FINAL

Total Maximum Daily Load of Polychlorinated Biphenyls in the Magothy River Mesohaline Chesapeake Bay Tidal Segment, Anne Arundel County, Maryland

FINAL

DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard, Suite 540
Baltimore MD 21230-1718

Submitted to:

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

February 2015

EPA Submittal Date: September 15, 2014
EPA Approval Date: March 16, 2015

FINAL

Table of Contents

FINAL

List of Figures

Magothy River PCB TMDL Report
Document version: February 12, 2015

List of Tables

List of Abbreviations

Adj-SediBAF	Adjusted Sediment Bioaccumulation Factor
Adj-tBAF	Adjusted Total Bioaccumulation Factor
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BMP	Best Management Practice
BSAF	Biota-sediment accumulation factor
CBP	Chesapeake Bay Program
CFR	Code of Federal Regulations
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
DRBC	Delaware River Basin Commission
EOF	Edge of Field
EOS	Edge of Stream
EPA	U.S. Environmental Protection Agency
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	Land Management Administration
LRP-MAP	Land Restoration Program Geospatial Database
M	Meter
M^2	Square meter
M^3	Cubic meter
MD	Maryland
MDE	Maryland Department of the Environment
MDL	Maximum Daily Load

mg	Milligram
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer Systems
Ng	Nanogram
NOAA	National Oceanic & Atmospheric Administration
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
TMDL	Total Maximum Daily Load
tBAF	Total Bioaccumulation Factor
tPCB	Total PCB
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	Wasteload 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 Magothy River Mesohaline Chesapeake Bay Tidal Segment (from this point on in the document the "Magothy River Mesohaline Chesapeake Bay Tidal Segment" will be referred to as "Magothy River") (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID:MD-MAGMH). 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 for the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2014a).

Maryland WQSs specify that all surface waters of the State shall be protected for water contact recreation, fishing, and protection of aquatic life and wildlife (COMAR 2014a). The designated use of the waters of the Magothy River (8-digit Basin Code: 02131001) is Use II – *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2014b). The Maryland Department of the Environment (MDE) has identified the waters of the Magothy River (Integrated Report Assessment Unit ID: MD-MAGMH) on the State's 2012 Integrated Report as impaired by nutrients (nitrogen & phosphorous) (1996), fecal coliform (1996), impacts to biological communities (2004), PCBs in fish tissue (2006), and fecal coliform (Deep Creek Tributary) (2012) (MDE 2012). A fecal coliform TMDL for the Magothy River was approved by EPA on February 20, 2006. The Chesapeake Bay TMDL, which was approved by the EPA on December 29, 2010, addressed the sediment and nutrient listings for the Magothy River. The TMDL established herein by MDE will address the total PCB (tPCB) listing for the tidal waters of the Magothy River, for which a data solicitation was conducted, and all readily available data have been considered. The listing for impacts to biological communities and fecal coliform (Deep Creek Tributary) will be addressed at a future date. The previously approved Fecal Coliform TMDL does not address the listing for the Deep Creek Tributary.

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 Magothy River 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 river, is supported. However, this TMDL will also ensure the protection of all other applicable designated uses within the river. This objective was achieved via the use of field observations and a one-segment Tidal Prism Model. The model incorporates the influences of freshwater discharge, tidal flushing and exchanges between the water column and bottom sediments, thereby representing the dynamic transport within the Magothy River. The water quality 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 Magothy River;
2. Simulate long-term tPCB concentrations in the water column and bottom sediments;
3. Estimate the load reductions necessary to meet the TMDL water column and sediment endpoint 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 to reach the TMDL water column and sediment 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 Magothy River and the Chesapeake Bay mainstem.

The CWA, as recently interpreted by the United States District Court for the District of Columbia, 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 Magothy River , these designated uses, as described previously, include "water contact recreation," "fishing," "the protection of aquatic life and wildlife," and "Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting". The TMDLs presented herein were developed specifically to be supportive of the "fishing" designated use, ensuring that the consumption of fish does not impact human health, thus addressing the impairment listings for "PCBs in fish tissue".

The water column and sediment TMDL endpoint tPCB concentrations applied within this analysis are derived from Maryland's Integrated Report fish tissue listing threshold tPCB concentration and site specific tBAFs. In the Magothy River, the tPCB endpoint concentrations are lower than: 1) EPA's human health criterion tPCB water column concentration relative to fish consumption, and 2) both Maryland's freshwater and saltwater chronic criteria tPCB water column concentrations (*i.e.*, water column TMDL endpoint tPCB concentrations < saltwater chronic tPCB criterion). 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 "Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting". 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 significant pathways 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.

