to the bottom sediment from the water column through settling and deposition. However, PCB concentrations within the water column decline more quickly over time than they do within sediment (the natural attenuation of PCBs in the environment). Thus, conditions may change, and the bottom sediments may become a source of PCBs to the water column. Should this occur, despite the fact that PCB loads from resuspension and diffusion are not considered to be directly controllable, these load contributions are still expected to decrease over time as the result of 1) the implementation of directly controllable point and nonpoint source reductions within the embayment's watershed and 2) the natural attenuation of PCBs in the environment.

After the initial decline in PCB water column concentrations within the embayment, due to the natural attenuation of PCBs in the environment, in addition to the expected decrease of point and nonpoint source inputs within the embayment's watershed, the net exchange of PCBs at the tidal boundary between the embayment and the Chesapeake Bay mainstem may shift as well. As a result, instead of loads being exported from the embayment into the Bay's mainstem, loads may be imported from the Bay's mainstem into the embayment, meaning that this boundary condition may start to dominate the recovery time of the impaired embayment. Should this occur, however, observations show that the average tPCB concentration in the Upper Chesapeake Bay is decreasing at a rate of 6.5% per year (MDE 2009). Thus, as a conservative estimate, a 5% per year decrease of tPCB concentrations can be expected at the tidal boundary between the embayment and the Bay mainstem. Given this natural rate of decline in the boundary concentrations, tPCB levels in the embayment are expected to continue to decline over time. Thus, discovering and remediating any existing PCB land sources throughout the upper Chesapeake Bay watershed via future TMDL development and implementation will further aid in the decline of the boundary condition tPCB concentrations and meeting water quality goals in the Back River embayment.

Once EPA has approved this TMDL, MDE will begin an iterative process of implementation that will first identify specific sources, or areas of PCB contamination, within the embayment's watershed, and second, target remedial action for those sources with the largest impact on water quality, while giving consideration to the relative cost and ease of implementation. The implementation efforts will be periodically evaluated, and if necessary, improved, in order to further progress toward achieving the water quality goals. Given that a number of contaminated sites have already undergone some degree of remediation and their baseline loads constitute a relatively small percentage of the Total Baseline Loads (i.e., 1.4%), these sites are not intended to be targeted during the initial stages of implementation and thus at this point were not subjected to any reductions (as discussed previously). However, if in the future it becomes clear that the TMDL goals cannot be achieved without load reductions from these sites, additional reduction measures might need to be considered. As part of Maryland's Watershed Cycling Strategy, follow-up monitoring and assessment will be routinely conducted to evaluate the implementation status in the Back River embayment. MDE also monitors and evaluates concentrations of contaminants in recreationally caught fish, shellfish, and crabs throughout Maryland. MDE will use these monitoring programs to evaluate progress towards meeting the "fishing" designated use in the embayment.

1. INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for Polychlorinated Biphenyls (PCBs) in the Back River Oligohaline Tidal Chesapeake Bay Segment. Section 303(d) of the federal Clean Water Act (CWA) and the EPA's 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 (WQSs). For each WQLS, the State is to either establish a TMDL of the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2011b).

TMDLs are established to determine the pollutant load reductions needed to achieve and maintain WQSs. A WQS is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, protection of aquatic life, fish and shellfish propagation and harvest, etc. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

Maryland WQSs specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life (COMAR 2011a). Additionally, the specific designated use of the Back River Oligohaline Tidal Chesapeake Bay Segment is Use II – Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting (COMAR 2011b). The Maryland Department of the Environment (MDE) has identified the waters of the Back River Oligohaline Tidal Chesapeake Bay Segment (Integrated Report Assessment Unit ID: BACOH) on the State's 2010 Integrated Report as impaired by PCBs in both sediment (1998) and fish tissue (2008), sediments (1996), chlordane (1996), zinc (1998), nutrients – nitrogen and phosphorus (1996), and impacts to biological communities (2002) (MDE 2011a). The Back River Oligohaline Tidal Chesapeake Bay Segment is often referred to as the Back River embayment, and therefore, for the purposes of this report, will be referred to as such for simplicity. The TMDL established herein by MDE will address the total PCB (tPCB) listing for the Back River embayment, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. Chlordane and nutrients (nitrogen and phosphorus) TMDLs, and a zinc water quality analysis (WQA) were approved by the EPA in 1999, 2005, and 2004, respectively. Then, in 2010, the Chesapeake Bay nutrient and sediment TMDLs were developed by EPA, which addressed the sediment impairment listing for the embayment. The listing for impacts to biological communities will be addressed at a future date. Table 1 provides further details regarding the 2010 Integrated Report PCB impairment listings.

Table 1: Maryland's 2010 Integrated Report PCB Impairment Listings for the Back River Embayment

Listing Year	Basin Name	Assessment Unit ID	Impairment
1998	Back River Oligohaline Chesapeake Bay Segment	MD-BACOH	PCB (Sediment)
2008	Back River Oligohaline Chesapeake Bay Segment	MD-BACOH	PCB (Fish Tissue)

PCBs are a class of man-made compounds that were manufactured and used for a variety of industrial applications. They consist of 209 related chemical compounds (congeners) that were manufactured and sold as mixtures under various trade names, commonly referred to as Aroclors (sixteen different Aroclor mixtures were produced, each formulated based on a specific chlorine composition by mass) (QEA 1999). Each of the 209 possible PCB compounds consists of two phenyl groups and one to ten chlorine atoms. The congeners differ in the number and position of the chlorine atoms along the phenyl group. From the 1940s to the 1970s, they were extensively used as heat transfer fluids, flame retardants, hydraulic fluids, and dielectric fluids because of their dielectric and flame resistant properties. They have been identified as a pollutant of concern due to the following:

1. They are bioaccumulative and can cause both acute and chronic toxic effects.
2. They have carcinogenic properties.
3. They are persistent organic pollutants that do not readily breakdown in the environment.

In the late 1970s, concerns regarding potential human health effects led the US government to take action to cease PCB production, restrict PCB use, and regulate the storage and disposal of PCBs. Despite these actions, PCBs are still being released into the environment through fires or leaks from old PCB containing equipment, accidental spills, burning of PCB containing oils, leaks from hazardous waste sites, etc. Since PCBs tend to bioaccumulate in aquatic organisms, including fish, people who consume fish may become exposed to PCBs. In fact, elevated levels of PCBs in edible parts of fish tissue are one of the leading causes of fish consumption advisories in the US.

The Back River embayment was originally identified as impaired by PCBs in sediment on Maryland's 1998 Integrated Report. The PCB sediment concentrations exceeded the sediment quality guideline (SQG) effects range median (ERM) of 180 nanograms/gram (ng/g), or parts per billion (ppb), thus indicating toxicological impacts to benthic organisms (Buchman 1999).

The Back River embayment was then identified as impaired by PCBs in fish tissue on the 2008 Integrated Report based on fish tissue PCB data from MDE's monitoring program that exceeded the tPCB fish tissue listing threshold of 39 ng/g, or ppb – (wet weight) (MDE 2011a). In addition to identifying impaired waterbodies on the State's Integrated Report, MDE also issues statewide and site specific fish consumption advisories (ranging from 0 to 4 meals per month) and recommendations (ranging from 4 to 8 meals per month). Current recreational fish consumption advisories suggest limiting the consumption of the following fish species caught in the Back River embayment: Atlantic Menhaden, American Eel, Brown Bullhead Catfish, Channel Catfish, Common Carp, and White Perch (MDE 2011b).

2. SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Back River Oligohaline Chesapeake Bay Segment is a tidal estuary, or embayment, located on the western shore of the Chesapeake Bay, just north of the Patapsco River embayment. Herring Run is the major freshwater tributary that drains to the Back River embayment. The tidal range of the embayment is 0.37 meters (m) (MES 1974). The watershed draining to the embayment covers approximately 141.7 square kilometers (km^2) (35,014 acres) and spans portions of Baltimore City and Baltimore County. There are no “high quality,” or Tier II, stream segments (Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) aquatic life assessment scores > 4 (scale 1-5)) located within the embayment’s watershed requiring the implementation of Maryland’s anti-degradation policy (COMAR 2011c; MDE 2010). Approximately 0.6% percent of the embayment’s drainage area is covered by water (i.e., streams, ponds, etc). The total population in the embayment’s watershed is approximately 331,400 (US Census Bureau 2000). The location of the Back River embayment is shown in Figure 1.

Land Use

According to the United States Geological Survey’s (USGS) 2006 land cover data (USGS 2011), which was specifically developed to be applied within the Chesapeake Bay Program’s (CBP) Phase 5.3.2 watershed model, land use in the Back River embayment’s watershed is predominantly urban. Urban land occupies approximately 87.4% of the watershed, while 7.8% is forested and 2.7% is wetlands. The remaining 2.1% is classified as barren, agricultural, natural grassland, and water. The land use distribution is displayed and summarized in Figures 2 and 3 as well as Table 2.

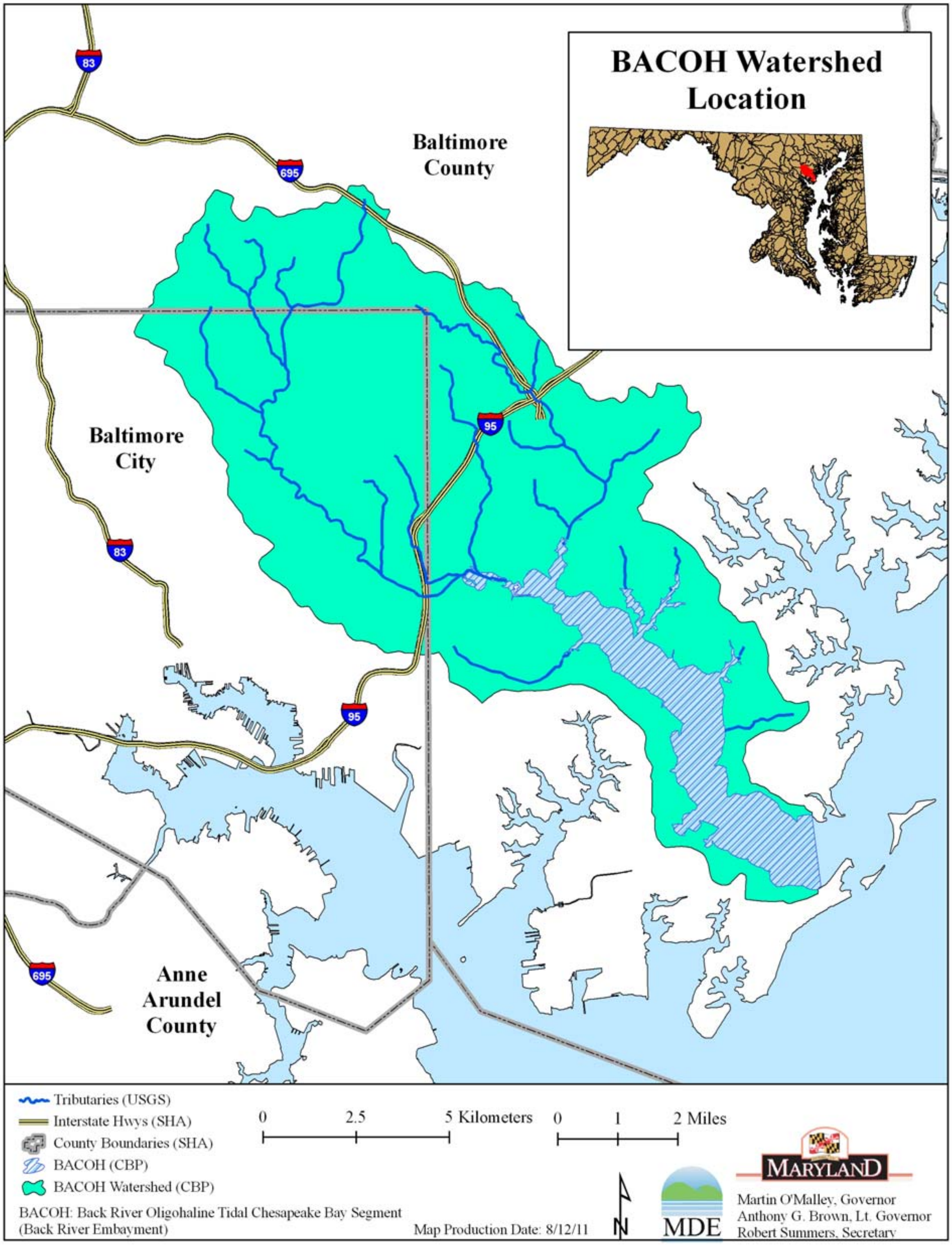


Figure 1: Location Map of the Back River Embayment and Watershed

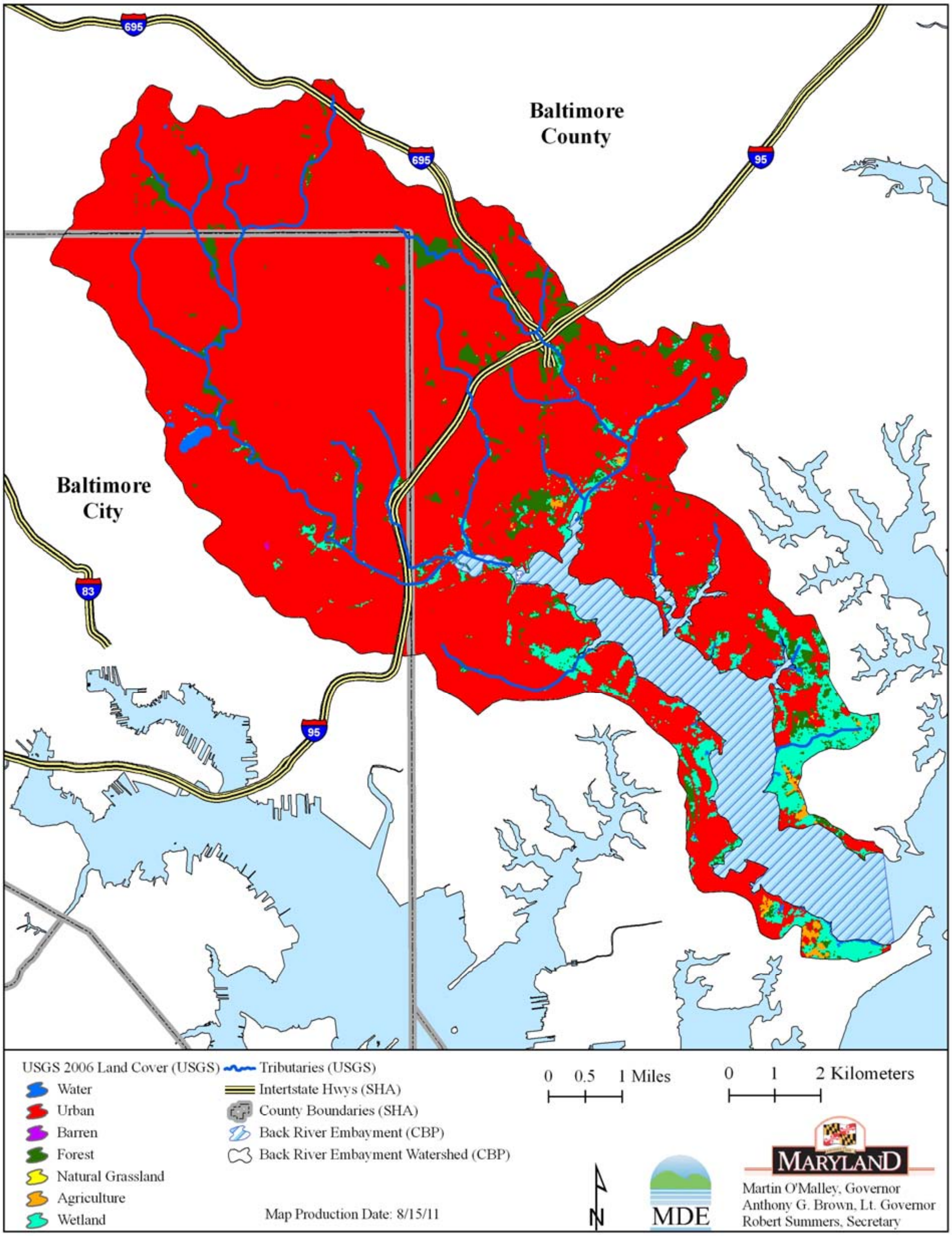


Figure 2: Land Use in the Back River Embayment's Watershed

Table 2: Land Use Distribution in the Back River Embayment's Watershed

Land Use	Area (km^2)	Percent of Total (%)
Water	0.8	0.6
Urban	123.9	87.4
Barren	0.5	0.4
Forest	11.0	7.8
Agriculture	1.5	1.0
Natural grass	0.1	0.1
Wetland	3.9	2.7
Total	**141.7**	**100**

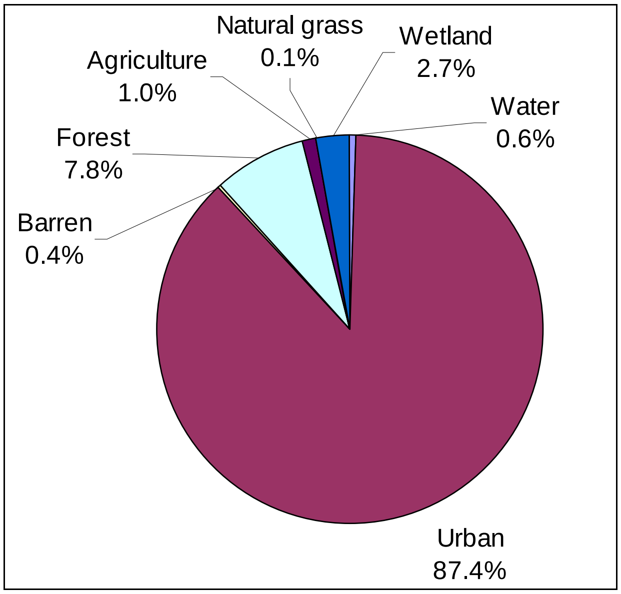


Figure 3: Land Use Distribution in the Back River Embayment's Watershed

2.2 Water Quality Characterization and Impairment

Maryland WQSs specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life and (COMAR 2011a). The specific designated use of Back River embayment is Use II – Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting (COMAR 2011b). The State of Maryland adopted three separate water column tPCB criteria: criterion for protection of human health associated with the consumption of PCB contaminated fish, as well as fresh and salt water chronic tPCB criteria for protection of aquatic life. The Maryland human health tPCB criterion is set at 0.64 nanograms/liter (ng/L), or parts per trillion (ppt) (COMAR 2011d; US EPA 2006). This criterion is based on a cancer slope factor (CSF) of 2 milligrams/kilogram-day (mg/kg-day), a bioconcentration factor (BCF) of 31,200 liters/kilogram (L/kg), a cancer risk level of 10^{-5}, a lifetime risk level and exposure duration of 70 years, and fish intake of 17.5 g/day. A cancer risk level provides an estimate of the additional incidence of cancer that may be expected in an exposed population. A risk level of 10^{-5} indicates a probability of one additional case of cancer for every 100,000 people exposed. The Maryland fresh and saltwater aquatic life chronic tPCB criteria are set at 14 ng/L and 30 ng/L, respectively (COMAR 2011d; US EPA 2006). The water column mean tPCB concentration within the embayment exceeds the human health criterion of 0.64 ng/L; however, none of the water column samples exceed the salt water aquatic life tPCB criterion of 30 ng/L.

A sediment tPCB criterion has not yet been established in Maryland; however, in order to assess waters of the State for toxic impairments in sediment, an Integrated Report assessment methodology has been established. If toxicity and a degraded benthic community are present within the sediment and the sediment concentration of a given toxic substance exceeds the ERM, the waterbody will be listed as impaired on the Integrated Report for that substance (MDE 2011a). The Back River embayment was listed as impaired for PCBs in sediment due to the presence of toxicity, degraded benthic community and exceedances of the sediment tPCB ERM concentration of 180 ng/g, or ppb. The sediment tPCB concentration data for these listings is presented in Appendix K.