Magothy River PCB TMDL Report
Document version: February 12, 2015

As part of this analysis, both point and nonpoint sources of PCBs have been identified throughout the Magothy River's watershed. Nonpoint sources include direct atmospheric deposition to the river, contaminated sites, runoff from non-regulated watershed areas and tidal influence from the Chesapeake Bay mainstem. Point sources only include National Pollutant Discharge Elimination System (NPDES) regulated stormwater runoff within the watershed. No NPDES wastewater treatment plants (WWTPs) or industrial process water facilities were identified within the watershed. The transport of PCBs from bottom sediments to the water column through resuspension and diffusion can also be a major source of PCBs in estuarine systems; however, under the framework of this TMDL it is not considered a source. The water quality model developed for this TMDL simulates conditions within the water column and sediment as a single system therefore exchanges between the sediment and water column are considered an internal loading. Only external sources to the system are assigned a baseline load or allocation within a TMDL. Therefore, PCB transport from bottom sediments through resuspension and diffusion will not be assigned a baseline load or allocation.

The objective of the TMDL established herein is to reduce current tPCB loads to the Magothy River so that the water column and sediment TMDL endpoint tPCB concentrations 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 2014a). 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 load, TMDL, and maximum daily load (MDL) for the Magothy River is presented in Table ES-1. When implemented, load reductions required under this TMDL will ensure that tPCB concentrations in the water column and sediment are at levels supportive of the "fishing" designated use. The transport of PCBs to the river from the Chesapeake Bay mainstem and from bottom sediment via resuspension and diffusion are currently estimated to be the major sources of PCBs. However, within this TMDL, as stated previously, the transport of PCBs from bottom sediments through resuspension and diffusion will not be assigned a tPCB baseline load or TMDL allocation.

The water quality model developed for simulating ambient sediment and water column tPCB concentrations within the Magothy River was used to determine the specific load reductions that would result in simulated tPCB concentrations in the sediment and water column that meet the TMDL endpoints. In this study, the model assumes that the tPCB concentrations in the Chesapeake Bay mainstem are decreasing at a rate of 5% per year as used in the Back River PCB TMDL study (MDE, 2011b). Given this rate of decline, the tPCB TMDL endpoints in both water column and sediment of the Magothy River embayment will be met in about 43.4 years with the natural attenuation of tPCB concentration in the Chesapeake Bay mainstem. Loads from the watershed, including non-point and point sources, and atmospheric deposition only account for

1.3% of the total tPCB baseline load. If these loads were reduced by 100% it would only reduce the time necessary to achieve the water column and sediment tPCB TMDL endpoints by 579 days (1.6 years). Therefore, no reductions to these loads are necessary in order to achieve the TMDL. When the TMDL endpoints are met, the tPCB load from the Chesapeake Bay mainstem will be reduced by about 92.3% including an explicit 5% Margin of Safety. At that time, the total load to the waterbody will be reduced by 90.6% from its baseline.

Table ES-1: Summary of Baseline tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in the Magothy River

Source	Baseline Load (g/year)	Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Chesapeake Bay Mainstem Tidal Influence	3,759.0	98.7%	289.4	92.3%	1.139
Direct Atmospheric Deposition	35.9	0.9%	35.9	0.0%	0.141
Maryland Non-regulated Watershed Runoff	3.3	0.1%	3.3	0.0%	0.013
Contaminated Sites	1.8	0.05%	1.8	0.0%	0.007
Nonpoint Sources	*3,800.0*	*99.8%*	*330.4*	*91.3%*	*1.300*
NPDES Regulated Stormwater	7.9	0.2%	7.9	0.0%	0.031
Point Sources	*7.9*	*0.2%*	*7.9*	*0.0%*	*0.031*
MOS	-	-	17.8	-	0.070
Total	**3,807.9**	**100.0%**	**356.1**	**90.6%**	**1.402**

Federal regulations require that TMDL analysis take into account the impact of critical conditions and seasonality on water quality (CFR 2014b). 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. PCB levels in fish tissue become elevated due to long term exposure primarily through consumption of lower trophic level organisms, rather than a critical condition defined by acute exposure to temporary fluctuations in water column tPCB concentrations. Therefore, the selection of the annual average 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 river. Thus, the TMDL implicitly accounts for seasonal variations as well as critical conditions.

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 the natural attenuation of PCBs in the environment. In addition, discovering and remediating any existing PCB land sources throughout the upstream Chesapeake Bay watershed via future TMDL development and implementation will further aid in the decline of the boundary condition tPCB concentrations and in meeting water quality goals in the river. 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 Magothy River.

1.0   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 Magothy River Mesohaline Chesapeake Bay Tidal Segment (from this point on in the document the "Magothy River Mesohaline Chesapeake Bay Tidal Segment" will be referred to as the "Magothy River") (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID:MD-MAGMH). 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 for the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2014a).

TMDLs are established to determine the pollutant load reductions required 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 protection of aquatic life and wildlife (COMAR 2014a). The designated use of the waters of the Magothy River (8-digit Basin Code: 02131001) is Use II – *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2014b). The Maryland Department of the Environment (MDE) has identified the waters of the Magothy River (Integrated Report Assessment Unit ID: MD-MAGMH) on the State's 2012 Integrated Report as impaired by nutrients (nitrogen & phosphorous) (1996), fecal coliform (1996), impacts to biological communities (2004), PCBs in fish tissue (2006), and fecal coliform (Deep Creek Tributary) (2012) (MDE 2012). A fecal coliform TMDL for the Magothy River was approved by EPA on February 20, 2006. The Chesapeake Bay TMDL, which was approved by the EPA on December 29, 2010, addressed the sediment and nutrient listings for the Magothy River. The TMDL established herein by MDE will address the total PCB (tPCB) listing for the tidal waters of the Magothy River, for which a data solicitation was conducted, and all readily available data have been considered. The listing for fecal coliform (Deep Creek Tributary) will be addressed at a future date. The Fecal Coliform TMDL from 2006 does not address the listing for the Deep Creek Tributary.

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

1

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 Magothy River was originally identified as impaired by PCBs in fish tissue on Maryland's 2006 Integrated Report based on fish tissue tPCB data from MDE's monitoring program that exceeded the tPCB fish tissue listing threshold of 39 ng/g, or ppb – (wet weight) based on 4 meals per month by a 76 kg individual (MDE 2012). 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 Magothy River: brown bullhead (6 meals per month) and white perch (4 meals per month) (MDE 2014a).

2.0   SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Magothy River is a 6-mile-long tidal tributary of the Chesapeake Bay in Anne Arundel County, Maryland. From its headwaters in northeast Anne Arundel County, in the vicinity of Pasadena, the river enters the Chesapeake Bay south of Gibson Island. The tidal range of the Magothy River is 0.97 feet (0.3 meters [m]) based on the United States National Oceanic and Atmospheric Administration tidal station in Annapolis, MD. The average depth of the Magothy River is 10.2 feet (3.1 m). The drainage area of the Magothy River is approximately 92.7 square kilometers (km^2) (22,901 acres). The location of the Magothy River watershed is shown in Figure 1.

Land Use

According to the United States Geological Survey's (USGS) 2006 land cover data (USGS 2014), which was specifically developed to be applied within the Chesapeake Bay Program's (CBP) Phase 5.3.2 watershed model, land use in the Magothy River watershed is predominantly urban. Urban land occupies approximately 60.9% of the watershed, while 21.3% is forest, 16.4% is water/wetland, and 1.4% is agriculture. The land use distribution is displayed and summarized in Figures 2 and Figure 3 as well as Table 1.
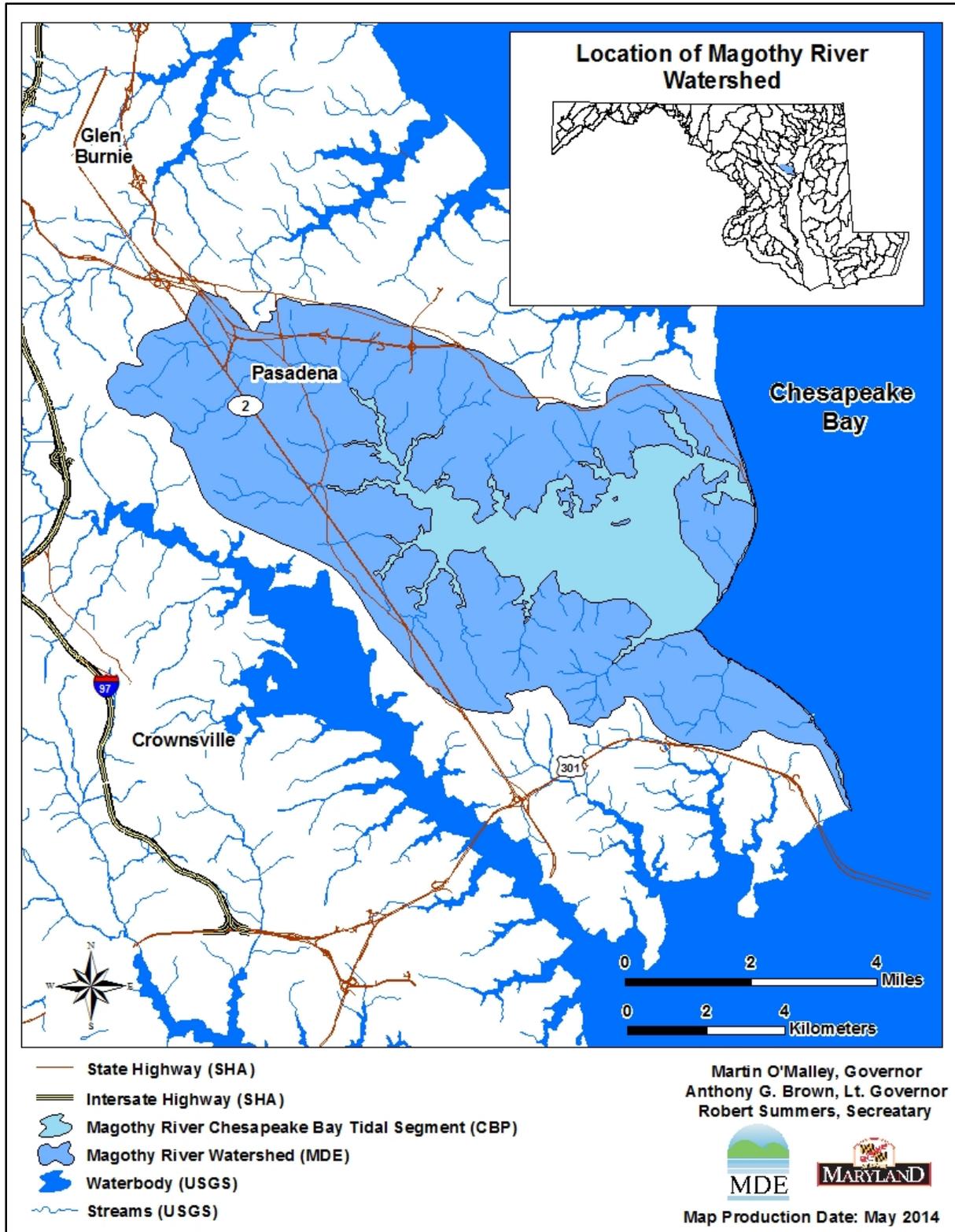
Figure 1: Location Map of the Magothy River Watershed