In addition to the water column and sediment criteria described above, fish tissue monitoring can serve as an indicator of PCB water quality conditions. The Maryland fish tissue monitoring data is used to issue fish consumption advisories/recommendations and determine whether Maryland waterbodies are meeting the “fishing” designated use. Only data results from the analysis of skinless fillets, the edible portion of fish typically consumed by humans, is used for assessment purposes and development of this TMDL. Currently Maryland applies 39 ng/g as the tPCB fish tissue listing threshold (MDE 2011a). MDE collected fish tissue samples for PCB analysis in the Back River embayment from 2000 to 2004. In 2008, additional fish tissue samples were collected in support of this TMDL. The tPCB concentrations for all of the fish samples (several species of fish including channel catfish, white perch, etc. were collected) exceed the listing threshold, demonstrating that a PCB impairment exists within the Back River embayment. The PCB fish tissue concentration data is presented in Appendix K.

From 2001 to 2002, monitoring surveys were conducted under the Comprehensive Harbor Assessment and Regional Modeling Study (CHARM) to measure tidal and non-tidal water column tPCB concentrations at stations throughout the Back River embayment and watershed (Baker et al. 2002). Sediment samples were collected in 2001 under the Back River Chemical Contaminant Survey (BRCCS) to characterize tPCB sediment concentrations throughout the embayment (Baker 2001). From 2008 to 2009, MDE collected additional fish tissue, water column (non-tidal and tidal), and stormwater samples for PCB analysis to further support TMDL development. Table 3 summarizes the tPCB data for fish tissue, water column (embayment only – nontidal data not included), and sediment samples that were applied in this analysis. Appendix K contains figures of the sampling locations and tables containing all of the tPCB water quality data.

Table 3: Summary of Fish Tissue, Water Column, and Sediment tPCB Data

tPCB Data	Units	Sampling Years	Sample Size	tPCB Concentration		
				Mean	Maximum	Minimum
Fish Tissue	ng/g	2000-2004, 2008	44	501.4	1368.4	78.9
Water Column[1]	ng/L	2001-2002, 2008-2009	35	10.3	24.7	1.4
Sediment	ng/g	2001, 2008	20	124.9	466.6	12.7

Note: [1] Water column data presented in this table is for the embayment (i.e., tidal areas) only and does not include nontidal or stormwater tPCB data, since this data does not actually characterize the PCB impairment in the actual embayment.

PCB analytical services were provided by the University of Maryland Center for Environmental Science (UMCES). Specific PCB congeners were identified and quantified by high resolution gas chromatography with electron capture detection. UMCES uses a slightly modified version of the PCB congener specific method described in Ashley and Baker (1999), in which the identities and concentrations of each congener in a mixed Aroclor standard (25:18:18 mixture of Aroclors 1232, 1248, and 1262) are determined based on their chromatographic retention times relative to the internal standards (PCB 30 and PCB 204). Based on this method, 86 chromatographic peaks can be quantified. Some of the peaks contain one PCB congener, while many are comprised of two or more co-eluting congeners. The PCB analysis presented in this document is based on tPCB concentrations that are calculated as the sum of the detected PCB congeners/congener groups representing the most common congeners that were historically used in the Aroclor commercial mixtures. A list of congeners detected under this analytical method is presented in Appendix A.

3. WATER COLUMN AND SEDIMENT TMDL ENDPOINTS

As described in Section 2.2, MDE evaluates whether a waterbody meets PCB related WQSs via 1) the use of the tPCB Integrated Report fish tissue listing threshold (39 ng/g, or ppb), 2) for PCBs in the water column, the human health tPCB water column criterion (0.64 ng/L, or ppt) and the fresh and saltwater chronic tPCB criteria for protection of aqutic life (14 ng/L and 30 ng/L, or ppt, respectively), or 3) for PCBs in sediments, the tPCB ERM (180 ng/g, or ppb), if there is toxicity present and a degraded benthic community in the sediment. Since the Back River embayment was identified as impaired for PCBs in fish tissue, the overall objective of the tPCB TMDL established in this document is to ensure that the "fishing" designated use, which is protective of human health related to the consumption of fish, in the embayment is supported; however, this TMDL will also ensure the protection of all other applicable designated uses within the embayment.

Since the overall objective of the tPCB TMDLs for the Back River embayment is to ensure the support of the "fishing" designated use, the tPCB fish tissue listing threshold was translated into an associated tPCB water column threshold concentration (see Equation 3.1 and Calculation 3.1). This was done using the Adjusted Total Bioaccumulation Factor (Adj-tBAF) of 68,496 L/kg for the Back River embayment, the derivation of which follows the method applied within the

Potomac River PCB TMDLs (Haywood and Buchanan 2007). A total Bioaccumulation Factor (tBAF) is calculated per fish species, and subsequently the tBAFs are normalized by the median species lipid content and median dissolved tPCB water column concentration in their home range to produce the Adj-tBAF per species (see Appendix B for further details regarding the calculation of the Adj-tBAF). The most environmentally conservative of the Adj-tBAFs is then selected to calculate the TMDL endpoint water column concentration. This final water column tPCB concentration was then subsequently compared to the water column tPCB criteria concentrations, as described in Section 2.2, to ensure that all applicable criteria within the embayment would be attained (Calculation 3.1)..

tPCB Water Column Concentration = (tPCB Fish Tissue Concentration/
(Adj-tBAF × Unit Conversion)) (Equation 3.1)

Substituting 39 ng/g into the equation results in:

tPCB Water Column Concentration =
(39 ng/g ÷ (68,496 L/kg × 1,000 g/kg)) = 0.57 ng/L,
which is < 0.64 ng/L (human health tPCB water column criterion); and
< 14 ng/L (freshwater aquatic life chronic tPCB water column criteria); and
< 30 ng/L (saltwater aquatic life chronic tPCB water column criteria)
(Calculation 3.1)

Based on this analysis, the water column tPCB concentration and TMDL endpoint of 0.57 ng/L for the Back River embayment, derived from the tPCB fish tissue listing threshold, is less than both the human health water column tPCB criterion of 0.64 ng/L as well as the fresh and saltwater aquatic life chronic tPCB criteria of 14 ng/L and 30 ng/L, respectively.

Similarly, in order to establish a tPCB sediment concentration that is protective of the “fishing” designated use within the embayment, a tPCB sediment concentration was derived from the tPCB fish tissue listing threshold (see Equation 3.2 and Calculation 3.2) to apply within this analysis as the sediment TMDL endpoint concentration. This was done using the Adjusted Sediment Bioaccumulation Factor (Adj-SediBAF) of 5.6 (unitless) for the Back River embayment, the derivation of which follows the method applied within the Potomac River PCB TMDLs (Haywood and Buchanan 2007). Similar to the calculation of the Adj-tBAF, a sediment Bioaccumulation Factor (SediBAF) is calculated per fish species, and subsequently the SediBAFs are normalized by the median species lipid content and median organic carbon tPCB sediment concentration in their home range to produce the Adj-SediBAF per species (see Appendix B for further details regarding the calculation of the Adj-SediBAF). The most environmentally conservative of the Adj-SediBAFs is then selected to calculate the sediment TMDL endpoint tPCB concentration.

Though the ERM is sufficient for providing an official assessment (i.e., Integrated Report listing purposes) of PCB sediment impairments, since it provides reasonable certainty that concentrations above this threshold do in fact result in toxicity, concentrations below this threshold may still be representative of conditions that adversely impact benthic life, in some instances. Conversely, the SQG Threshold Effects Level (TEL) of 21.6 ng/g, or ppb, for PCBs in estuarine sediments indicates that concentrations below this threshold are highly unlikely to result in toxicity and will therefore be protective of benthic life. Thus, the final target sediment tPCB concentration was then subsequently compared to the tPCB TEL of 21.6 ng/g, since the endpoint concentration must be protective of benthic life within the Back River embayment, in order to address the specific sediment PCB impairment listing (Calculation 3.2).

tPCB Sediment Concentration = (tPCB Fish Tissue Threshold/
Adj-SediBAF) (Equation 3.2)

Substituting 39 ng/g into the equation results in:

tPCB Sediment Concentration = (39 ng/g ÷ 5.6) = 6.9 ng/g
which is < 21.6 ng/g (tPCB Sediment TEL) (Calculation 3.2)

Based on this analysis, the sediment tPCB concentration of 6.9 ng/g for the Back River embayment, derived from the tPCB fish tissue listing threshold, is less than the TEL of 21.6 ng/g. By establishing a TMDL endpoint for sediments protective of the "fishing" designated use in the embayment the benthic life in the Back River embayment will also be protected when this endpoint is achieved (i.e., the impairment listing for PCBs in sediment for the Back River embayment will be addressed).

The CWA, as recently interpreted by the United States District Court, requires TMDLs to be protective of all the designated uses applicable to a particular waterbody (US District Court for the District of Columbia 2011). In addition to the "fishing" designated use, the TMDL presented herein is also supportive of the other applicable designated uses within the embayment, as described in the Introduction to this report and Section 2.2. These include "water contact recreation", "the protection of aquatic life", and "marine and estuarine aquatic life and shellfish harvesting". Specifically, the TMDL is protective of the "aquatic life" designated use, in particular the protection of "marine and estuarine aquatic life and shellfish harvesting" and benthic aquatic life, since 1) the water column TMDL endpoint tPCB concentration is less than the saltwater aquatic life chronic criterion, and 2) the sediment TMDL endpoint tPCB concentration is less than the SQG TEL. Lastly, the designated use for "water contact recreation" is not associated with any potential human health risks due to PCB exposure. Dermal contact and consumption of water from activities associated with "water contact recreation" are not a significant pathway for the uptake of PCBs. The EPA human health criterion was developed solely based on organism consumption, as drinking water consumption does not pose any risk for cancer development at environmentally relevant levels. The only human health risk associated with PCB exposure is through the consumption of aquatic organisms, which is addressed by the water column and sediment endpoints applied within this TMDL developed to be supportive of the "fishing" designated use for the embayment.

4. SOURCES ASSESSMENT

PCBs do not occur naturally in the environment. Therefore, unless existing or historical anthropogenic sources are present, their natural background levels are expected to be zero. Although PCBs are no longer manufactured in the United States, they are still being released to the environment via accidental fires, leaks, or spills from PCB-containing equipment; potential leaks from hazardous waste sites that contain PCBs; illegal or improper dumping; and disposal of PCB-containing products (e.g., transformers, old fluorescent lighting fixtures, electrical devices or appliances containing PCB capacitors, old microscope oil, and old hydraulic oil) into landfills not designed to handle hazardous waste. Once in the environment, PCBs do not readily break down and tend to cycle between various environmental media such as air, water, and soil.

PCBs exhibit low water solubility, are moderately volatile, strongly adsorb to organics, and preferentially partition to upland and bottom sediments. The major fate process for PCBs in water is adsorption to sediment or other organic matter. Adsorption and subsequent sedimentation may immobilize PCBs for relatively long periods of time. However, desorption into the water column may also occur; PCBs contained in layers near the sediment surface may be slowly released over time, while concentrations present in the lower layers may be effectively sequestered from environmental distribution (RETEC 2002).

The linkage between the “fishing” designated use and PCB concentrations in the water column is via the uptake and bioaccumulation of PCBs by aquatic organisms. Bioaccumulation occurs when the combined uptake rate of a given chemical from food, water, and/or sediment by an organism exceeds the organisms’ ability to remove the chemical through metabolic functions, dilution, or excretion, resulting in excess concentrations of the chemical being stored in the body of the organism. Humans can be exposed to PCBs via consumption of aquatic organisms, which over time have bioaccumulated PCBs. Depending on the life cycle and feeding patterns, aquatic organisms can bioaccumulate PCBs via exposure to concentrations present in the water column (in dissolved and/or particulate form) and sediments, as well as from consumption of other organisms resulting in the biomagnification of PCBs within the food chain (RETEC 2002).

A simplified conceptual model of PCB fate and transport in the Back River embayment is diagramed in Figure 4. PCB sources, resulting primarily from historical uses of these compounds and potential releases to the environment as described above, include point and nonpoint sources. This section provides a summary of these existing nonpoint and point sources that have been identified as contributing PCB loads to the Back River embayment.

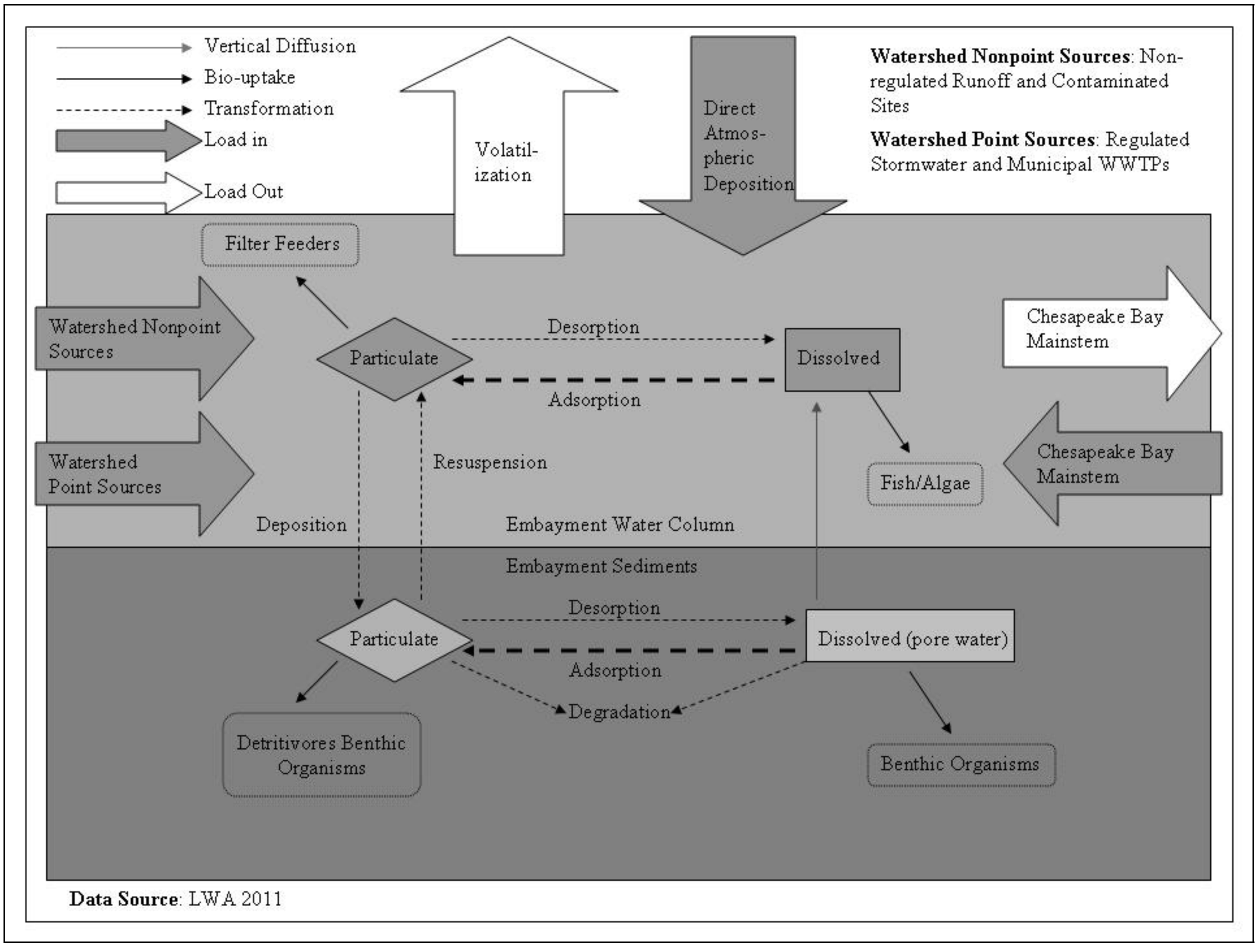


Figure 4: Conceptual Model of the Key Transport and Transformation Processes of PCBs in Surface Water and Bottom Sediments of the Back River Embayment and Entry Points to the Food Chain

4.1 Nonpoint Sources

For the purpose of this TMDL, under current conditions, the following nonpoint sources have been identified: direct atmospheric deposition to the embayment, runoff from non-regulated watershed areas, contaminated sites, tidal influence from the Chesapeake Bay mainstem, and resuspension and diffusion from bottom sediments.

Resuspension and Diffusion from Bottom Sediments

Because PCBs tend to bind to the organic carbon fraction of suspended sediment in the water column, which settles to the embayment floor, a large portion of the tPCB loads delivered from various point and non-point sources to the embayment will end up in the bottom sediments. This accumulation of PCBs can subsequently become a significant source of PCBs to the water column in the embayment via the disturbance and resuspension of sediments. Dissolved tPCB concentrations in sediment pore water will also diffuse to the water column. However, under current conditions, due to elevated particulate PCB concentrations resultant from PCB adsorption to the organic carbon component of suspended sediment in the water column, when compared to tPCB concentrations in the bottom sediment, there is a net transport of PCBs to the bottom sediment from the water column through settling and deposition. The tidal prism model, applying observed tPCB concentrations in the water column and sediment, predicts a net tPCB transport of 11,339.8 gram/year to the bottom sediment of the Back River embayment. Even if resuspension and diffusion from bottom sediments served as a source of PCBs to the water column it would still not be considered a directly controllable source (reducible), since the load contribution is resultant from other point and nonpoint source inputs (both historic and current) within the embayment's watershed.

Chesapeake Bay Mainstem Tidal Influence

The Back River embayment is highly influenced by tidal exchange of PCBs from the Chesapeake Bay mainstem. The tidal prism model, using observed tPCB concentrations measured at the mouth of the Back River embayment, predicts an estimated net tPCB transport of 7,262.9 g/year from the Back River embayment to the Chesapeake Bay mainstem. Thus, there is a net export of tPCBs from the Back River embayment to the Chesapeake Bay mainstem due to the higher water column concentrations inside the embayment. However, upon reductions to watershed loads, this net transport of PCBs out of the embayment and into the Bay mainstem could shift in the future. Even if this shift occurred though, the load contribution is resultant from historic and present point and nonpoint source inputs throughout the Upper Chesapeake Bay watershed, and it is therefore still not considered to be a directly controllable source (reducible).

Atmospheric Deposition

PCBs enter the atmosphere through volatilization. There is no recent study of the atmospheric deposition of PCBs to the surface of the Back River embayment. CBP's Atmospheric Deposition Study (US EPA 1999) estimated a net deposition of 16.3 micrograms/square meter/year ($\mu g/m^2$/year) of tPCBs for urban areas and a net deposition of 1.6 $\mu g/m^2$/year of tPCBs for regional (non urban) areas. In the Delaware River estuary, an extensive atmospheric deposition monitoring program found PCB deposition rates ranging from 1.3 (non urban) to 17.5 (urban) $\mu g/m^2$/year of tPCBs (DRBC 2003). The District of Columbia's Anacostia PCB TMDL (DC DOH 2003), while referencing CBP's Atmospheric Deposition Study, applied a net atmospheric deposition rate of 16.3 $\mu g/m^2$/year in that particular urbanized watershed. Since urban land use comprises the majority of the Back River embayment's watershed (87.4%, see Table 2), the 16.3 $\mu g/m^2$/year tPCB depositional rate for urban areas resultant from CBP's 1999 study is appropriate for the Back River embayment. Therefore, this value was used in the development of this TMDL. The direct atmospheric deposition load to the surface of the embayment of 267.8 g/year was calculated by multiplying the surface area of the Back River embayment (16.4 km^2) and the deposition rate of 16.3 $\mu g/m^2$/year.

Similarly, the atmospheric deposition load to the embayment's watershed can be calculated by multiplying 16.3 $\mu g/m^2$/year by the embayment's watershed area (total) of 141.8 km^2, which results in a load of 2,310.7 g/year. However, according to Totten et al. (2006), not all of the atmospherically deposited tPCB load to the terrestrial part of the watershed is expected to be delivered to the embayment. Applying the PCB pass-through efficiency estimated by Totten et al. (2006) for the Delaware River watershed of approximately 1%, the atmospheric deposition load to the Back River embayment from the watershed is approximately 23.1 g/year. This load is inherently captured in the non-regulated watershed runoff load estimation described in the section below. This load, however, is inherently modeled as part of the non-regulated watershed runoff/National Pollutant Discharge Elimination System (NPDES) Regulated Stormwater loads described below and in Section 4.2.