4
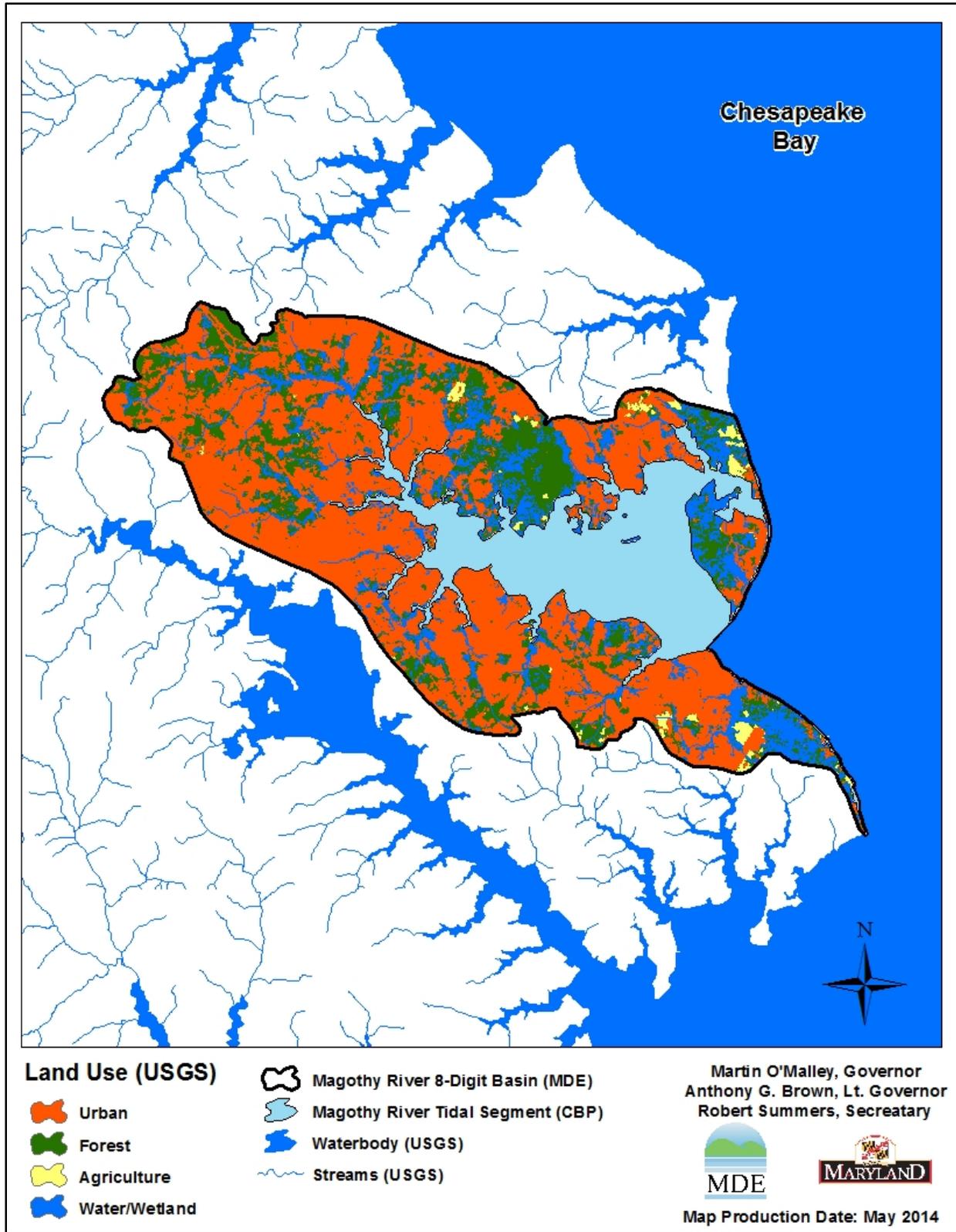
Figure 2: Land Use of the Magothy River Watershed