Non-regulated Watershed Runoff

From April 2008 to March 2009, MDE collected monthly water column samples for PCB analysis at one non-tidal monitoring station in the Herring Run tributary draining to the Back River embayment (See Appendix C). Additionally, flow information from the closest USGS gage (USGS 1585200) was obtained for each sample date, and the average daily flow was calculated. A tPCB load for each sample was then calculated based on the observed tPCB concentration and average daily flow, and the relationship between loads and flows was developed via regression analysis for the monitoring station. With this relationship, the tPCB load corresponding to any flow can be estimated. A watershed load time series was then calculated using this relationship and the flow time series from CBP's Phase 5 watershed model output for the model segments within the Back River embayment's watershed. The load calculation is described in further detail in Appendix C.

The non-regulated watershed runoff tPCB load only corresponds to the non-urbanized areas (i.e., primarily forest and wetland areas) of the Back River embayment's watershed. The load associated with the urbanized area of the embayment's watershed represents the NPDES Regulated Stormwater tPCB baseline load. The breakout between the non-regulated watershed runoff tPCB load and the NPDES Regulated Stormwater tPCB baseline load is described in more detail in Section 4.2. The non-regulated watershed runoff tPCB baseline load to the Back River embayment is 65.7 g/year.

About 23.1 g/year of the Back River embayment watershed's baseline load is attributed to atmospheric deposition to the land surface of the watershed, and is inherently captured within the total watershed baseline load of 522.1 g/year.

Contaminated Sites

The term contaminated site used throughout this report refers to areas with known PCB soil contamination, as documented by state or federal hazardous waste cleanup programs (i.e., state or federal Superfund programs). When compared against the human health screening criteria for soil and groundwater exposure pathways, PCBs are not necessarily a contaminant of concern at these sites, but they have been screened for, reported, and detected during formal site investigations. A total of five contaminated sites have been identified within the Back River embayment's watershed. Table 4 provides information on these sites, and Figure 5 depicts their locations.

The list of sites has been compiled based on information gathered from the EPA's Superfund database and MDE's Land Restoration Program Geospatial Database (LRP-MAP) (US EPA 2011; MDE 2011c). Five sites have been identified with PCB soil concentrations at or above method detection levels, as determined via soil sample results contained within MDE Land Management Administration's (LMA) contaminated site survey and investigation records. The median tPCB concentration of the site samples was multiplied by the soil loss rate, which is a function of soil type, pervious area, and land cover, to estimate the tPCB edge of field (EOF) load. Since all of the sites were immediately adjacent to the tidal embayment, a sediment delivery ratio of one was applied, and as a result the final edge-of-stream (EOS) load is equivalent to the final EOF load.

The contaminated site tPCB baseline load is estimated to be 12.8 g/year. This load is the summation of individual PCB loads from the five identified contaminated sites within the Back River embayment's watershed. Three of these sites have already undergone some degree of soil remediation, in which case the estimated tPCB load is reflective of post remediation PCB soil levels. A more detailed description of the methodology used to estimate the contaminated site tPCB baseline load is presented in Appendix I.

Table 4: Summary of Contaminated Site tPCB Baseline Loads

Site Name	Jurisdiction	Site Description	Area (acres)	EOS Load (g/year)
68th Street Dump	Baltimore County	Moderate Soil Remediation[1]	101.1	7.09
Keywell Property	Baltimore County	No Soil Remediation[2]	36.6	2.95
Industrial Enterprises	Baltimore County	Moderate Soil Remediation	89.6	1.06
Colgate Dump	Baltimore City and Baltimore County	Moderate Soil Remediation[1]	36.8	0.79
Sauer Dump	Baltimore County	No Soil Remediation	6.3	0.87
Total			**270.4**	**12.8**

Notes: [1] Moderate soil remediation conducted during highway construction.
[2] Soil remediation was conducted at the site but not in the area of PCB contamination

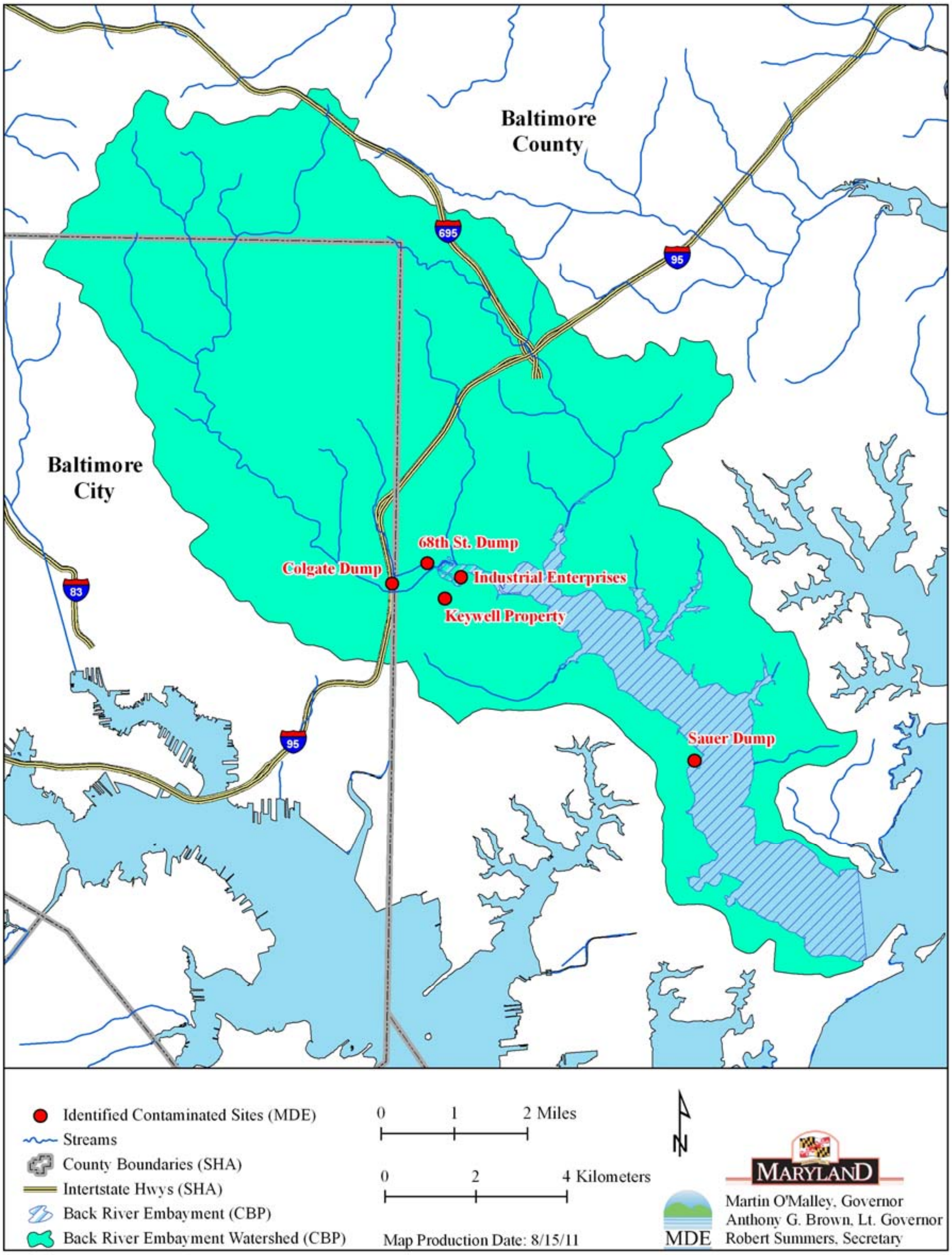


Figure 5: Location of Contaminated Sites in the Back River Embayment's Watershed

4.2 Point Sources

Point Sources in the Back River embayment's watershed include one waste water treatment plant (WWTP) and stormwater discharges that are regulated under Phase I and Phase II of the NPDES stormwater program.

Industrial process water facilities are included in Maryland's PCB TMDL analyses if 1) they are located within the applicable watershed, and 2) they have the potential to discharge PCBs. One facility was identified using guidance developed by Virginia (VA) for monitoring point sources in support of TMDL development. As per VA's guidance, specific types of industrial and commercial operations are more likely than others to discharge PCBs based on historic or current activities. The State identified specific types of permitted industrial and municipal facilities based on their Standard Industrial Classification (SIC) codes as having the potential to contain PCBs within their process water discharge (VADEQ 2009). This methodology has been applied within several of VA's PCB TMDLs, which have been approved by the EPA, such as the Roanoke (Staunton) River watershed PCB TMDL (VADEQ 2010). One industrial process water facility with an SIC code defined in the VA guidance as having the potential to discharge PCBs was identified within the Back River embayment's watershed. However, the facility was considered *de minimis* under this analysis, as its average flow was below 1 Million Gallons per Day (MGD).

The Department applies EPA's requirement that "stormwater discharges that are regulated under Phase I or Phase II of the NPDES stormwater program are point sources that must be included in the Wasteload Allocation (WLA) portion of a TMDL" (US EPA 2002). Phase I and II permits can include the following types of discharges:

- Small, medium, and large Municipal Separate Storm Sewer Systems (MS4s) – these can be owned by local jurisdictions, municipalities, and state and federal entities (e.g., departments of transportation, hospitals, military bases);
- Industrial facilities permitted for stormwater discharges; and
- Small and large construction sites.

A list of all the NPDES regulated stormwater permits within the Back River embayment's watershed that could potentially convey PCB loads to the embayment is presented in Appendix J. This section provides detailed explanations regarding the calculation of the point source tPCB baseline loads.

<u>Municipal WWTPs</u>

Back River WWTP (NPDES: MD0021555) is the only municipal WWTP that has been identified within the Back River embayment's watershed. The facility contains two outfalls, 001A and 002A. Effluent from Outfall 002A is sent to the RG Steel industrial facility, located in the Baltimore Harbor Maryland 8-Digit (MD 8-Digit) watershed, for use in its plant processes and will therefore not be included in this analysis. Outfall 001A was sampled by MDE in March and May of 2006 for PCB analysis. The baseline tPCB loading was calculated based on the average discharge flow for the period of March 2010 through February 2011 and the average observed tPCB effluent concentration. The estimated tPCB baseline load for outfall 001A is

133.2 g/year. Figure 6 depicts the location of the municipal WWTP, and Table 4 provides information on the data used in calculating the tPCB baseline load.

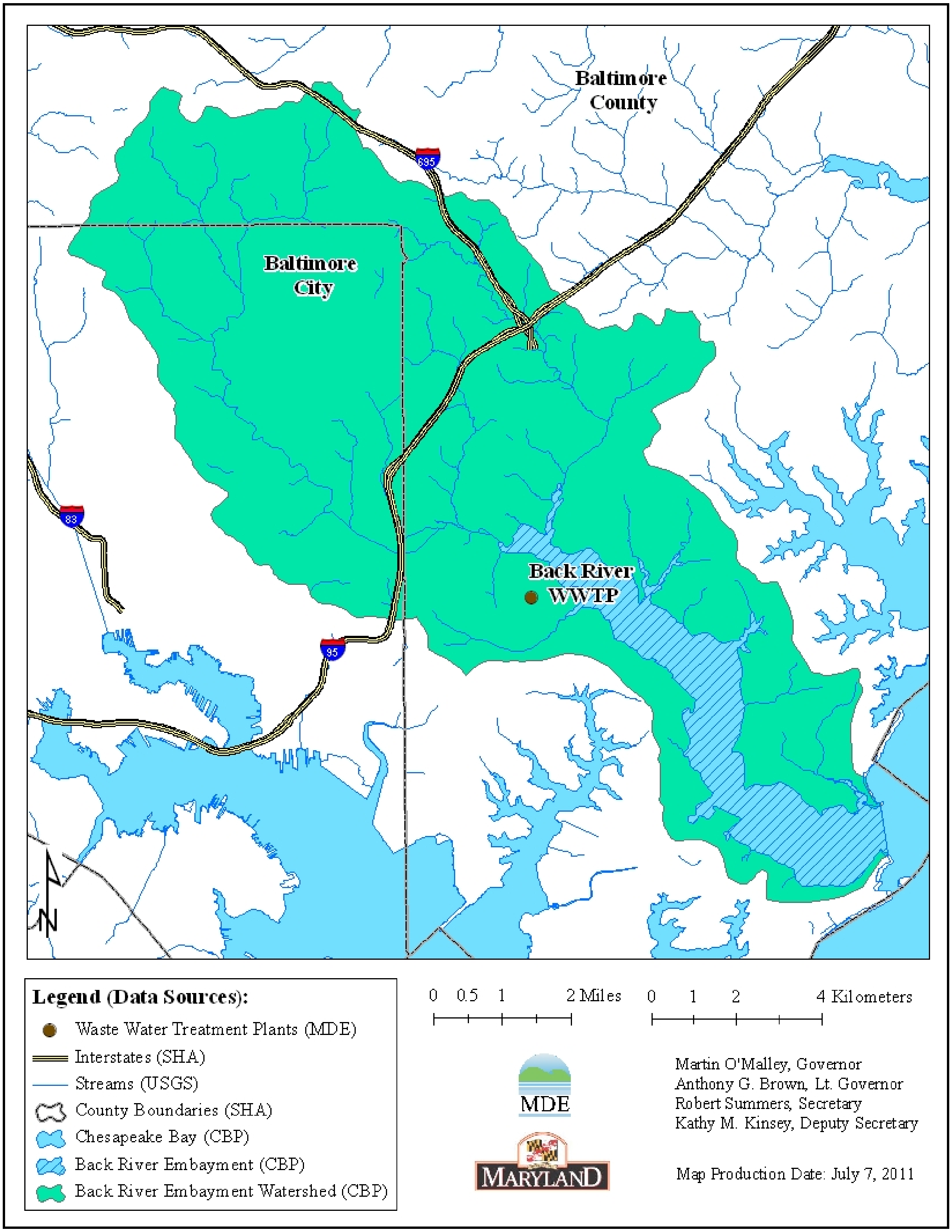


Figure 6: Location of Municipal WWTP in the Back River Embayment's Watershed

Table 5: Summary of Municipal WWTP tPCB Baseline Loads

Facility Name	NPDES #	Jurisdiction	Outfall	Average Concentration (ng/L)	Average Flow (MGD)	tPCB Baseline Load (g/day)	tPCB Baseline Load (g/year)
Back River WWTP	MD002155	Baltimore County	001A	0.906	106	0.365	133.2

NPDES Regulated Stormwater

MDE estimates pollutant loads from NPDES regulated stormwater areas based on urban land use classification within a given watershed. The 2006 USGS spatial land cover, which was used to develop CBP's Phase 5.3.2 watershed model land use, was applied in this TMDL to estimate the NPDES Regulated Stormwater tPCB Baseline Load.

The Back River embayment's watershed spans a portion of Baltimore County and Baltimore City, Maryland. The NPDES stormwater permits within the Back River embayment's watershed include: (i) the area covered under Baltimore County and Baltimore City's Phase I jurisdictional MS4 permit, (ii) the State Highway Administration's Phase I MS4 permit, (iii) and state and federal general Phase II MS4's, (iv) industrial facilities permitted for stormwater discharges, and (v) construction sites (see Appendix J for a list of all NPDES regulated stormwater permits).

The NPDES Regulated Stormwater tPCB Baseline Load was estimated by multiplying the percentage of urban land use (i.e., residential, commercial, open urban, industrial and institutional land use classifications) within the Back River embayment's watershed by the total watershed baseline load. The remainder of the total watershed baseline load is associated with the non-regulated watershed runoff tPCB baseline load (nonpoint source load described in Section 4.1). Since the identified contaminated sites are located within the urban land use area, their total load of 12.8 g/year is subtracted giving a final NPDES Regulated Stormwater tPCB baseline load of 443.6 g/year. Table 6 lists the aggregate NPDES Regulated Stormwater tPCB Baseline Load, subdivided by jurisdiction (Baltimore County and Baltimore City).

Table 6: Summary of NPDES Regulated Stormwater tPCB Baseline Load

Jurisdiction	tPCB Baseline Load (g/year)[1]
Baltimore County	273.7
Baltimore City	169.9
Total	**443.6**

Note: [1] The load per jurisdiction represents an aggregation of loads from all of the permitted stormwater entities within the jurisdiction.

4.3 Source Assessment Summary

From this source assessment all point and nonpoint sources of PCBs to the Back River embayment have been identified and characterized. Nonpoint sources include direct atmospheric deposition to the embayment, identified contaminated sites, runoff from non-regulated watershed, resuspension and diffusion from bottom sediments, and the tidal influence from the Chesapeake Bay mainstem. Point sources include a WWTP and NPDES regulated stormwater runoff. An additional industrial facility with the potential to discharge PCBs to the embayment was also identified; however, it was considered *de minimis*, since its average flow was less than 1.0 MGD. Estimated tPCB loads from these point and nonpoint sources represent the baseline conditions for the embayment.

A summary of the tPCB baseline loads for the Back River embayment is presented in Table 7. As explained in Section 4.1, since 1) resuspension and diffusion from bottom sediments and the tidal influence from the Chesapeake Bay mainstem do not contribute tPCB loads to the embayment under current conditions and 2) these sources are not considered to be directly controllable (reducible) within the framework of this TMDL, they are not included in the tPCB baseline load summary.

Table 7: Summary of tPCB Baseline Loads in the Back River Embayment

Source	Baseline Load (g/year)	Percent of Total Baseline Load (%)
Direct Atmospheric Deposition	267.8	29.0
Non-regulated Watershed Runoff	65.7	7.1
Contaminated Sites	12.8	1.4
Nonpoint Sources	***346.3***	***37.5***
WWTP	133.2	14.4
NPDES Regulated Stormwater[1]		
Baltimore County	273.7	29.7
Baltimore City	169.9	18.4
Point Sources	***576.8***	***62.5***
Total	**923.1**	**100.0**

Notes: [1] Load per jurisdiction applies to all NPDES stormwater dischargers within the jurisdiction's portion of the watershed draining to the Back River embayment. These dischargers are identified in Appendix J.

5. TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATION

5.1 Overview

A TMDL is the total amount of an impairing substance that a waterbody can receive and still meet WQSs. The TMDL may be expressed as a mass per unit time, toxicity, or other appropriate measure and should be presented in terms of WLAs, load allocations (LAs), and either an implicit or explicit margin of safety (MOS) (CFR 2011a):

$$\text{TMDL} = \text{WLAs} + \text{LAs} + \text{MOS} \qquad \text{(Equation 5.1)}$$

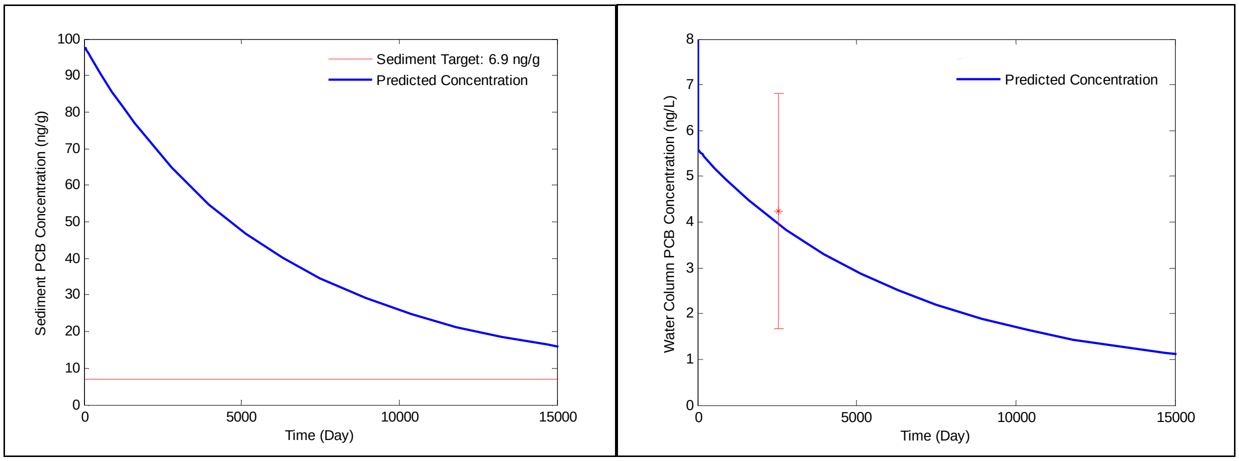
This section describes how the tPCB TMDL and the corresponding LAs and WLAs have been developed for the Back River embayment. The analysis framework for simulating PCB concentrations is described in Section 5.2. Section 5.3 addresses critical conditions and seasonality, and Section 5.4 presents the allocation of loads between point and nonpoint sources. The MOS and model uncertainties are discussed in Section 5.5, and the TMDL is summarized in Section 5.6.