5

Table 1: Land Use Distributions in the Magothy River Watershed

Land Use	Urban	Forest	Water/ Wetland	Agriculture	Total
Area (km^2)	56.5	19.7	15.2	1.3	**92.7**
Percent (%)	60.9%	21.3%	16.4%	1.4%	**100.0%**
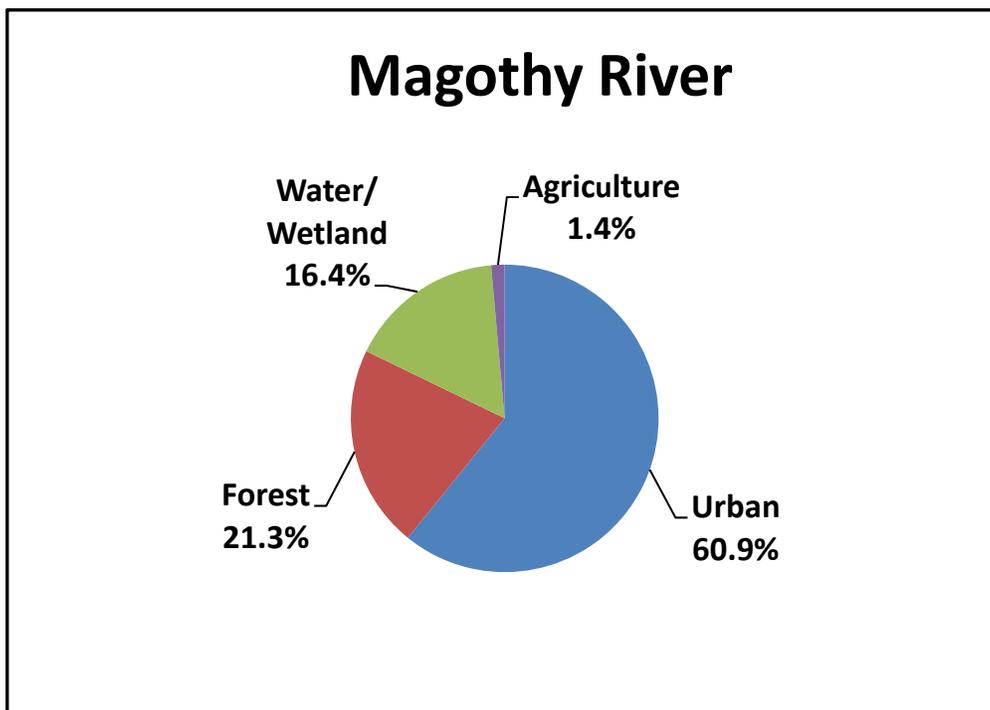
Figure 3: Land Use Distribution in the Magothy River Watershed

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 protection of aquatic life and wildlife (COMAR 2014a). The designated use of the waters of the Magothy River is Use II – *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2014b). There are no "high quality", or Tier II, stream segments (Benthic Index of Biotic Integrity [BIBI] and Fish Index of Biotic Integrity [FIBI]

6

aquatic life assessment scores > 4 [scale 1-5]) located within the direct drainage portions of the Magothy River (COMAR 2014c).

The State of Maryland has adopted three separate water column tPCB criteria: a criterion for the protection of human health associated with the consumption of PCB contaminated fish, as well as fresh and salt water chronic tPCB criteria for the protection of aquatic life. The freshwater aquatic life chronic criterion is used to assess non-tidal systems while the saltwater aquatic life chronic criterion is used to assess tidal systems. As the Magothy River is a tidal system, the saltwater aquatic life chronic criterion is applied for assessing these waters. The Maryland human health tPCB criterion is set at 0.64 nanograms/liter (ng/L), or parts per trillion (ppt) (COMAR 2014d; US EPA 2014a). The human health 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 CSF is used to estimate the risk of cancer associated with exposure to a carcinogenic substance (i.e. PCBs). A BCF is the ratio of the concentration of a chemical (i.e. tPCBs) in an aquatic organism to the concentration of the chemical in the water column. The slope factor is a toxicity value for evaluating the probability of an individual developing cancer from exposure to a chemical substance over a lifetime through ingestion or inhalation. 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 salt water chronic aquatic life tPCB criterion are set at 14 ng/L and 30 ng/L, respectively (COMAR 2014d; US EPA 2014a). The water column mean tPCB concentration in the Magothy River exceeds the human health tPCB criterion of 0.64 ng/L; however, none of the water column samples exceed the fresh and salt water aquatic life tPCB criterion of 14 ng/L and 30 ng/L (Table 2).

In addition to the water column 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, based on a fish consumption limit of 4 meals per month. When tPCB fish tissue concentrations exceed this threshold, the waterbody is listed as impaired for PCBs in fish tissue in Maryland's Integrated Report as it is not supportive of the "fishing" designated use (MDE 2012). MDE collected 12 fish tissue composite samples (53 total fish) for PCB analysis in the Magothy River in September 2009, September 2011 and March 2012. The tPCB concentrations for 7 out of the 12 fish tissue composite samples (several species of fish including white perch, yellow perch, spot, pumpkinseed sunfish and brown bullhead catfish) exceeded the listing threshold, demonstrating that a PCB impairment exists within the Magothy River.

In 2011 and 2012, monitoring surveys were conducted by MDE to measure water column tPCB concentrations at five tidal and five non-tidal (three stream & two stormwater) monitoring stations throughout the Magothy River and its watershed. The non-tidal tPCB water column

concentration data is required to characterize loadings from the watershed. The Magothy River watershed is heavily tidally influenced, limiting the number of non-tidal streams that may be sampled in order to characterize tPCB water column concentrations in freshwater flow from the watershed. Therefore, two additional non-tidal monitoring stations were located within stormwater culverts and sampled during rain events to characterize tPCB water column concentrations in freshwater surface runoff from the watershed. One of the tidal stations is located at the boundary of the Magothy River and the main stem of the Chesapeake Bay. The tPCB water column concentration data from this station is required to characterize tidal influences from the bay.   Sediment samples were collected at tidal stations ,including the boundary station, in 2011 to characterize tPCB sediment concentrations.

Table 2 summarizes the tPCB data for the fish tissue, water column, and sediment samples that were applied in developing this TMDL. Water column tPCB criteria and the tPCB fish tissue listing threshold are displayed in Table 3. Figure 4 shows a map of the PCB water quality station locations in the Magothy River. Appendix J contains tables of all the water column, sediment and fish tissue tPCB data.

Table 2: Summary of Fish Tissue, Water Column, and Sediment tPCB Data

Sample Media	Sample Type	Units	Sample Years	Sample Size	tPCB Concentration		
					Mean	Max.	Min.
Fish Tissue	Tidal	ng/g	2009/2011/2012	53*	51.45	125.29	10.68
Sediment	Tidal	ng/g	2011	8	22.23	94.49	0.17
	Tidal (Boundary)			2	8.90	15.53	2.28
Water Column	Tidal	ng/L	2011/2012	16	0.99	1.70	0.30
	Tidal (Boundary)		2011/2012	4	1.30	1.83	0.63
	Non-Tidal (Stream)		2011/2012	12	0.56	1.74	0.08
	Non-Tidal (Stormwater)		2011	4	0.56	0.70	0.34

*Total Fish Tissue Samples

Magothy River PCB TMDL Report
Document version: February 12, 2015

Table 3: Water Column tPCB Criteria and tPCB Fish Tissue Listing Threshold

tPCB Criteria/Threshold	Concentration
Fresh Water Chronic Aquatic Life Criterion	14 ng/L
Salt water Chronic Aquatic Life Criterion	30 ng/L
Human Health Criterion	0.64 ng/L
Fish Tissue Listing Threshold	39 ng/g

Magothy River PCB TMDL Report
Document version: February 12, 2015
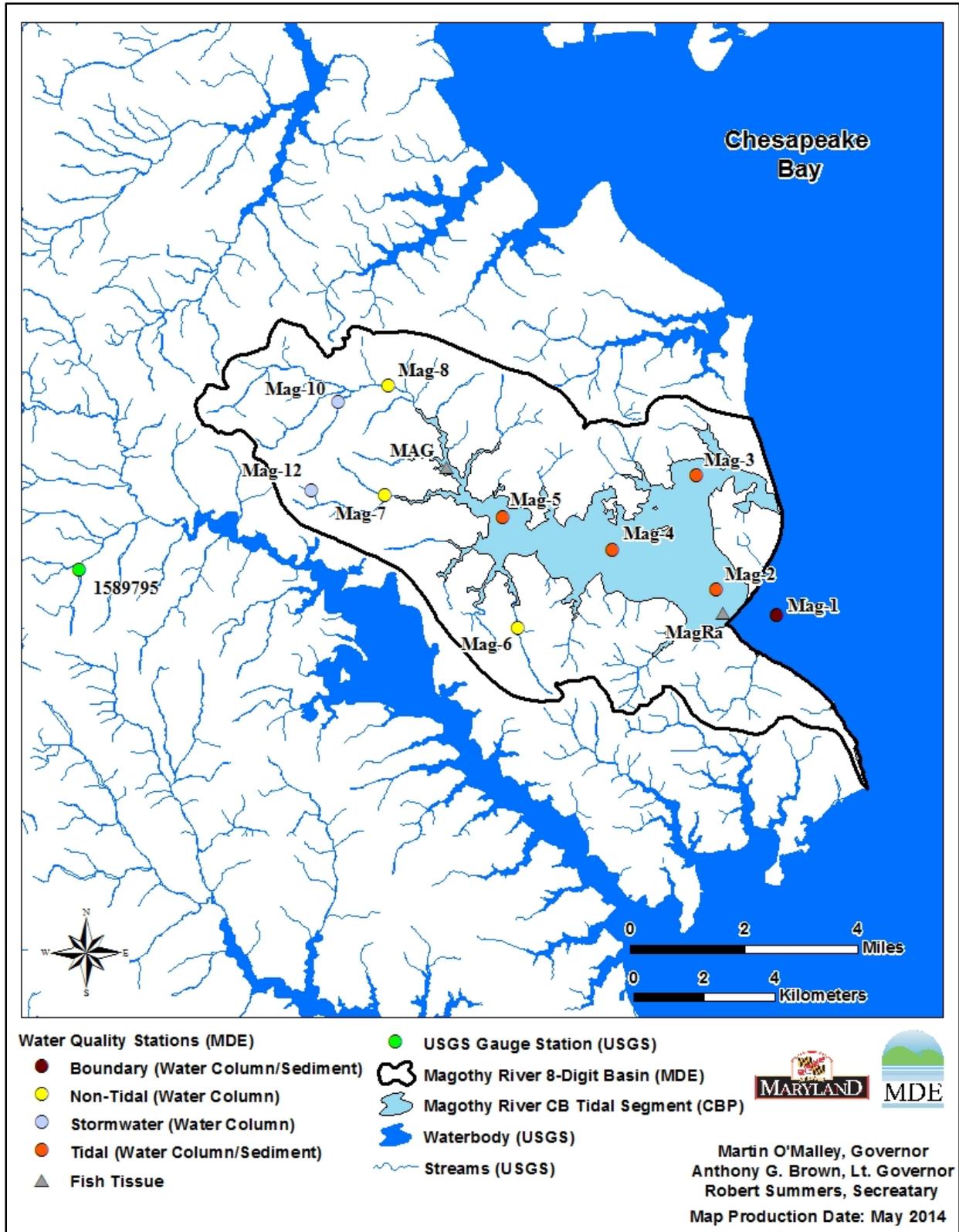
Figure 4: Water Quality Monitoring Stations in the Magothy River