5.2 Analysis Framework

A tidal prism model that incorporates the influences of both freshwater inputs and tidal flushing was used to simulate the dynamic interactions between the water column and bottom sediments within the Back River embayment and the Chesapeake Bay mainstem (MDE 2005; Kuo et al. 2005). Within the Back River embayment, the tidal exchange with the Chesapeake Bay mainstem, freshwater inputs, exchanges with the atmosphere due to deposition and volatilization, and the exchange with the bottom sediments through diffusion, resuspension, and settling are the dominant processes affecting the transport of PCBs in the water column. The burial of PCBs to deeper inactive layers of sediment and exchanges at the sediment-water column interface (through diffusion, resuspension, and settling) are the dominant processes affecting the transport of PCBs in the bottom sediments. A detailed description of the model is presented in Appendices D and E.

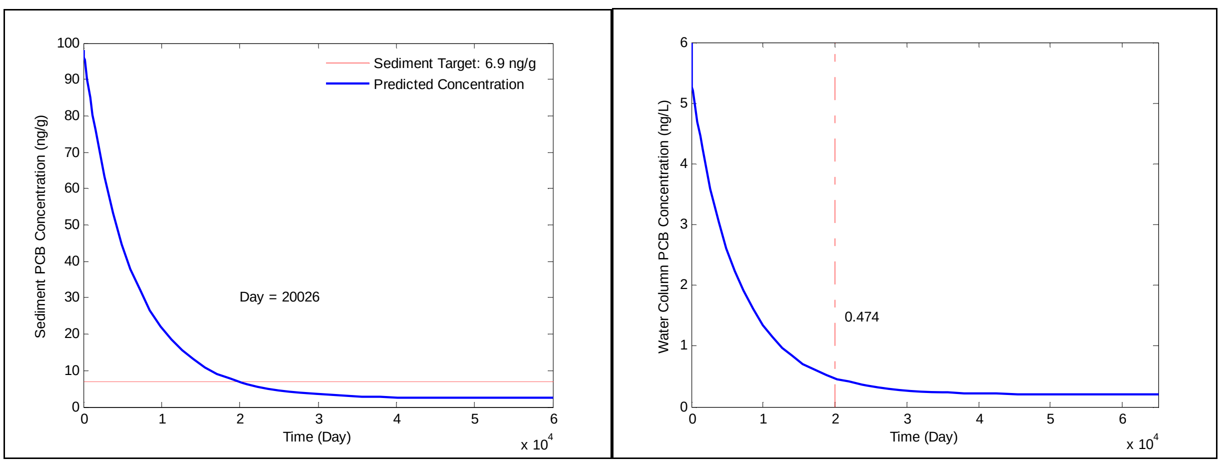
The mean 2001 observed tPCB concentrations in the water column and sediment were used to characterize initial (baseline) model conditions. Relative to the tidal influence from the Chesapeake Bay mainstem and Upper Chesapeake Bay, the Susquehanna River is the major freshwater input, and as a result the major source of PCBs, to the upper Bay (Ko and Baker 2004). In order to determine the temporal changes in tPCB loads from the Susquehanna River to the Upper Chesapeake Bay, Ko and Baker (2004) measured tPCB concentrations downstream of the Susquehanna River and compared their results with those reported by Foster et al. (2000) and Godfrey et al. (1995). According to this analysis, flow normalized tPCB loads decreased from 37 kg/m^3/year in 1992 to 24 kg/m^3/year in 1998. Based on these results, it is estimated that on average the tPCB concentrations in the Upper Chesapeake Bay are decreasing at a rate of 6.5% per year. Since inflow from the Susquehanna River dominates the freshwater input to the upper Chesapeake Bay, it is reasonable to assume that tPCB concentrations in the upper Bay are decreasing as well. A comparison of tPCB water column data collected between 2001 and 2008 near the mouth of the Back River embayment confirms that tPCB concentrations have in fact declined. The average tPCB water column concentrations from stations near the boundary in 2001 and 2008, are 6.3 ng/L and 2.2 ng/L, respectively. Due to the interactions between the water column and bottom sediments and additional sources from lateral adjacent watersheds, however, the PCB attenuation rate near the mouth of the Back River embayment may deviate from the estimated 6.5% decrease that has been observed in the Susquehanna River and upper Chesapeake Bay. Freshwater flow from the Susquehanna River will only account for a portion of the water that transports across the boundary of the Back River embayment under tidal influence Thus, as a conservative estimate, it was assumed within this analysis that boundary condition tPCB concentrations between the Back River embayment and the Chesapeake Bay mainstem will decrease at a rate of 5%, following the current trend observed in the upper Chesapeake Bay but taking into consideration specific conditions within the embayment. Figure 7 depicts the model predicted time series of sediment and water column tPCB concentrations. The time series applies 2001 tPCB water column and sediment concentrations within the Back River embayment and tidal boundary with the Chesapeake Bay mainstem as the initial conditions. The mean observed water column tPCB concentrations from 2008-2009 are used to validate the model. All other factors (i.e., freshwater inputs, tidal exchange rates, bottom sediment and water column exchange rates, and burial rates) were kept constant. Comparison of the model predicted tPCB concentrations to the observed tPCB 2008 concentrations demonstrates that the model is reasonably accurate, since the predicted concentrations fell within the range of the mean of the 2008 observed concentrations, plus/minus one standard deviation (see Figure 7). Considering the high variation of PCB concentrations within the embayment, it was concluded that the model results were acceptable.

As previously discussed, assuming that water column tPCB concentrations decrease at a rate of 5.0% per year at the tidal boundary of the embayment with the Chesapeake bay mainstem, it will take approximately 50 years for the water column tPCB concentration near the mouth of the Back River embayment to meet the TMDL endpoint. Thus, it is reasonable to use 50 years as an approximate time frame for achieving the TMDL. Different model simulation scenarios were conducted by reducing point and nonpoint source loads, while assuming that the boundary tPCB concentrations will decrease exponentially at a rate of 5.0% per year. The simulation results show that with a 52.5% reduction for all watershed sources (i.e., non-regulated watershed runoff and NPDES regulated stormwater), with slight variations in the regulated stormwater due to the locations of contaminated sites, as well as a 40.3% reduction from atmospheric deposition, it will take approximately 54.9 years (20,026 days) for the Back River embayment to meet the TMDL endpoints and thus be supportive of the "fishing" designated use (see Figure 8). However, the time required to reach the TMDL endpoint will depend on the selection of the initial conditions. In order to assess the effect of varying the baseline conditions on the time required to achieve the TMDL, the upper and lower bounds of the 95% confidence interval (CI) around the mean water column tPCB concentration were estimated and applied in the analysis. The time required to reach the TMDL endpoints increased by about 20% (11 years) when the higher tPCB water column concentration was used as the baseline condition. Results of the CI analysis are presented in Appendix G.



Note: Red asterisk and brackets in water column graph denote the 2008 mean observed tPCB concentration plus/minus one standard deviation.

Figure 7: Change of Average Water Column and Bottom Sediment tPCB Concentrations Over Time Within the Back River Embayment (Natural Attenuation Only)



Note: The dashed red line in the water column graph represents what the water column concentration will be within the embayment when the sediment TMDL endpoint concentration is achieved, which is lower than the water column endpoint.

Figure 8: Change of Average Water Column and Bottom Sediment tPCB Concentrations Over Time Within the Back River Embayment (Watershed Load Reductions Applied)

5.3 Critical Condition and Seasonality

Federal regulations require TMDL analysis take into account the impact of critical conditions and seasonality on water quality (CFR 2011b). The intent of this requirement is to ensure that water quality is protected during the most vulnerable times.

The TMDL is protective of human health at all times; thus, it implicitly accounts for seasonal variations as well as critical conditions. Since PCB levels in fish tissue become elevated due to long-term exposure it has been determined that the selection of the annual average tPCB water column and sediment concentrations for comparison to the endpoints applied within the TMDL adequately considers the impact of seasonal variations and critical conditions on the "fishing" designated use in the Back River embayment. Furthermore, the water column tPCB TMDL endpoint is lower than the current human health criterion for fish consumption. The water column TMDL endpoint tPCB concentration also is more protective of water quality than the freshwater and saltwater chronic criteria tPCB concentrations, which are necessary to protect aquatic life. In addition, the sediment TMDL endpoint tPCB concentration is also lower, and thus more conservative, than the TEL, which is protective of benthic aquatic life.

5.4 TMDL Allocations

All TMDLs need to be presented as a sum of WLAs for point sources and LAs for nonpoint source loads generated within the assessment unit, and if applicable LAs for the natural background, tributary, and adjacent segment loads (CFR 2011b). The State reserves the right to revise these allocations provided the revisions are consistent with achieving WQSs. The allocations described in this section summarize the tPCB TMDL established to meet the "fishing" designated use in the Back River embayment.

5.4.1 Wasteload Allocations

Municipal WWTPs

Back River WWTP (NPDES: MD0021555) is the only municipal WWTP that has been identified within the Back River embayment's watershed. The facility has two outfalls, 001A and 002A. Effluent from outfall 002A is sent to the RG Steel industrial facility, located in the Baltimore Harbor MD 8-Digit watershed, for use in its plant processes and will therefore not be incorporated in this analysis. The estimated tPCB baseline loading for outfall 001A is 133.2 g/year, which was calculated based on the average discharge flow for the period of March 2010 through February 2011 and the average observed tPCB effluent concentration. Since, 1) WWTP allocations in Maryland's PCB TMDLs are calculated as facility design flow multiplied by the water column TMDL endpoint tPCB concentration for the applicable waterbody, and 2) the effluent from outfall 002A will eventually discharge to the Baltimore Harbor via the RG Steel industrial facility, the tPCB load from this outfall must comply with the water column TMDL endpoint tPCB concentration applied within the Baltimore Harbor PCB TMDL of 0.27 ng/L (MDE 2011d). This water column TMDL endpoint tPCB concentration is lower than the endpoint concentration applied within this analysis of 0.57 ng/L. Since there is only one waste stream from the Back River WWTP, it is not possible to provide two different levels of treatment for the two separate outfalls at the facility. Thus, the WLA for outfall 001A was calculated by multiplying the water column TMDL endpoint tPCB concentration of 0.27 ng/L from the Baltimore Harbor PCB TMDL by the design flow for the WWTP allocated to the outfall (130 MGD). The WLA for outfall 001A is 48.5 g/year. The WLA is presented in Table 8. Under current conditions, the WLA is lower than the tPCB baseline loading, resulting in a load reduction to the facility. The elevated tPCB concentrations in wastewater are believed to be primarily due to external sources (e.g., source water, atmospheric deposition, and stormwater runoff) infiltrating the waste water collection system through broken sewer lines and connections. There are currently no effluent PCB limits established in the discharge permits for the Back River WWTP. Inclusion of a WLA in this document does not reflect any determination to impose an effluent limit in a future permit.

Table 8: Summary of Municipal WWTP tPCB WLA, Baseline Load, and Load Reduction

Facility Name	NPDES #	Outfall	tPCB Water Column TMDL Endpoint (ng/L)	Design Flow (MGD)	tPCB WLA (g/year)	tPCB Baseline Load (g/year)	tPCB Reduction (%)
Back River WWTP	MD002155	001A	0.27	130.0	48.5	133.2	63.6

Further characterization of the municipal WWTP baseline load will need to be conducted through the NPDES permitting implementation process, since the current load estimation is based on limited tPCB data from the plant's effluent. With additional information, along with current WWTP Enhanced Nutrient Removal (ENR) upgrades, more accurate tPCB loads from these facilities can be estimated, which may result in a change to the overall reduction.

Congener specific analytical methods should be used when collecting any future samples from this municipal WWTP. Ideally, the most current version of EPA Method 1668 should be used, or other equivalent methods capable of providing low-detection level, congener specific results. Other methods deemed appropriate, and approved in advance by the permitting authority, could also be used. In establishing the necessity and extent of data collection, MDE will take into account data that is already available as well as the proper characterization of intake (or pass through) conditions, consistent with NPDES program "reasonable potential" determinations and the applicable provisions of the Environment Article and the Code of Maryland Regulations (COMAR) for permitted facilities, including NPDES regulated stormwater.

Relative to industrial process water facilities, these facilities are included in Maryland's PCB TMDL analyses if 1) they are located within the applicable watershed, and 2) they have the potential to discharge PCBs. One facility was identified within the embayment's watershed using this criteria, which is explained in full detail in Section 4.2; however, the facility was considered *de minimis* in terms of this analysis, since its average flow was below 1 MGD. Therefore, any potential baseline loading from the facility was not factored into the analysis, and no WLA will be assigned.

NPDES Regulated Stormwater

Per EPA Requirements, "stormwater discharges that are regulated under Phase I or Phase II of the NPDES stormwater program are point sources that must be included in the WLA portion of a TMDL".EPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (US EPA 2002). Therefore, NPDES regulated stormwater allocations to the Back River embayment will be expressed as a single, aggregate WLA for each county (or local political jurisdiction, i.e., Baltimore City). Upon approval of the TMDL, "NPDES-regulated municipal storm water and small construction storm water discharges effluent limits should be expressed as Best Management Practices (BMPs) or other similar requirements, rather than as numeric effluent limits" (US EPA 2002).

The NPDES Regulated Stormwater WLA was established by reducing the NPDES Regulated Stormwater Baseline Loads proportionally to the Non-regulated Watershed Runoff Baseline Load, after the WLAs for the remaining source sectors were set, until the TMDL was achieved. For more information on methods used to calculate the NPDES Regulated Stormwater PCB Baseline Load, please see Section 4.2. The NPDES Regulated Stormwater WLA may include any or all of the NPDES stormwater discharges listed in Section 4.2 (see Appendix J for a complete list of stormwater permits within the Back River embayment's watershed). As stormwater assessment and/or other program monitoring efforts result in a more refined source assessment, MDE reserves the right to revise the current NPDES Regulated Stormwater WLA provided the revisions are protective of the "fishing" designated use in the Back River embayment.

The NPDES Regulated Stormwater Baseline Load to the Back River embayment constitutes a large portion of the total baseline load to the embayment, and it therefore requires a 52.7 % reduction, with slight variations due to the locations of the contaminated sites. The NPDES Regulated Stormwater WLA for the Back River embayment is 167.6 g/year. Table 9 lists the aggregate NPDES Regulated Stormwater WLA subdivided by jurisdiction (Baltimore County and Baltimore City).

Table 9: Summary of the NPDES Regulated Stormwater tPCB Baseline Load, WLA, and Load Reduction

Jurisdiction	**tPCB Baseline Load (g/year)**	**tPCB WLA (g/year)**	**tPCB Reduction (%)[1]**
Baltimore County	273.7	127.6	53.4
Baltimore City	169.9	82.3	51.6
Total	**443.6**	**209.9**	**52.7**

Note: [1] The load per jurisdiction represents an aggregation of loads from all of the permitted stormwater entities within the jurisdiction.

5.4.2 Load Allocations

LAs have been assigned to the following nonpoint sources in order to meet the "fishing" designated use in the Back River embayment: direct atmospheric deposition to the surface of the embayment and non-regulated watershed runoff. The model results show that in order to meet the "fishing" designated use in the embayment, the TMDL requires load reductions of 40.3% from atmospheric deposition and 52.5% from non-regulated watershed runoff. A smaller reduction for atmospheric deposition is required since it has a much smaller impact on water quality than the watershed land sources. Given that a number of contaminated sites have already undergone some degree of remediation and their baseline loads constitute a relatively small percentage of the Total Baseline Load to the embayment (1.4%), these sites were currently not subjected to any reductions. Loads from resuspension and diffusion from bottom sediments and the tidal influence from the Chesapeake Bay mainstem were included in the model in order to predict tPCB concentrations within the embayment; however, they are not deemed to be directly controllable within the framework of the TMDL. Therefore, these sources will not be assigned an allocation or a required reduction. These loads are expected to reduce over time via natural attenuation as evidenced by the observed decrease in tPCB concentrations in both the Upper Chesapeake Bay and at the tidal boundary between the embayment and the Bay mainstem.

5.5 Margin of Safety

All TMDLs must include a MOS to account for the lack of knowledge and the many uncertainties in the understanding and simulation of water quality parameters in natural systems (i.e., the relationship between modeled loads and water quality). The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection. Uncertainty within the model framework includes the estimated rate of decline in tPCB concentrations within the upper Chesapeake Bay as well as the initial condition of mean tPCB concentrations that was selected for the Back River embayment. A model sensitivity analysis was conducted using the 95% CI's as the initial condition to determine the influence on recovery time for achieving the TMDL endpoints supportive of the "fishing" designated use. Further explanation of this analysis is found in Section 5.2 and Appendix G. In order to account for these uncertainties, MDE applied an explicit 5% MOS, in order to provide an adequate and environmentally protective TMDL.

5.6 TMDL Summary

Table 10 summarizes the tPCB baseline loads, TMDL allocations, load reductions, and maximum daily loads (MDLs) (see Appendix H for further details regarding MDL calculations) for the Back River embayment.

Table 10: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in the Back River embayment

Source	Baseline Load (g/year)	Percent of Total Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Direct Atmospheric Deposition	267.8	29.0	160.0	40.3	1.09
Non-regulated Watershed Runoff	65.7	7.1	31.2	52.5	0.21
Contaminated Sites	12.8	1.4	12.8	0.0	0.09
Nonpoint Sources/LAs	***346.3***	***37.5***	***204.0***	***41.1***	***1.39***
WWTP	133.2	14.4	48.5	63.6	0.41
NPDES Regulated Stormwater[1]					
Baltimore County	273.7	29.7	127.6	53.4	0.87
Baltimore City	169.9	18.4	82.3	51.6	0.56
Point Sources/WLAs	***576.8***	***62.5***	***258.4***	***55.2***	***1.84***
MOS (5%)	***-***	***-***	***24.3***	***-***	***0.17***
Total	**923.1**	**100.0**	**486.7**	**47.3**	**3.40**

Notes: [1] Load per jurisdiction applies to all NPDES stormwater dischargers within the jurisdiction's portion of the watershed draining to the Back River embayment. These dischargers are identified in Appendix J.

6 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurance that the tPCB TMDLs for the Back River embayment will be achieved and maintained. As discussed in the previous sections, assuming a future decrease in watershed loads and loads, resuspension and diffusion from bottom sediments and loads from he tidal influence of the Chesapeake Bay mainstem could be a significant source of PCBs to the embayment in the future; however, currently, neither of these currently serve as a source of PCBs to the embayment, nor is either source considered to be directly controllable within the framework of this TMDL.

The TMDL presented in this report calls for substantial reductions in PCB loads from diffuse sources present throughout the Back River embayment's watershed. Given that PCBs are no longer manufactured, and their use has been substantially restricted, it is reasonable to expect that with time PCB concentrations in the aquatic environment will decline. The Chesapeake Bay tidal influence and resuspension and diffusion from the bottom sediments will drive the recovery time of tPCBs within the water column and bottom sediments of the Back River embayment once reductions to watershed sources of PCBs are implemented. Observations show that the average tPCB concentration in the Upper Chesapeake Bay is decreasing at a rate of 6.5% per year (MDE 2009). No historical data is currently available to estimate the specific rate of decline at the boundary between the embayment and the bay mainstem; however, water quality data for sediments and the water column in the embaymnent from 2001 and 2008 demonstrate that PCB concentrations are declining over time (see Appendix K). The average tPCB water column concentrations from stations near the boundary in 2001 and 2008, are 6.3 ng/L and 2.2 ng/L, respectively. Thus, within this model, as a conservative estimate, a 5% rate of decline in tPCB concentrations at the boundary between the embayment and the Bay mainstem has been assumed, following the current trend in the Upper Bay but at the same time taking into consideration specific conditions within the embayment. Given this rate of decline, the tPCB levels in the Back River embayment are expected to decline over time due to natural attenuation, such as the burial of contaminated sediments with newer, less contaminated materials and biodegradation.

Aside from the processes of natural attenuation, there are two alternatives that can assist in reducing the tPCB concentrations in the water column so as to meet WQSs. First, the physical removal of the PCB-contaminated sediments (i.e., dredging) would minimize one of the primary, potential sources of tPCBs to the water column. In this particular situation, dredging is the least desirable alternative because of its potential biological destruction. It damages the habitat of benthic macroinvertebrates and may directly kill some organisms. The process of stirring up suspended sediments during dredging may damage the gills and/or sensory organs of benthic macroinvertebrates and fish. Suspended sediments can also affect the prey gathering ability of sight-feeding fish. In addition, the resuspension of contaminated sediments provides organisms with additional exposure to PCBs. In the case of the Back River embayment, natural attenuation is a better implementation method because it involves less habitat disturbance/destruction and is less costly. Second, should the net transport of tPCB loads at the boundary between the Back River embayment and the Chesapeake Bay mainstem shift, a reduction in Bay mainstem tPCB loads, which is expected due to the 6.5% yearly observed decline in the Upper Chesapeake Bay, would greatly accelerate the process of natural attenuation. Thus, discovering and remediating any existing PCB land sources throughout the Upper Chesapeake Bay watershed via future

TMDL development and implementation efforts will further help to meet water quality goals in the Back River embayment.

PCBs are still being released to the environment via accidental fires, leaks, or spills from older PCB-containing equipment; potential leaks from hazardous waste sites that contain PCBs; illegal or improper dumping; and disposal of PCB containing products (e.g., transformers, old fluorescent lighting fixtures, electrical devices, or appliances containing PCB capacitors, old microscope oil, and old hydraulic oil) into landfills that are not designed to handle hazardous waste. Therefore, natural attenuation and a reduction in loads from the Chesapeake Bay mainstem alone are not expected to completely eliminate the PCB impairment in the Back River embayment.

Due to the potential existence of unidentified sources of PCB contamination through the watershed and the significant load reductions required to meet the TMDL endpoints, achievement of these TMDLs may not be feasible by solely enforcing effluent limitations on known point sources and implementing BMPs on nonpoint sources. Therefore, an adaptive approach of implementation is anticipated, with subsequent monitoring to assess the effectiveness of the ongoing implementation efforts to manage potential risks to both recreational and subsistence fish consumers.

The success of the implementation process will depend in large part on the feasibility of locating and evaluating opportunities to control on-land PCB sources, such as unidentified contaminated sites, leaky equipment, and contaminated soil or sediment. A collaborative approach involving MDE and the identified NPDES permit holders as well as those responsible for nonpoint PCB runoff throughout the watersheds will be used to work toward attaining the WLAs and LAs presented in this report. The reductions will be implemented in an adaptive and iterative process, that will 1) identify specific sources, or areas of PCB contamination, within the embayment's watershed, and 2) target remedial action to those sources with the largest impact on water quality, while giving consideration to the relative cost and ease of implementation. The implementation efforts will be periodically evaluated, and if necessary, improved, in order to further progress toward achieving the water quality goals.

Any future monitoring should include congener specific analytical methods. Ideally, the most current version of EPA Method 1668 should be used, or other equivalent methods capable of providing low-detection level, congener specific results. In establishing the necessity and extent of data collection, MDE will collaborate with the affected stakeholders, and take into account data that is already available as well as the proper characterization of intake (or pass through) conditions, consistent with NPDES program "reasonable potential" determinations and the applicable provisions of the Environment Article and COMAR for permitted facilities.

Under certain conditions, EPA's NPDES regulations allow the use of non-numeric, BMP water quality based effluent limits (WQBELs). BMP WQBELs can be used where "numeric effluent limitations are infeasible; or the practices are reasonably necessary to achieve effluent limitations and standards or to carry out the purposes and intent of the CWA" (CFR 2011c). For example, MDE's Phase I MS4 permits require restoration targets for impervious surfaces (i.e., restore 10% or 20% of a jurisdiction's total impervious cover with no stormwater management/BMPs), and these restoration efforts have known total suspended solids (TSS) reduction efficiencies. Since PCBs are known to adsorb to sediments and their concentrations correlate with TSS concentrations, the significant restoration requirements in the MS4 permits, which will lead to a reduction in sediment loads entering the Back River embayment, will also contribute toward PCB load reductions and meeting PCB water quality goals. Other BMPs that focus on PCB source tracking and elimination at the source rather than end-of-pipe controls are also warranted. Due to this known relationship between TSS and PCB concentrations, implementation of the existing TMDLs for sediments and nutrients in the Back River Oligohaline Tidal Chesapeake Bay Segment's watershed (i.e., loads specified as part of the Chesapeake bay Nutrient and Sediment TMDLs) will further progress towards achieving the NPDES Regulated Stormwater WLAs, and additionally the nonpoint source LAs.

Where necessary, the source characterization efforts will be followed with pollution minimization and reduction measures that will include BMPs for reducing runoff from urban areas, identification and termination of ongoing sources (e.g., industrial uses of equipment that contain PCBs), etc. The identified NPDES regulated WWTP and stormwater control agency permits will be expected to be consistent with the WLAs presented in this report. Numerous stormwater dischargers are located in the Back River embayment's watershed including Municipal Phase I MS4, the SHA Phase I MS4, industrial facilities, State and Federal Phase II MS4s, and any construction activities on area greater than 1 acre (see Appendix H of this document to view the current list of known NPDES stormwater dischargers). The current Montgomery County Phase I MS4 permit already requires that the jurisdiction develops an implementation plan to meet its assigned NPDES Regulated Stormwater WLAs. Similar requirements are expected to be put in place in the future Baltimore County, Baltimore City, and Maryland SHA Phase I MS4 permits.

Subtitle 14 of the Environment Article within COMAR establishes the administrative procedures and standards for identifying, investigating, and remediating sites that have a release of, or imminent threat to release, hazardous substances to the environment. Specifically, Section 14.02.04 of the Article requires MDE to establish criteria for ranking these sites relative to their need for investigation and remediation (COMAR 2011e). MDE incorporates factors into the criteria that relate to the degree to which each site poses a risk to public health or the environment. Newly identified sites are placed on a list for tracking purposes.

Consistent with these requirements, MDE has developed a Hazard Ranking Model. The purpose of this model is to calculate a numerical hazard score based on information supplied from the following sources: 1) laboratory derived analytical data of environmental media samples taken at the site, 2) a comparison of the data to EPA based concentrations, and 3) information on natural resources located at the site or in close proximity to the site. Newly identified sites are investigated using EPA's Site Assessment Grant. This investigation determines whether the site qualifies for inclusion on the Federal Superfund list (US EPA 2011a), or instead, if it will be handled under State oversight. Sites that have no responsible party are investigated using State Capital Funds. Additionally, sites may also be investigated and subsequently remediated under the Voluntary Cleanup Program (VCP).

Given that a number of contaminated sites have already undergone some degree of remediation and their baseline loads constitute a relatively small percentage of the Total Baseline Load (1.3%), these sites are not intended to be targeted during the initial stages of implementation and thus at this point were not subjected to any reductions. However, if in the future it becomes clear that the TMDL goals cannot be achieved without load reductions from these sites, additional reduction measures might need to be considered.

Given the persistent nature of PCBs, the difficulty in removing them from the environment, and the significant reductions necessary in order to achieve water quality goals in the Back River embayment, effectiveness of the implementation effort will need to be reevaluated throughout the process to ensure progress is being made towards reaching the TMDLs. As part of Maryland's Watershed Cycling Strategy, follow-up monitoring and assessment will be routinely conducted to evaluate the implementation status. MDE also periodically monitors and evaluates concentrations of contaminants in recreationally caught fish, shellfish, and crabs throughout Maryland. MDE will use these monitoring programs to evaluate progress towards meeting the "fishing" designated use.

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Appendix A: List of Analyzed PCB Congeners

PCB analytical services were provided by UMCES. Specific PCB congeners were identified and quantified by high resolution gas chromatography with electron capture detection. UMCES uses a slightly modified version of the PCB congener specific method described in Ashley and Baker (1999), in which the identities and concentrations of each congener in a mixed Aroclor standard (25:18:18 mixture of Aroclors 1232, 1248, and 1262) are determined based on their chromatographic retention times relative to the internal standards (PCB 30 and PCB 204). Based on this method, 86 chromatographic peaks can be quantified (see Table A-1). Some of the peaks contain one PCB congener, while many are comprised of two or more co-eluting congeners. The PCB analysis presented in this document is based on tPCB concentrations that are calculated as the sum of the detected PCB congeners/congener groups representing the most common congeners that were historically used in the Aroclor commercial mixtures.

Table A-1: List of Analyzed PCB Congeners

1	45	110, 77	177
3	46	114	180
4, 10	47, 48	118	183
6	49	119	185
7, 9	51	123, 149	187, 182
8, 5	52	128	189
12, 13	56, 60	129, 178	191
16, 32	63	132, 153, 105	193
17	66, 95	134	194
18	70, 76	135, 144	197
19	74	136	198
22	81, 87	137, 130	199
24	82, 151	141	201
25	83	146	202, 171, 156
26	84, 92	157, 200	203, 196
29	89	158	205
31, 28	91	163, 138	206
33, 21, 53	97	167	207
37, 42	99	170, 190	208, 195
40	100	172	209
41, 64, 71	101	174	
44	107	176	

Appendix B: Derivation of Adj-tBAF and Adj-SediBAF

This appendix describes how the Adj-tBAF and Adj-SediBAF were derived. The method followed the Potomac River PCB TMDL (Haywood and Buchanan 2007).

I. Data Description

The observation-based Adj-tBAF and Adj-SediBAF were calculated for the fish species within the Back River embayment from the available fish tissue, water column, and sediment tPCB data. Each fish species was assigned a trophic level and a home range (see Table B-1). The Adj-tBAF and Adj-SediBAF were calculated based on the geometric mean tPCB concentrations of all the samples within the home range for each species.

Table B-1: Species Trophic Levels and Home Ranges

Common Name	Scientific Name	Trophic Level	Home Range (miles)
American Eel	*Anguilla rostrata*	Predator	5.0
Atlantic Menhaden	*Brevoortia tyrannus*	Benthivore-generalist	5.0
Brown Bullhead Catfish	*Ameiurus nebulosus*	Benthivore-generalist	5.0
Carp	*Cyprinus carpio*	Benthivore-generalist	2.0
Channel Catfish	*Ictalurus punctatus*	Benthivore-generalist	5.0
White Perch	*Morone americana*	Predator	10.0

II. Total BAFs

First, the tBAFs were calculated using Equation B-1 (US EPA 2003):

$$\text{tBAF} = \frac{[\text{tPCB}]_{\text{fish}}}{[\text{tPCB}]_{\text{Water}}} \qquad \text{(B-1)}$$

Where: $[\text{tPCB}]_{\text{fish}}$ = tPCB concentration in wet fish tissue (ng/kg)
$[\text{tPCB}]_{\text{water}}$ = water column tPCB concentration in fish species home range (ng/L)

III. Baseline BAFs

As the tBAFs vary depending on the food habits and lipid concentration of each fish species as well as the freely-dissolved tPCB concentrations in the water column, the baseline BAFs were calculated as recommended by US EPA (2000):

$$\text{Baseline BAF} = \frac{[\text{PCB}]_{\text{fish}} / \%\text{Lipid}}{[\text{PCB}]_{\text{Water}} \times \% fd} \qquad \text{(B-2)}$$

Where: %fd = fraction of the tPCB concentration in water that is freely-dissolved
%lipid = fraction of tissue that is lipid (if the lipid content was not available for a certain fish, the average lipid content of the whole ecosystem was used.)

The freely-dissolved tPCBs are those not associated with dissolved organic carbon (DOC) or particulate organic carbon (POC). The %fd can be calculated as (US EPA 2003):

$$\%\text{fd} = \frac{1}{1 + \text{POC} \times \text{K}_{\text{ow}} + \text{DOC} \times 0.08 \times \text{K}_{\text{ow}}} \qquad \text{(B-3)}$$

Where: K_{ow} is the PCB octanol-water partition coefficient, POC and DOC are the particulate and dissolved organic carbon concentrations in the water column.

The K_{ow} of PCB congeners have large ranges. Therefore, a %fd was calculated for each PCB homolog using the midpoint of the homolog's K_{ow} range [see Table B-2 (Hayward and Buchanan 2007)].

Table B-2: K_{ow} Values of Homologs Used in the Baseline BAF Calculation

Homolog	Midpoint K_{ow}
Mono+Di	47,315
Tri	266,073
Tetra	1,011,579
Penta	3,349,654
Hexa	5,370,318
Hepta	17,179,084
Octa	39,810,717
Nona	82,224,265
Deca	151,356,125

The %fd for tPCBs (PCB %fd) was derived by dividing the freely-dissolved PCB concentrations by the water column tPCB concentrations:

$$\text{PCB \%fd} = \frac{\sum(\text{Homolog \%fd} \times \text{Homolog Concentration})}{[\text{tPCB}]_{\text{water}}} \qquad \text{(B-4)}$$

The PCB %fd was used in Equation B-2 to calculate the baseline BAFs.

IV. Adjusted Total BAFs

The baseline BAFs were normalized by the species median lipid content and a single freely-dissolved PCB concentration (i.e., median %fd within the fish's home range) representative of the ecosystem, resulting in no variability attribution to differences in fish lipid content or freely-dissolved PCB concentration in the water column:

$$\text{Adj-tBAF} = (\text{Baseline BAF} \times \text{Median \% Lipid} + 1) \times \text{Median \%fd} \qquad \text{(B5)}$$

The tPCB fish tissue listing threshold of 39 ng/g can then be divided by the median Adj-tBAF for each species to translate an associated tPCB water column threshold concentration. The lowest tPCB water column concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the "fishing" designated use (Table 3). In the Back River embayment, the lowest concentration (0.30 ng/L) is associated with channel catfish. However, since channel catfish are benthivores and primarily feed in the sediment, it would be inappropriate to use this species value to establish the water column TMDL endpoint. Therefore, then next lowest value (American eel, 0.57 ng/L) was selected.

Table B-3: tBAF, Baseline BAF, Adj-tBAF, and Water Column tPCB Threshold Concentrations for Each Species

Species Name	Number of Fish	tBAF (L/kg)	Baseline BAF (L/kg)	Adj-tBAF (L/kg)	Median Fd (%)[1]	Median Lipid (%)	Water Column tPCB Threshold Concentration (ng/L)
Atlantic Menhaden	3	52,839	5,821,080	50,928	18.4	4.8	0.77
American Eel	8	87,820	3,552,616	68,496	19.0	10.5	0.57
Brown Bullhead Catfish	2	12,238	5,624,244	17,062	18.4	1.6	2.29
Channel Catfish	11	110,196	16,663,399	131,632	18.4	4.0	0.30
Common Carp	5	65,955	5,817,415	65,352	22.0	5.1	0.60
White Perch	21	53,840	13,374,718	59,156	22.1	2.0	0.66

Note: [1]Median value of the freely-dissolved percentage of the total tPCB concentration for water column samples within each fish's home range.

V. Biota-Sediment Accumulation Factors and Adjusted Sediment BAFs

The biota-sediment accumulation factors (BSAFs) were derived by the following equation:

$$BSAF = \frac{tPCB_{tissue} / \%\ Lipid}{tPCB_{sediment} / \%\ Oraganic\ Carbon} \quad \text{(B-6)}$$

where: % Organic Carbon is the species home range's average sediment organic carbon fraction.

Since there is no available % Organic Carbon information for some of the study sites, a default values of 1% was used (US EPA 2004). Each species' BSAF was then standardized to a common condition by normalizing them to the median lipid content of the species and a sediment organic carbon fraction representative of the ecosystem:

$$Adj\text{-}SedBAF = BSAF \times \frac{Median\ \%\ Lipid}{Median\ \%\ Oraganic\ Carbon} \quad \text{(B-7)}$$

The tPCB fish tissue listing threshold of 39 ng/g can then be divided by the median Adj-SedBAF for each species to translate an associated tPCB sediment threshold concentration. The lowest tPCB sediment concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the "fishing" designated use (Table B4). In the Back River embayment, the lowest concentration (6.9 ng/g) is associated with carp and will be selected as the sediment TMDL endpoint.

Table B-4: BSAF, Adj-SedBAF, and Sediment tPCB Threshold Concentrations for Each Species

Species Name	BSAF	Adj-SedBAF	Sediment tPCB Threshold Concentration (ng/g)
Atlantic Menhaden	1.71	2.22	17.6
American Eel	1.04	2.99	13.1
Brown Bullhead Catfish	1.65	0.71	55.2
Carp	4.05	5.66	6.9
Channel Catfish	4.89	5.28	7.4
White Perch	2.58	1.41	27.6

Appendix C: Method Used to Estimate Watershed tPCB Load

From April 2008 to March 2009, MDE collected monthly water column PCB measurements at the B-series station (B353) in the Back River embayment's watershed (see Figure C-1). In order to assess whether or not these samples covered all flow ranges so that they could be used to calculate watershed loads, the USGS station closest to Station B353 (USGS 01585200) was identified (see Figure C-1), and its daily average flow rates from January 1, 2008 to December 30, 2009 were used to generate the flow duration curves. The flows for the dates on which the B353 samples were collected were identified on the flow duration curve (see Figure C-2). This comparison indicates that the PCB samples span the full range of flows. It was therefore justified to apply these samples to calculate the watershed loads.