10

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 GC-MS detection (Ayris *et al*. 1997, Holwell *et al*. 2007, Konietckka and Namiesnik 2008, Mydlová-Memersheimerová *et al*. 2009). This method is based on EPA method 8082 which was developed in 1996. Since that time the extraction protocols have been enhanced to fall in line with those of EPA method 1668a. 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 and ten C13 labeled standards). Based on this method, upwards of 100 chromatographic peaks can be quantified. Some of the peaks contain one PCB congener, while many are comprised of two or more co-eluting congeners (Appendix A).

3.0 TARGETED WATER COLUMN AND SEDIMENT TMDL ENDPOINTS

As described in Section 2.2, MDE evaluates whether a waterbody meets PCB related WQSs based on three criteria: 1) the tPCB Integrated Report fish tissue listing threshold (39 ng/g, or ppb), or 2) the human health tPCB water column criterion (0.64 ng/L, or ppt) or 3) the saltwater chronic tPCB criterion for protection of aquatic life (30 ng/L, or ppt). Since the Magothy River 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 river, is supported; however, this TMDL will also ensure the protection of all other applicable designated uses.

The tPCB fish tissue listing threshold was translated into an associated tPCB water column concentration to provide a TMDL endpoint, as the water quality model only simulates tPCB water column and sediment concentration and does not incorporate a food web model to predict tPCB fish tissue concentrations (see Equation 3.1 and Calculation 3.1). This was accomplished using the Adjusted Total Bioaccumulation Factor (Adj-tBAF) of 94,881 L/kg for the Magothy River, the derivation of which follows the method applied within the Potomac River tPCB 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).

$$\text{tPCB Water Column Concentration} = \frac{\text{tPCB Fish Tissue Concentration Listing Threshold}}{\text{Adj - tBAF} \times \text{Unit Conversion}}$$

(Equation 3.1)

Substituting 39 ng/g into the equation results in:

$$\text{tPCB Water Column Concentration} = \frac{39\,\text{ng/g}}{94,881\,\text{L/kg} \times 0.001\,\text{kg/g}} = 0.41\,\text{ng/L}$$

(which is < 0.64 ng/L [human health tPCB water column criterion]).

(Calculation 3.1)

Based on this analysis, the water column tPCB concentration of 0.41 ng/L, derived from the tPCB fish tissue listing threshold, is selected as the TMDL endpoint for the Magothy River, which is more stringent than the value of 0.64 ng/L for human health, and the fresh and salt water chronic aquatic life tPCB criteria of 14 ng/L and 30 ng/L, respectively.

Similarly, in order to establish a tPCB TMDL endpoint for the sediment in the Magothy River, a target tPCB sediment concentration was derived from the tPCB fish tissue listing threshold as the water quality model only simulates tPCB sediment concentrations and not tPCB fish tissue concentrations (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 19.76 (unitless) for the Magothy River, the derivation of which follows the method applied within the Potomac River tPCB TMDLs (Haywood and Buchanan 2007). Similar to the calculation of the water column 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.

$$\text{tPCB Sediment Concentration} = \frac{\text{tPCB Fish Tissue Concentration Listing Threshold}}{\text{Adj - SediBAF}}$$

(Equation 3.2)

Substituting 39 ng/g into the equation results in:

$$\text{tPCB Sediment Concentration} = \frac{39\ \text{ng/g}}{19.76} = 1.97\ \text{ng/g}$$

(Calculation 3.2)

Based on this analysis, the tPCB level of 1.97 ng/g derived from the fish tissue listing threshold is set as the sediment TMDL endpoint.