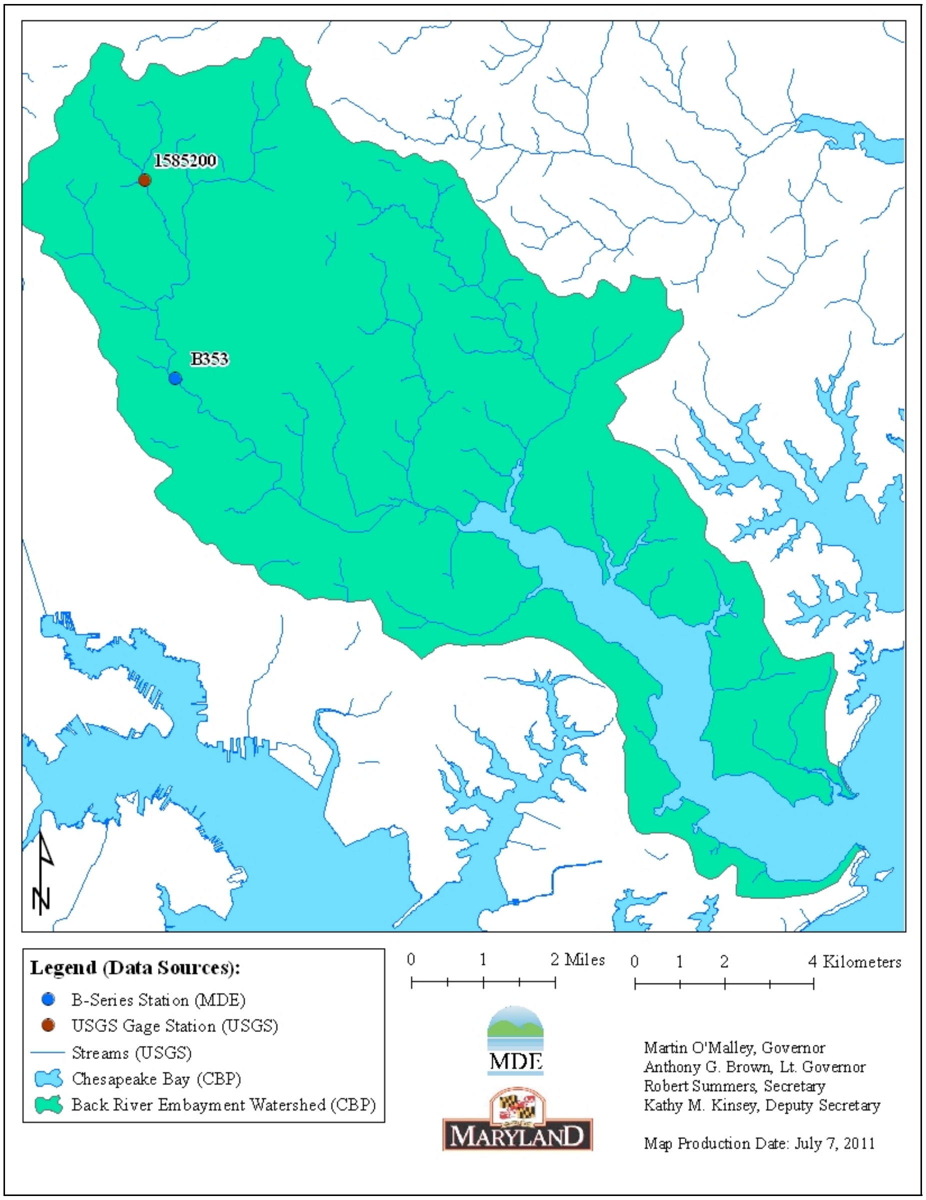
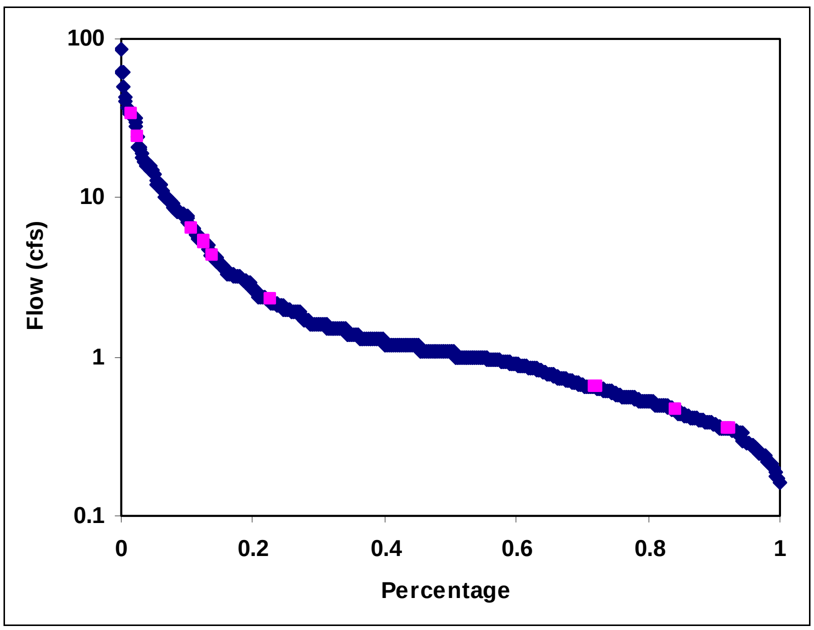


Figure C-1: The Locations of Station B353 and the USGS Gage Station

Using the average daily flow at USGS Station 01585200 and the ratio of Station B353's drainage area to the USGS station drainage area, the flows corresponding to each sampling date at Station B353 were calculated. The tPCB load was calculated as the flow multiplied by the measured tPCB concentration. Then, the relationship between flow and tPCB loads was generated, as shown in Figure C-3. The logarithmic regression was selected, as the other regressions did not have as high of correlation coefficients (R^2), and problems occurred when using other regressions to project loads at very high flows.

The average daily flows for the past 15 years (1996-2011) at USGS Station 01585200 were downloaded and converted to flows for Station B353, based on the ratio of their corresponding drainage areas. Then, the converted flows were fit to the logarithmic regression in order to predict the tPCB loads. The predicted loads were averaged, divided by Station B353's drainage area, and multiplied by the watershed area for the entire Back River embayment to get the total watershed tPCB loads (522.1 g/year).



Note: The magenta points represent the location of flows of station B353 samples

Figure C-2: Relative Locations of Station B353 Samples on the Flow Duration Curve

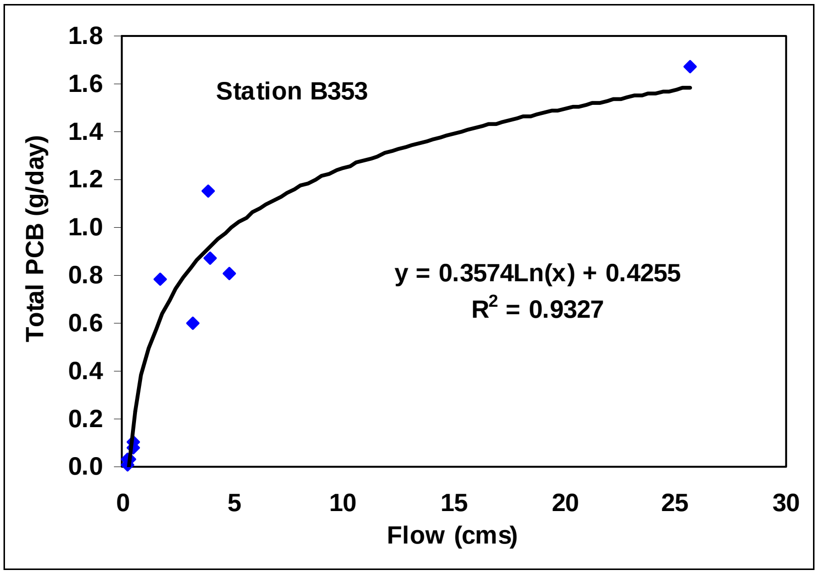


Figure C-3: Regression Between Flow and tPCB Loads at Station B353

Appendix D: Tidal Prism Model

A description of the tidal prism model applied in the development of the Back River embayment TMDL is presented in this Appendix. The model assumes that a single volume can represent a waterbody, and that the pollutant is well mixed in the waterbody, as shown in Figure D-1. Assuming no decay, PCBs can enter the water column via loads from watershed sources and the atmosphere (L_f), loads from the Chesapeake Bay mainstem (Q_0C_0), resuspension from the bottom sediments ($V_r AC_2$), and the diffusion between the sediment-water column interface ($V_dA(F_{do2}C_2 - F_{do1}C)$). PCBs leave the water column via volatilization ($V_vAF_{do1}C_1$), flows to the Chesapeake Bay mainstem (Q_bC_1), and sedimentation ($V_sAF_{p1}C_1$). In the sediment, PCBs enter the system via settling ($V_sAF_{p1}C_1$), and leave the system via diffusion ($V_dA(F_{do2}C_2 - F_{do1}C)$), resuspension ($V_r AC_2$), and burial to a deeper layer (V_bAC_2). Specifically, the mass balance for the PCBs in the water column and sediment can be written as:

$$\frac{dV_1C_1}{dt} = L_f - V_v AF_{do1}C_1 + (1-\alpha)Q_0C_0 - Q_bC_1 + V_r AC_2 - V_s AF_{p1}C_1 + V_d A(F_{do2}C_2 - F_{do1}C_1) \quad \text{(D-1)}$$

$$\frac{dV_2C_2}{dt} = -V_r AC_2 + V_s AF_{p1}C_1 - V_d A(F_{do2}C_2 - F_{do1}C_1) - V_b AC_2 \quad \text{(D-2)}$$

Where:
L_f = PCB load from upstream (point and nonpoint sources) and direct atmosphere deposition;
V_v = volatilization coefficient (m/d);
α = return ratio, which is the percentage of water that flowed to the Chesapeake Bay during the previous ebb tide and flows back to the embayment during the flood tide;
A = area of the embayment (m^2);
Q_0 = quantity of water that enters the embayment through the open boundary (m^3/d);
Q_b = quantity of water that leaves the embayment through the open boundary (m^3/d);
C_0 = tPCB concentrations in the water column of the Chesapeake Bay (ng/L);
C_1 = tPCB concentrations in the water column of the embayment (ng/L);
C_2 = tPCB concentrations in the sediment of the embayment (ng/L);
V_1 = volume of the water column in the embayment (m^3);
V_2 = volume of the active sediment layer of the embayment (m^3);
V_d = diffusive mixing velocity;
F_{p1} = fraction of particular-associated PCBs in the water column;
F_{do1}= fraction of truly dissolved and DOC-associated PCBs in the water column;
F_{do2}= fraction of truly dissolved and DOC-associated PCBs in the sediment;
V_r = rates of resuspension (m/d);
V_s = rates of settling (m/d);
V_b = rates of burial (m/d).

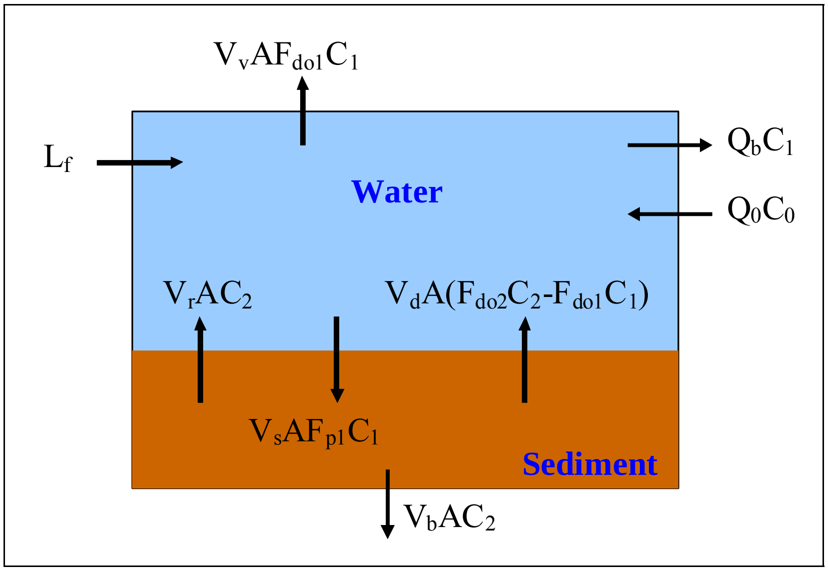


Figure D-1: Schematic Diagram of the Tidal Prism Model and PCB Budget

Appendix E: Tidal Prism Model Calculations for the Back River Embayment

For the Back River embayment tidal prism model, the parameter values are as follows:

L_f = 2,529,017 ug/day
V_v = 89.8 m/year = 0.246 m/day [derived using the method of Chapra (1997), assuming a wind speed of 1 m/s and a temperature of 10℃]
α = 0.78 (return ratio varies from 0.1 to 0.9)
A = 16,431,174 (m^2).
$Q_0 = A$ × Tidal range ÷ Tidal circle×24 hours = 16,431,174×0.366÷12.42×24 = 11,620,888 (m^3).
Q_b = Volume of water entering the embayment from the watershed $Q_f + Q_0 \times (1-\alpha)$ = 187,105 + 11,620,888 ×(1-0.78) = 2,743,700 (m^3) (Q_f is obtained by dividing the 16 year mean flow recorded at USGS station 1585200 by its drainage area, and multiplying the normalized flow by the entire drainage area of the Back River embayment's watershed)
$C_0 = 8.1 \times (0.95)^t$ (ng/L) (2001 was used as the baseline year)
C_1 = 14.5 (ng/L, measured and averaged)
C_2 = Measured tPCB concentration on a dry sediment base × Sediment density × (1-porosity) ÷ Fraction of particular-associated PCBs in the sediment = 130.8×2,500×(1-0.80) ÷ 0.9983 = 65,512 (ng/L) [the porosity (water content on a volume base) of 0.80 is selected based on observations and reference (Thomann and Mueller 1987)]
V_1 = 30,487,000 (m^3).
$V_2 = A$ × Active sediment layer thickness = 16,431,174 ×0.10=1,643,117 (m^3) (active sediment layer thickness value of 0.10 m is a typical value frequently used in water quality models)
V_d = 69.35× Porosity × (Molecular weight of PCBs)$^{-2/3}$ ÷ 365 = 69.35 × 0.85× (305.6)$^{-2/3}$ ÷ 365 = 0.00356 (m/d; Thomann and Mueller 1987)
F_{p1} = 0.1755; F_{do1} = 0.8245; F_{do2}= 0.00171 (see Appendix F for derivation)
V_s= 1.5 (m/d) (a default value of settling rate normally used in literature)
$V_b = 3.935 \times 10^{-6}$ (m/d, average of the measured sedimentation rates of Northeast River, Corsica River, Bohemia River, and Sassafras River through ^{210}Pb technology)
V_r can be calculated via mass balance of the sediment in the active sediment layer at steady state:

$$\frac{d\rho(1-\varphi)}{dt} = V_s \times TSS - V_r \times \rho \times (1-\varphi) - V_b \times \rho \times (1-\varphi) = 0 \qquad \text{(E-1)}$$

Where: TSS is the total suspended solid concentration (g/m^3, measured)
ρ is the sediment density (g/m^3; Thomann and Mueller, 1987)
φ is the porosity.

Rearrange Equation E-1:

$$V_r = \frac{V_s \times TSS}{\rho \times (1-\varphi)} - V_b = \frac{1.5 \times 13.28}{2500000 \times (1-0.80)} - 3.935 \times 10^{-6} = 3.59 \times 10^{-5} \text{(m/d)} \qquad \text{(E-2)}$$

Appendix F: Calculation of Fractions of Different PCB Forms

The fractions in equations D-1 and D-2 can be calculated as follows:

$$F_{p1} = \frac{TSS \times 10^{-6} K_{oc} \times f_{oc1}}{1 + (K_{oc} \times 10^{-6})(TSS \times f_{oc1} + DOC_1)} \quad \text{(F-1)}$$

$$F_{do1} = \frac{1 + (K_{oc} \times 10^{-6}) DOC_1}{1 + (K_{oc} \times 10^{-6})(TSS \times f_{oc1} + DOC_1)} \quad \text{(F-2)}$$

$$F_{do2} = \frac{\phi + \phi(K_{oc} \times 10^{-6}) DOC_2}{\phi + (K_{oc} \times 10^{-6})(f_{oc2} \times \rho \times (1-\phi) + \phi DOC_2)} \quad \text{(F-3)}$$

Where:

K_{oc} = the organic carbon/water partition coefficient of PCBs (L/kg). It describes the ratio of a compound adsorbed to solids and in solution, normalized for organic carbon content. It can be calculated via the relationship of $\log_{10} K_{oc} = 0.00028 + 0.983 \times \log_{10} K_{ow}$ (Hoke et al. 1994), where K_{ow} is the octanol-water partition coefficient with $\log_{10}K_{ow}$ equals to 6.261 (De Bruijn et al. 1989).

f_{oc1} and f_{oc2} = the fractions of organic carbon in suspended solids in the water column and the sediment solids, respectively (US EPA 2004).

DOC_1 and DOC_2 = the dissolved organic carbon concentration in water column and pore water, respectively.

φ = the porosity of the sediment.

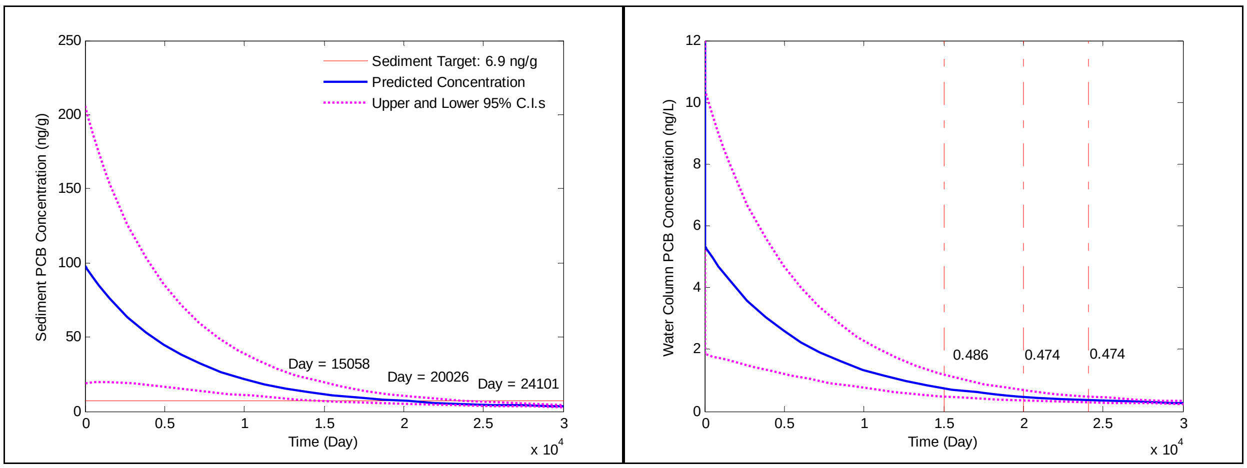
Appendix G: Calculation of 95% Confidence Intervals

The 95% CIs for the baseline mean tPCB concentrations were calculated as follows:

$$\text{Upper 95\% CI} = \text{Mean} + \frac{\text{t - value} \times \text{Standard Deviation}}{\sqrt{\text{Sample Size}}}$$

$$\text{Lower 95\% CI} = \text{Mean} - \frac{\text{t - value} \times \text{Standard Deviation}}{\sqrt{\text{Sample Size}}}$$

The model was run with the mean as well as the upper- and lower- 95% CIs as the initial conditions in the embayment and outside of the embayment. The results are presented in Figures G-1 and G-2. The time required to meet the sediment and water column TMDL endpoint tPCB concentrations are listed in Table G-1. The time required to meet the TMDL endpoints in the embayment increased by approximately 20% (11 years) when the higher tPCB water column concentration was used as the baseline.



Note: The dashed red lines in the water column graph represent what the water column concentrations will be within the embayment when the sediment TMDL endpoint concentration is achieved in the 3 different scenarios (i.e., mean and upper/lower CIs).

Figure G-1: Change of Average Bottom Sediment and Water Column tPCB Concentrations Over Time Within the Back River Embayment

Table G-1: Sediment TMDL Endpoint tPCB Achievement - Mean and 95% CI Water Column tPCB Concentrations

Initial Conditions Scenario	Time Required to Meet the Sediment TMDL Endpoint tPCB Concentration (Days)	Water Column tPCB Concentration (ng/L) When Sediment TMDL endpoint tPCB Concetration is Achieved
Mean	20,026	0.474
Upper 95% C.I.	24,101	0.474
Lower 95% C.I.	15,058	0.486

Appendix H: Technical Approach Used to Generate Maximum Daily Loads

I. Summary

This appendix documents the technical approach used to define MDLs of tPCBs consistent with the average annual TMDL, which is protective of the "fishing" designated use, which is protective of human health related to the consumption of fish, in the Back River embayment. The approach builds upon the modeling analysis that was conducted to determine the loads of tPCBs and can be summarized as follows.

- The approach defines MDLs for each of the source categories.
- The approach builds upon the TMDL modeling analysis that was conducted to ensure that average annual load targets result in compliance with the TMDL endpoint tPCB concentrations.
- The approach converts daily time-series loads into TMDL values in a manner that is consistent with available EPA guidance on generating daily loads for TMDLs.
- The approach considers a daily load level of a resolution based on the specific data that exists for each source category.

II. Introduction

This appendix documents the development and application of the approach used to define TMDLs on a daily basis. It is divided into sections discussing:

- Basis for approach,
- Options considered,
- Selected approach,
- Results of approach.

III. Basis for Approach

The overall approach for the development of daily loads was based upon the following factors:

- **Average Annual TMDL:** The basis of the average annual tPCB TMDL is that the baseline tPCB load rates result in tPCB levels in fish tissue that exceed the tPCB fish tissue listing threshold. Thus, the average annual tPCB TMDL was calculated to be protective of the "fishing" designated use, which is protective of human health related to the consumption of fish.
- **Draft EPA guidance document entitled *Developing Daily Loads for Load-based TMDLs***: This guidance provides options for defining MDLs when using TMDL approaches that generate daily output.

The rationale for developing TMDLs expressed as *daily* loads was to accept the existing average annual TMDL, but then develop a method for converting this value to a MDL – in a manner consistent with EPA guidance and available information.

VI. Options Considered

The draft EPA guidance document for developing daily loads does not specify a single approach that must be adhered to, but rather, it contains a range of acceptable options. The selection of a specific method for translating a time-series of allowable loads into the expression of a TMDL requires decisions regarding both the level of resolution (e.g., single daily load for all conditions vs. loads that vary with environmental conditions) and level of probability associated with the TMDL.

This section describes the range of options that were considered when developing methods to calculate the MDL for the Back River Embayment.

<u>Level of Resolution</u>

The level of resolution pertains to the amount of detail used in specifying the MDL. The draft EPA guidance on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Back River embayment:

1. **Representative daily load:** In this option, a single daily load (or multiple representative daily loads) is specified that covers all time periods and environmental conditions.
2. **Flow-variable daily load:** This option allows the MDL to vary based upon the observed flow condition.
3. **Temporally-variable daily load:** This option allows the MDL to vary based upon seasons or times of varying source or water body behavior.

<u>Probability Level</u>

All TMDLs have some probability of being exceeded, with the specific probability being explicitly specified or implicitly assumed. This level of probability directly or indirectly reflects two separate phenomena:

1. Water quality criteria consist of components describing acceptable magnitude, duration, and frequency. The frequency component addresses how often conditions can allowably surpass the combined magnitude and duration components.
2. Pollutant loads, especially from wet weather sources, typically exhibit a large degree of variability over time. It is rarely practical to specify a "never to be exceeded value" for a daily load, as essentially any load value has some finite probability of being exceeded.

The draft daily load guidance document states that the probability component of the MDL should be "based on a representative statistical measure" that is dependent upon the specific TMDL and best professional judgment of the developers. This statistical measure represents how often the MDL is expected/allowed to be exceeded. The primary options for selecting this level of protection would be:

1. **The MDL reflects some central tendency:** In this option, the MDL is based upon the mean or median value of the range of loads expected to occur. The variability in the actual loads is not addressed.

2. **The MDL reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the MDL is based upon the allowable load that is

predicted to occur during some critical period examined during the analysis. The developer does not explicitly specify the probability of occurrence.

3. **The MDL is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the MDL based upon a characterization of the variability of daily loads. For example, selection of the 95^{th} percentile value would result in a MDL that would be exceeded 5% of the time.

V. Selected Approach

The approach selected for defining a Back River Embayment MDL was based upon the specific data that exists for each source category. The approach consists of unique methods for each of the following categories of sources:

- Approach for Nonpoint Sources and NPDES Regulated Stormwater Point Sources
- Approach for WWTPs

VI. Approach for Nonpoint Sources and NPDES Regulated Stormwater Point Sources

The level of resolution selected for the Back River Embayment MDL was a representative daily load, expressed as a single daily load for each load source. This approach was chosen due to the nature of PCBs and the focus of this study on a TMDL endpoint protective of the "fishing" designated use. Daily flow and temporal variability do not affect the rate of PCB bioaccumulation in fish tissue over the long term thus establishing no influence on achievement of the TMDL endpoint. A MDL at this level of resolution is unwarranted.

The MDL was estimated based on three factors: a specified probability level, the average annual PCB TMDL, and the coefficient of variation (CV) of the initial condition for ambient water column tPCB concentrations in the Back River embayment. The probability level (or exceedance frequency) is based upon guidance from US EPA (1991) where examples suggest that when converting from a long-term average to a daily value, the z-score corresponding to the 99^{th} percentile of the log-normal probability distribution should be used.

The CV was calculated using the arithmetic mean and standard deviation of the baseline ambient water column tPCB concentrations in the Back River embayment. The resulting CV of 0.73 was calculated using the following equation:

$$CV = \frac{\beta}{\alpha} \qquad \text{(Equation H-1)}$$

Where,
CV = coefficient of variation
α = mean (arithmetic)
β = standard deviation (arithmetic)

The maximum "daily" load for each contributing source is estimated as the long-term average annual load multiplied by a factor that accounts for expected variability of daily load values. The equation is as follows:

$$MDL = LTA * e^{(z\sigma - 0.5\sigma^2)} \qquad \text{(Equation H-2)}$$

Where,
MDL = Maximum daily load
LTA = Long-term average (average annual load)
Z = z-score associated with target probability level
$\sigma = \ln(CV^2+1)$
CV = Coefficient of variation based on arithmetic mean and standard deviation

Using a z-score associated with the 99th percent probability of 2.33, a CV of 0.73, and consistent units, the resulting dimensionless conversion factor from long-term average loads to a maximum daily value is 2.47. The average annual Back River Embayment PCB TMDL is reported in g/year, and the conversion from g/year to a maximum daily load in g/day is 0.0068 (e.g. 2.47/365)

VIII. Approach for WWTPs

The TMDL also considers contributions from NPDES permitted WWTPs that discharge quantifiable concentrations of tPCBs to the Back River embayment. The MDLs were calculated for these WWTPs based on the guidance provided in the Technical Support Document (TSD) for Water Quality-based Toxics Control (US EPA 1991). The long-term average annual TMDL was converted to maximum daily limits using Table 5-2 of the TSD assuming a coefficient of variation of 0.6 and a 99th percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual Back River Embayment TMDL of PCBs is reported in g/year, and the conversion from g/year to a maximum daily load in g/day is 0.0085 (i.e. 3.11/365).

IX. Results of Approach

This section lists the results of the selected approach to define the Back River Embayment MDLs.

- Calculation Approach for Nonpoint Sources (Direct Atmospheric Deposition, Non-regulated Watershed Runoff, and Contaminated Sites) and NPDES Regulated Stormwater Point Sources.

  Direct Atmospheric Deposition LA (g/day) = Average Annual TMDL Direct Atmospheric Deposition LA (g/year) * 0.0068

  Non-regulated Watershed Runoff LA (g/day) = Average Annual TMDL Non-regulated Watershed Runoff LA (g/year) * 0.0068

  Contaminated Site LA (g/day) = Average Annual TMDL Contaminated Site LA (g/year) * 0.0068

  NPDES Stormwater WLA (g/day) = Average Annual TMDL NPDES Regulated Stormwater WLA (g/year) * 0.0068

- Calculation Approach for WWTPs

  WWTP WLA (g/day) = Average Annual TMDL WWTP WLA (g/year)* 0.0085

Table H-1: Summary of tPCB MDLs for the Back River Embayment

Source	**MDL (g/day)**
Direct Atmospheric Deposition (to the Surface of the Embayment)	1.09
Non-regulated Watershed Runoff	0.21
Contaminated Sites	0.09
Nonpoint Sources/LAs	***1.39***
WWTP	0.41
NPDES Regulated Stormwater[1]	
Baltimore City	0.87
Baltimore County	0.56
Point Sources/WLAs	***1.84***
MOS	***0.17***
Total	**3.40**

Notes: [1] Load per jurisdiction applies to all NPDES stormwater dischargers within the jurisdiction's portion of the watershed draining to the Back River embayment. These dischargers are identified in Appendix J.

Appendix I: Contaminated Site Load Calculation Methodology

The term contaminated site used throughout this report refers to areas with known PCB soil contamination, as documented by state or federal hazardous waste cleanup programs (i.e., state or federal Superfund programs). When compared against the human health screening criteria for soil and groundwater exposure pathways, PCBs are not necessarily a contaminant of concern at these sites, but have been screened for, reported, and detected during formal site investigations. MDE has identified five contaminated sites within the Back River embayment's watershed, for which EOF tPCB baseline loads have been estimated. These sites (see Table I-1) were identified based on information gathered from MDE's LRP-MAP database (MDE 2011c) and have tPCB soil concentrations at or above method detection levels, as determined via soil sample results contained within MDE-LMA's records of contaminated site surveys and investigations.

tPCB EOF loads from these sites have been calculated, and subsequently, these EOF loads would usually be converted to EOS loads using methods applied within Maryland's nontidal sediment TMDLs, thirteen of which have been approved by the EPA since 2006. The modeling assumption behind the conversion to EOS loads is that not all of the contaminated site tPCB loads are expected to reach the impaired waterbody. Thus, EOS loads are thought to be a more accurate representation of tPCB loads from these sites. However, all of the identified contaminated sites are located immediately adjacent to the tidal embayment. Therefore, a delivery factor of one is applied, and the resultant EOS loads are equivalent to the base EOF loads.

The purpose of this appendix is to describe the detailed procedures used to calculate the Contaminated Site tPCB Baseline Loads.

I. tPCB Soil Concentration Data Processing

The Contaminated Site tPCB Baseline Loads were only characterized for those sites (contained within MDE's LRP-MAP database and located within the Back River embayment's watershed) with samples where tPCB concentrations were found to be at or above the method detection limits used in the soil sampling analyses conducted as part of site investigations. For the most part, these soil sampling analyses employed an Aroclor based analytical method. Thus, when a given sample was analyzed for multiple Aroclors and more than one mixture was detected (e.g., 1232, 1248, 1262, etc.), the results were added together to represent tPCB concentrations. Next, the median value of the tPCB concentrations from each site was calculated (see Table I-1).

Table I-1: Median tPCB Soil Concentrations at Contaminated Sites in the Back River Embayment's Watershed

Site Name	Site Description	Median tPCB (µg/kg)	n[1] [%][2]
68th St. Dump	Moderate Soil Remediation[3]	620	21 [91%]
Industrial Enterprises	Moderate Soil Remediation	290	8 [50%]
Keywell Propoerty	No Soil Remediation[4]	435	4 [100%]
Colgate Dump	Moderate Soil Remediation[3]	300	9 [90%]
Sauer Dump	No Soil Remediation	6,050	84 [93%]

Notes: [1] n = number of samples above method detection limits.
[2] % = percentage of all samples that are above method detection limits.
[3] Moderate soil remediation conducted during highway construction.
[4] Soil remediation was conducted at the site but not in the area of PCB contamination.

II. Revised Universal Soil Loss Equation Version II Soil Loss Calculation Procedures

The Revised Universal Soil Loss Equation Version II (RUSLE2)[1] was run for each site with the use of the Maryland state climate database, county soil databases, and management databases that can be downloaded from the following website: http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm. The site characteristics (i.e., soil types, land cover, slope, etc.) were selected from drop down menus provided in the RUSLE2 worksheet. Input parameters were selected via the following decision rules:

1. **Location:** The appropriate county name was selected from the Maryland state climate database in the RUSLE2 *location* field. This resulted in an automatic selection of the appropriate climatic factors.

2. **Soil:** Soil types were identified per site via Geographic Information System (GIS) analysis using a digitized site area and soils data acquired from the USDA-NRCS. The soil types were then subsequently selected from the appropriate county's soils database in the RUSLE2 worksheet.

3. **Slope Length:** Slope length (length of the site), which was identified via GIS analysis using flow direction grids generated from Digital Elevation Models (DEMs) from the USGS, and/or digital USGS quadrangles (i.e., topographic maps), was manually inserted into the *slope length* field. The maximum slope length permitted by the soil loss equation was 2000 feet. For sites with length greater than 2000 feet, 2000 feet was used.

4. **Percent Slope:** Percent slope, or slope steepness (the difference between maximum and minimum site elevations/slope length), which was identified via GIS analysis, was manually inserted into the *percent slope* field. Percent slope was calculated using GIS analysis by calculating the slope per DEM grid cell within the digitized site area and subsequently taking the average of the cell values.

[1] RUSLE2 is an advanced, user-friendly software model developed by the University of Tennessee Biosystems Engineering & Soil Science Department, in cooperation with the United States Department of Agriculture (USDA) – Agricultural Research Service (ARS), the National Sedimentation Laboratory, USDA – Natural Resources Conservation Service (NRCS), and the Bureau of Land Management.

5. **<u>Management:</u>** The *management option* field was used to represent a site's land cover (i.e., forest, grass, barren, etc.), which was identified via GIS analysis (i.e., agricultural management options were used to approximate the soil loss characteristics of the land covers present at these non-agricultural sites). For example, for sites covered by grass, the warm season grass – not harvested management option was selected; for wooded sites, the established orchard - full cover option was selected; and for sites with bare soil, the bare ground management option was selected. Land cover classification areas were estimated using GIS analysis by digitizing the various land cover areas within the site's boundaries using the State of Maryland's 2007 6-inch resolution orthophotography. This includes impervious areas of the site; however, these areas were left out of the soil loss calculations, since there is no potential for soil runoff. Please see Section III below for more information on how impervious areas were removed from the total site soil loss calculation.

For sites with multiple soil types and land cover classifications present, soil loss was first calculated for each unique soil type-land cover combination based on the entire site's parameters (e.g. slope and slope length). Then, the soil loss values for each soil type-land cover combination were weighted based on the percentage of the site that the unique combination occupied (determined by the GIS intersection between the soil type data layer and digitized land cover data layer). Finally, the summation of the weighted soil loss values was calculated to produce a total soil loss for the entire site.

III. Calculating EOF tPCB loads

The RUSLE2 generated soil loss values, reported in tons/acre/year, were used in conjunction with adjusted pervious area estimates and median tPCB soil concentrations to determine the EOF contaminated site PCB loads. As discussed previously, the various land cover types per site were digitized. The land cover types include: impervious, barren, grass, and forest classifications. Barren, grass, and forest all constitute pervious areas. The area of these pervious land covers were calculated and summed to produce a total pervious area. Then, the total pervious area estimates were adjusted for at each site based on the percent of samples that were above the method detection limit (e.g., if only 25% of the samples had tPCB concentrations above the method detection limit, only 25% of the previous area of the site was used in the calculations). These total adjusted pervious areas were then used in conjunction with the RUSLE2 generated soil loss values to produce a total soil loss value for each site in tons/year. To be consistent with the RUSLE2 soil loss units, the median tPCB soil concentrations were converted to pounds of tPCBs per pound of soil (lbs/lb). The EOF contaminated site tPCB loads are reported in Table I-2 in g/year.

Table I-2: Summary of Contaminated Site Soil Loss Values and EOF tPCB Loads

Site Name	Site Description	Median tPCB (µg/kg)	Soli Loss (lbs/year)	EOF PCB Loads (g/year)
68th St. Dump	Moderate Remediation[1]	620	25,206	7.09
Industrial Enterprises	Moderate Soil Remediation	290	8,041	1.06
Keywell Propoerty	No Soil Remediation[2]	435	14,929	2.95
Colgate Dump	Moderate Soil Remediation[1]	300	5,820	0.79
Sauer Dump	No Soil Remediation	6,050	316	0.87
Total				**12.8**

Notes: [1] Moderate soil remediation conducted during highway construction.
[2] Soil remediation was conducted at the site but not in the area of PCB contamination.

IV. Calculating EOS tPCB loads

All land areas within the identified contaminated sites are located immediately adjacent to the tidal embayment. Therefore, the entire edge of field load is expected to be delivered directly to the system with no losses expected to occur over land, and a delivery factor of one is consequently applied to the EOF loads. The resultant EOS loads are therefore equivalent to the base EOF loads.

V. Contaminated Site Baseline Load Summary

The Contaminated Site tPCB Baseline Load from the identified sites in the Back River embayment's watershed is estimated to be 12.8 g/year (see Table I-2). This load is the summation of the individual tPCB loads from five contaminated sites within the embayment's watershed, three of which have undergone some degree of remediation. The average tPCB concentrations at the non-remediated sites are generally above levels detected at the sites that have already been remediated.

Appendix J: List of NPDES Regulated Stormwater Permits

Table J-1: NPDES Regulated Stormwater Permit Summary for the Back River Embayment Watershed[1]

MDE Permit	NPDES	Facility	City	County	Type	TMDL
04DP3313	MD0068276	STATE HIGHWAY ADMINISTRATION (MS4)	STATE-WIDE	ALL PHASE I (Baltimore City, Baltimore County, Anne Arundel)	WMA6	STORMWATER WLA
	MDR100000	MDE GENERAL PERMIT TO CONSTRUCT	ALL	ALL		STORMWATER WLA
05DP3317	MD0068314	BALTIMORE COUNTY MS4	COUNTY-WIDE	BALTIMORE	WMA6	STORMWATER WLA
04DP3315	MD0068292	BALTIMORE CITY MS4	BALTIMORE	BALTIMORE CITY	WMA6	STORMWATER WLA
02SW0033		THE DAVIDSON TRANSFER & STORAGE COMPANY	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0254		BOWLEY'S LANE LANDFILL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0287		CROWN CORK & SEAL COMPANY, INC. - BALTIMORE	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0302		ROCKLAND INDUSTRIES, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0468		SHASTA BEVERAGES, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0576		DAP INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0581		GRAHAM PACKAGING PLASTIC PRODUCTS, INC. - BLT047	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0630		BACK RIVER WWTP	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0655		AMERICAN YEAST CORPORATION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0683		BFI - NORRIS FARM LANDFILL	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0706		BALTIMORE CITY DPW - EASTERN SUBSTATION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0708		BALTIMORE CITY DPW - MECHANIC SHOP	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0745		U.S. POSTAL SERVICE - PARKVILLE AUXILLARY VMF	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0829		AUTOMATIC ROLLS OF BALTIMORE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0852		UNITED PARCEL SERVICE - QUAD AVENUE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0879		BALL - STEELTIN	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0979		BALTIMORE REINFORCING STEEL	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0989		COCA-COLA BOTTLING CO. - BALTIMORE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1032		VALLEYWOOD INDUSTRIES, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1044		FEDERAL EXPRESS CORP. - BALTIMORE	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1055		CON-WAY CENTRAL EXPRESS - XBX -BALTIMORE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1149		EASTSIDE AUTO RECYCLING, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1157		NORFOLK SOUTHERN RAILWAY COMPANY - BAYVIEW YARD	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1253		MARYLAND RECYCLE COMPANY, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1275		UNIVERSAL DISTRIBUTION SERVICES, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1301		MARINE CORPS TRAINING CENTER	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1328		SHA - GOLDEN RING SHOP	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA

02SW1351		SULLIVAN GARAGE	ROSEDALE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1359		P & J CONTRACTING COMPANY, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1463		ERDMAN AUTO PARTS	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1491		CAVANAUGH PRESS, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1496		NELSON ENTERPRISES, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1502		O.S.T. TRUCKING COMPANY, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1548		LONZA BALTIMORE, INC. - BALTIMORE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1549		SIEMENS WATER TECHNOLOGIES CORPORATION - BALTIMORE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1552		CONSOLIDATED CONTAINER COMPANY, LP.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1628		DORACON CONTRACTING COMPANY - EAST BIDDLE STREET	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1663		USF HOLLAND, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1698		LONZA BALTIMORE, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1800		MHS ENTERPRISES, LLC	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1852		ENGINEERED POLYMER SOLUTIONS, INC. - BALTIMORE	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1859		POMPEIAN, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1905		COMMUNITY COLLEGE OF BALTIMORE COUNTY - ESSEX	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1921		AMTRAK - QUAD AVENUE ELECTRIC TRACTION OFFICE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1970		BALTIMORE COUNTY BUREAU OF HIGHWAYS - SHOP 7-1	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1987		4600 EAST FAYETTE, LLC	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1989		FRANKFORD AUTO RECYCLERS	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW2020		A-1 TREE & LAWNCARE, LTD.	ROSEDALE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW3018		BALTIMORE GALVANIZING COMPANY, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW3021		ROBBINS MOTOR TRANSPORTATION, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1257		BALTIMORE AUTO RECYCLING, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA

Note: [1] Although not listed in this table, some individual process water permits incorporate stormwater requirements and are accounted for within the NPDES Stormwater WLA, as well as additional Phase II permitted MS4s, such as military bases, hospitals, etc.

Appendix K: Total PCB Concentrations and Locations of the PCB Monitoring Stations

Tables K-1 through K-4 list the tPCB concentrations in the water column, sediment, and fish tissue samples collected in the Back River embayment. Figures K-1 through K-3 show the locations of these monitoring stations.

Table K-1: Sediment tPCB Concentrations (ng/g) in the Back River Embayment

Station	Date	Conc.	Study	Station	Date	Conc.	Study
BR101	7/23/01	466.63	BRCCS	BR74	7/23/01	192.72	BRCCS
BR120	7/23/01	125.86	BRCCS	BR89	7/23/01	26.39	BRCCS
BR14	7/23/01	57.09	BRCCS	BR91	7/23/01	400.35	BRCCS
BR26	7/23/01	40.58	BRCCS	XIF6633	7/23/01	122.25	BRCCS
BR27	7/23/01	95.77	BRCCS	XIF8008	3/15/01	194.72	BRCCS
BR27	7/23/01	104.53	BRCCS	XIF8008	7/23/01	206.04	BRCCS
BR36	7/23/01	23.22	BRCCS	BR09	6/05/08	12.72	2008 PCB TMDL Survey
BR50	7/23/01	45.03	BRCCS	BRSEP	6/05/08	53.69	2008 PCB TMDL Survey
BR55	7/23/01	140.08	BRCCS	BR09	11/12/08	29.98	2008 PCB TMDL Survey
BR60	7/23/01	101.71	BRCCS	BRSEP	11/12/08	59.26	2008 PCB TMDL Survey

Table K-2: Water Column tPCB Concentrations (ng/L) in the Back River Embayment - CHARM Study

Date	Station	Type	Conc.	Date	Station	Type	Conc.	Date	Station	Type	Conc.
1/22/01	B352	Non-tidal	124.73	1/22/01	B362	Non-tidal	10.62	7/23/01	XIF4660	Tidal	4.66
2/25/01	B352	Non-tidal	39.85	2/25/01	B362	Non-tidal	15.74	9/20/01	XIF4660	Tidal	5.64
7/25/01	B352	Non-tidal	29.81	7/25/01	B362	Non-tidal	4.35	1/24/01	XIF5633	Tidal	12.56
9/20/01	B352	Non-tidal	12.74	9/20/01	B362	Non-tidal	11.47	2/25/01	XIF5633	Tidal	22.80
3/13/02	B352	Non-tidal	7.77	3/13/02	B362	Non-tidal	26.28	7/23/01	XIF5633	Tidal	6.51
4/3/02	B352	Non-tidal	1.63	4/3/02	B362	Non-tidal	12.39	9/20/01	XIF5633	Tidal	9.94
4/25/02	B352	Non-tidal	14.97	4/25/02	B362	Non-tidal	16.24	1/24/01	XIF6633	Tidal	15.28
1/22/01	B353	Non-tidal	8.45	4/3/02	B363	Non-tidal	4.99	2/25/01	XIF6633	Tidal	10.11
2/25/01	B353	Non-tidal	5.44	4/25/02	B363	Non-tidal	12.73	7/23/01	XIF6633	Tidal	15.69
7/25/01	B353	Non-tidal	2.17	4/3/02	B372	Non-tidal	1.83	9/20/01	XIF6633	Tidal	13.74
9/20/01	B353	Non-tidal	15.41	4/3/02	B373	Non-tidal	1.74	1/24/01	XIF7615	Tidal	18.26
3/13/02	B353	Non-tidal	9.85	4/25/02	B373	Non-tidal	0.92	2/25/01	XIF7615	Tidal	11.93
4/3/02	B353	Non-tidal	1.06	4/3/02	B441	Non-tidal	4.98	7/23/01	XIF7615	Tidal	21.69
4/25/02	B353	Non-tidal	3.11	4/25/02	B441	Non-tidal	5.70	9/20/01	XIF7615	Tidal	22.54
2/25/01	B361	Non-tidal	3.95	1/24/01	XIF4450	Tidal	4.23	1/24/01	XIF8008	Tidal	22.85
7/25/01	B361	Non-tidal	5.38	2/25/01	XIF4450	Tidal	15.48	2/25/01	XIF8008	Tidal	13.58
9/20/01	B361	Non-tidal	16.13	7/23/01	XIF4450	Tidal	5.24	7/23/01	XIF8008	Tidal	20.93
3/13/02	B361	Non-tidal	12.82	9/20/01	XIF4450	Tidal	7.36	9/20/01	XIF8008	Tidal	24.68
4/3/02	B361	Non-tidal	10.01	1/24/01	XIF4660	Tidal	3.68				
4/25/02	B361	Non-tidal	9.25	2/25/01	XIF4660	Tidal	4.46				

Table K-3: Water Column tPCB Concentrations (ng/L) in the Back River Embayment - 2008 PCB TMDL Survey

Date	Station	Type	Conc.	Date	Station	Type	Conc.	Date	Station	Type	Conc.
6/5/08	BRSEP	Tidal	8.09	8/25/08	BD5	Tidal	1.43	5/12/08	B353	Non-tidal	0.76
6/5/08	BRSEP	Tidal	10.40	8/25/08	BD5	Tidal	2.11	6/24/08	B353	Non-tidal	0.48
6/5/08	BR09	Tidal	5.08	10/23/08	BD3	Tidal	0.54	7/14/08	B353	Non-tidal	3.41
6/5/08	BR09	Tidal	6.95	10/23/08	BD3	Tidal	0.34	8/28/08	B353	Non-tidal	1.43

11/12/08	BRSEP	Tidal	4.53	10/23/08	BD5	Tidal	2.06	9/26/08	B353	Non-tidal	1.93
11/12/08	BR09	Tidal	4.11	10/23/08	BD5	Tidal	1.43	10/30/08	B353	Non-tidal	1.00
6/30/08	BD3	Tidal	1.12	12/8/08	BD5	Tidal	3.03	11/14/08	B353	Non-tidal	1.98
6/30/08	BD3	Tidal	1.13	12/8/08	BD5	Tidal	4.23	12/10/08	B353	Non-tidal	2.52
6/30/08	BD5	Tidal	2.29	2/25/09	BD3	Tidal	3.16	1/7/09	B353	Non-tidal	9.48
6/30/08	BD5	Tidal	4.77	2/25/09	BD3	Tidal	2.12	2/26/09	B353	Non-tidal	2.55
8/25/08	BD3	Tidal	1.35	2/25/09	BD5	Tidal	5.05	3/26/09	B353	Non-tidal	2.14
8/25/08	BD3	Tidal	0.85	4/29/08	B353	Non-tidal	5.21				

Table K-4: Fish Tissue tPCB Concentrations (ng/g) in the Back River Embayment

Site	Date	Conc.	Species	Site	Date	Conc.	Species
BCSEP	8/20/03	183.43	White Perch	BRU	9/28/00	488.28	American Eel
BR	5/17/01	1368.35	Carp	BRU	9/30/04	338.32	Atlantic Menhaden
BR	5/17/01	710.87	Carp	BRU	9/30/04	560.39	Atlantic Menhaden
BR	5/17/01	854.50	Carp	BRU	9/30/04	409.40	Atlantic Menhaden
BR	5/17/01	1253.93	Carp	BRU	9/19/00	853.81	Channel Catfish
BR	5/17/01	1352.93	Carp	BRU	9/19/00	880.37	Channel Catfish
BR09	11/7/08	244.52	White Perch	BRU	9/30/04	273.95	Channel Catfish
BR09	11/7/08	132.52	White Perch	BRU	9/30/04	408.10	Channel Catfish
BRL	9/20/00	695.30	American Eel	BRU	9/30/04	361.97	Channel Catfish
BRL	9/28/00	766.45	American Eel	BRU	9/30/04	1155.95	Channel Catfish
BRL	9/19/00	624.45	Channel Catfish	BRU	9/20/00	251.13	White Perch
BRL	9/19/00	406.67	Channel Catfish	BRU	9/30/04	545.72	White Perch
BRL	9/20/00	327.64	White Perch	BRU	9/30/04	260.38	White Perch
BRSEP	8/19/03	246.45	White Perch	BRU	9/30/04	419.73	White Perch
BRSEP	5/29/08	92.97	White Perch	BRUM	9/28/00	644.37	American Eel
BRSEP	5/29/08	78.85	Brown Bullhead	BRUM	9/28/00	632.76	American Eel
BRSEP	5/29/08	117.48	White Perch	BRUM	9/18/00	818.23	Channel Catfish
BRSEP	5/29/08	94.40	White Perch	BRUM	9/20/00	592.55	Channel Catfish
BRSEP	5/29/08	151.10	White Perch	HMISW	9/17/02	367.77	White Perch
BRSEP	5/29/08	201.31	White Perch	HMISW	9/17/02	291.13	White Perch
BRSEP	5/29/08	120.08	White Perch	LBR	7/18/02	231.99	White Perch
BRU	9/18/00	862.70	American Eel	LBR	7/18/02	389.38	White Perch

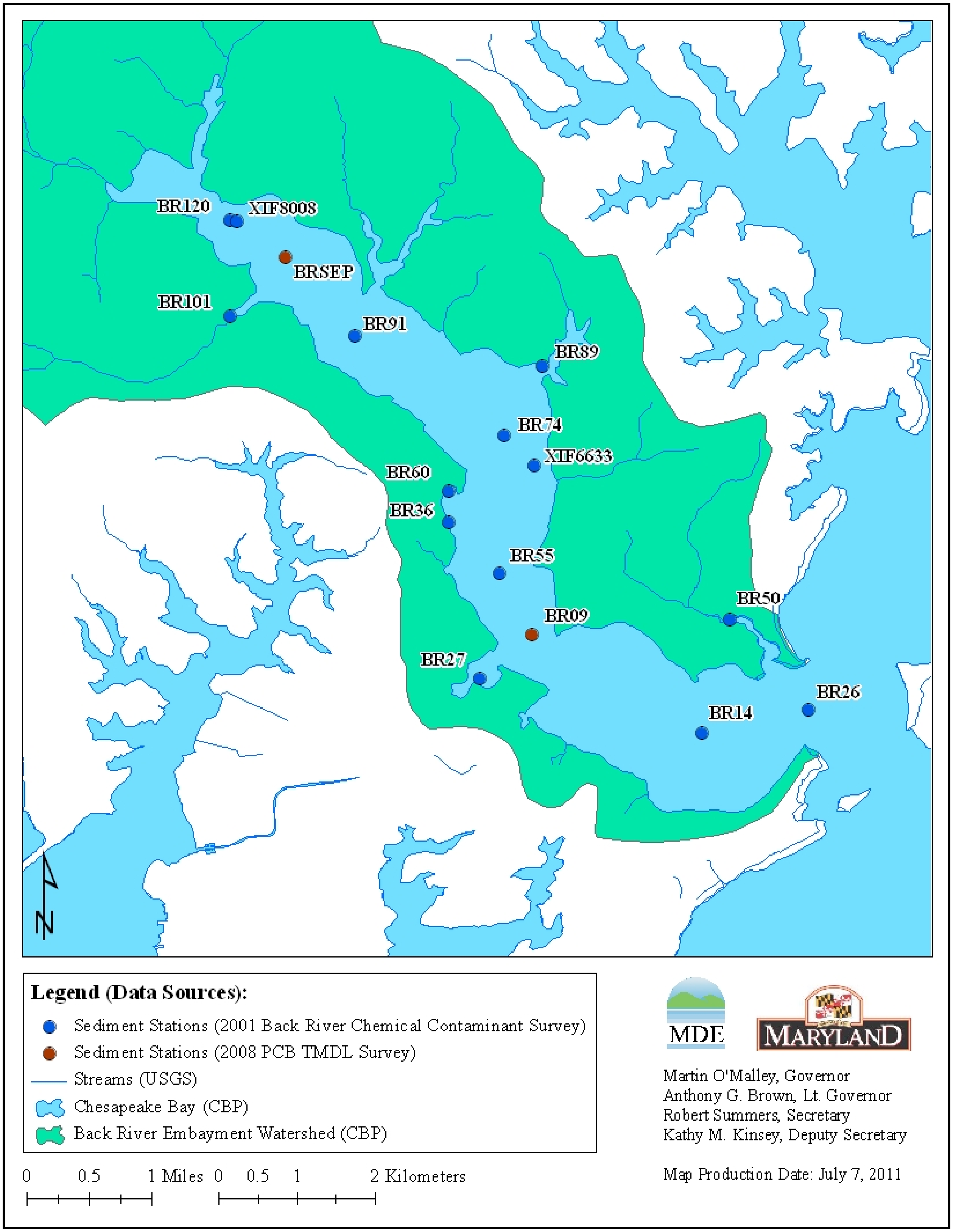


Figure K-1: PCB Sediment Monitoring Stations in the Back River Embayment

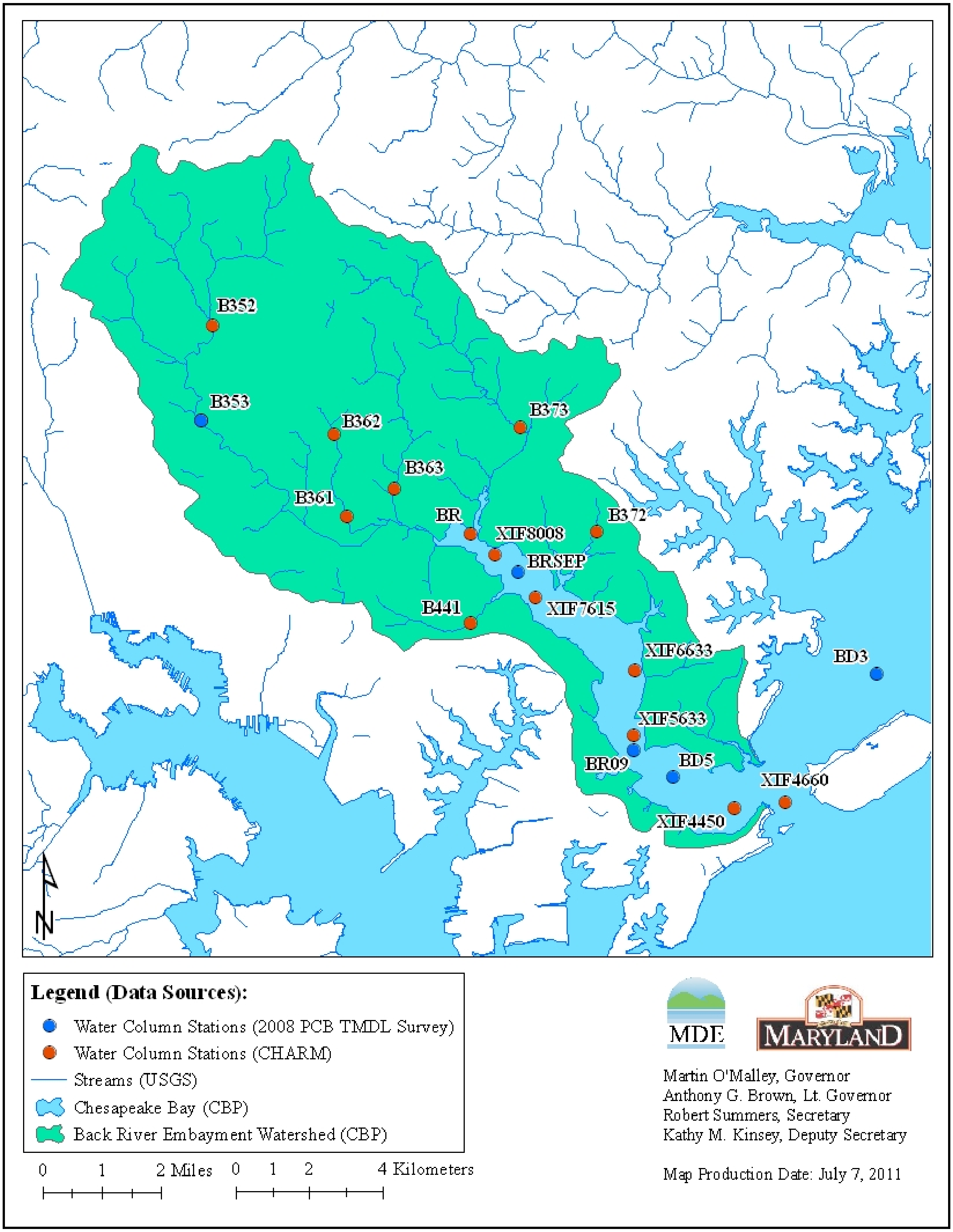


Figure K-2: PCB Water Column Monitoring Stations in the Back River Embayment

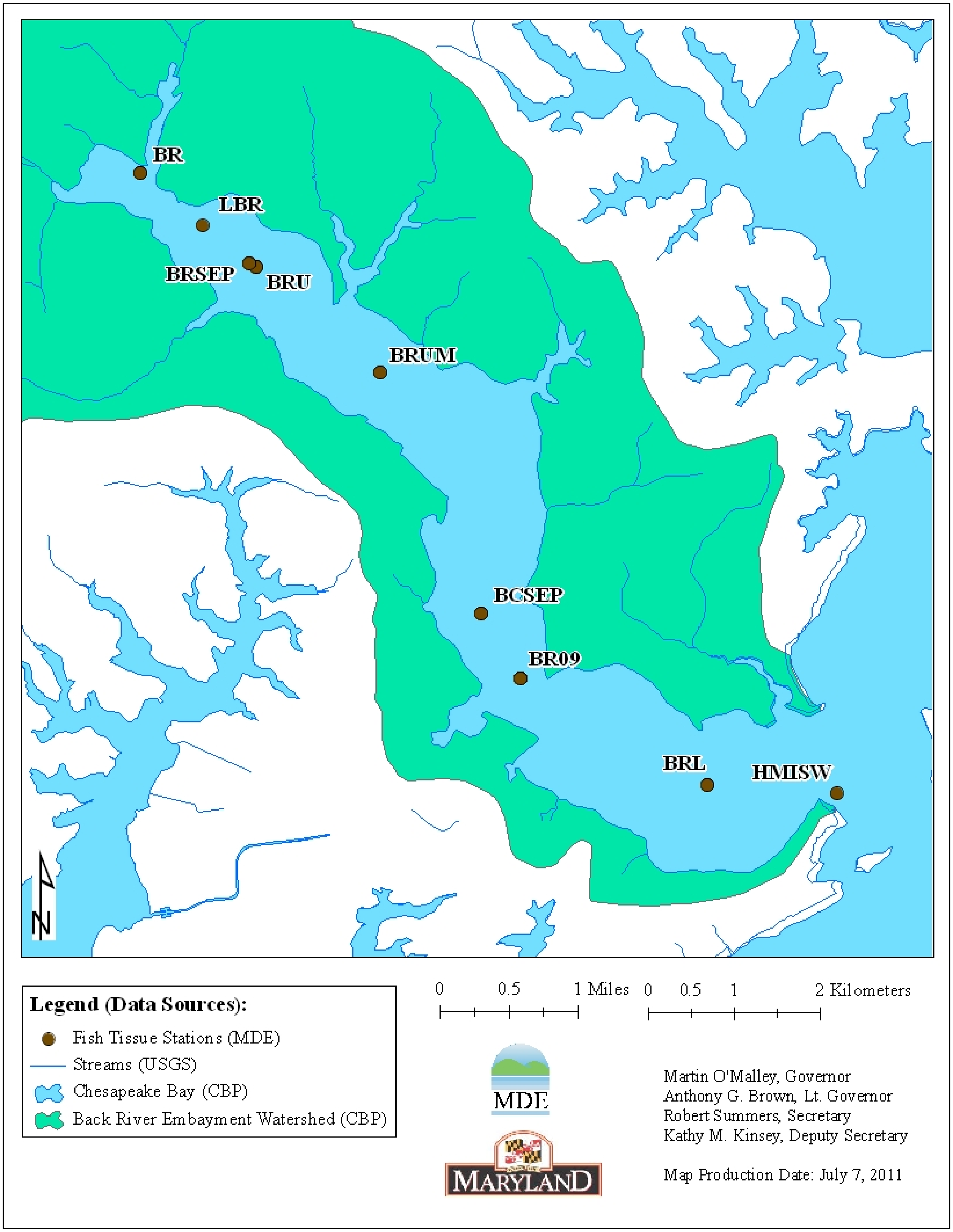


Figure K-3: PCB Fish Tissue Monitoring Stations in the Back River Embayment