The CWA, as recently interpreted by the United States District Court for the District of Columbia, 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 impaired waters, as described in the Introduction to this report and Section 2.2. These include "marine and estuarine aquatic life", "shellfish harvesting", and "water contact recreation". The water column endpoint tPCB concentrations are more stringent than Maryland's saltwater aquatic life chronic criterion tPCB water column concentration. This indicates that the TMDLs are protective of the "aquatic life" designated use, specifically the protection of "marine and estuarine aquatic life and shellfish harvesting". Lastly, the designated use for "water contact recreation" is not associated with any potential human health risks due to PCB exposure. Dermal contact and accidental consumption of water from activities associated with "water contact recreation" is not a significant pathway for the uptake of PCBs. The EPA human health criterion was developed solely based on aquatic organism (e.g. fish or shellfish) 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.

4.0 SOURCE 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 organism's 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. 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). Humans can be exposed to PCBs via consumption of aquatic organisms, which over time have bioaccumulated PCBs.

A simplified conceptual model of PCB fate and transport in the Magothy River is diagramed in Figure 5. 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 tPCB loads to the Magothy River.

FINAL
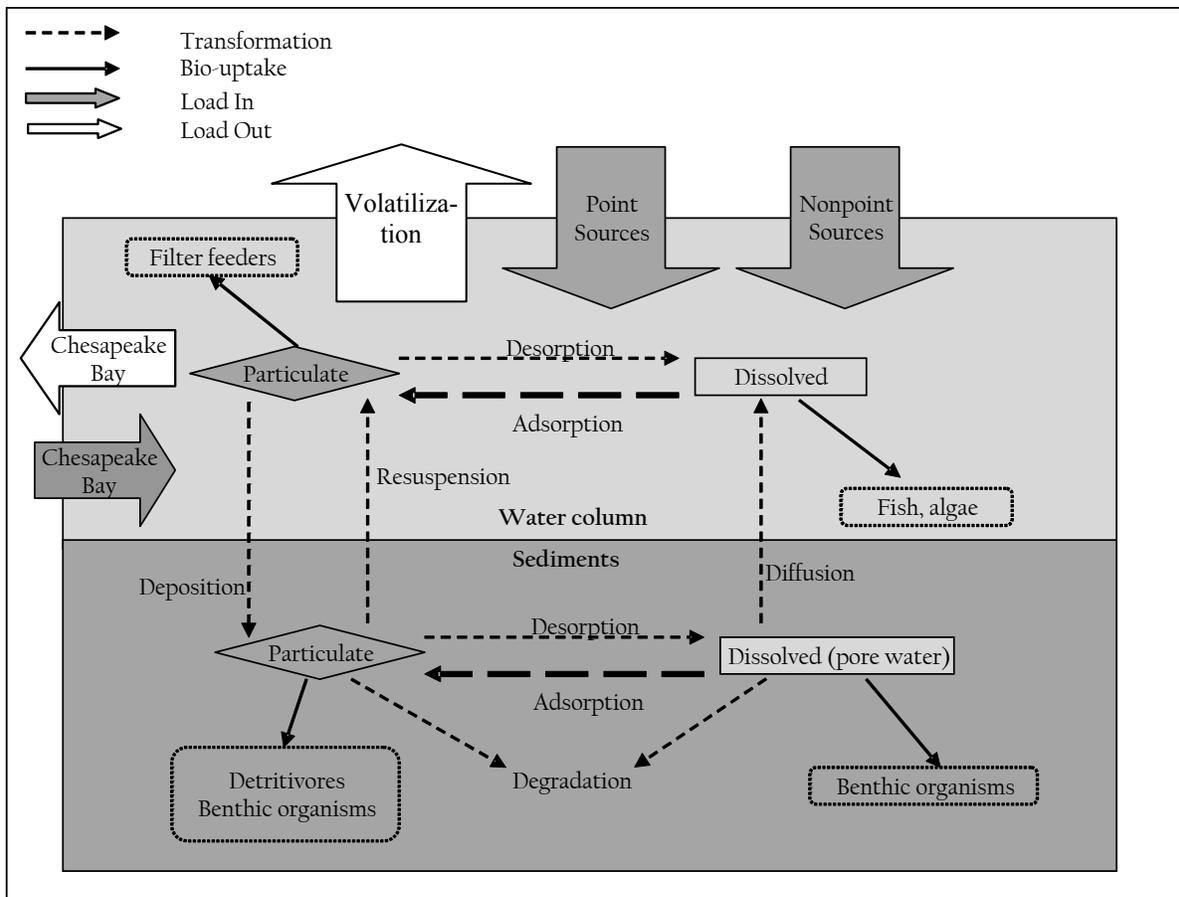
Figure 5: Conceptual Model of the Key Transport and Transformation Processes of PCBs in Surface Water and Bottom Sediments of the Magothy River and Entry Points to the Food Chain

4.1 Nonpoint Sources

For the purpose of this TMDL, under current conditions, the following nonpoint sources of PCBs have been identified: 1) Chesapeake Bay mainstem tidal influence, 2) direct atmospheric deposition to the river, 3) contaminated sites and 4) runoff from non-regulated watershed areas. The transport of PCBs from bottom sediments to the water column through resuspension and diffusion can also be a major source of PCBs in estuarine systems; however, under the framework of this TMDL it is not considered a source. A detailed explanation of each nonpoint source category will be presented in the following sections including additional information on resuspension and diffusion from bottom sediments.

Chesapeake Bay Mainstem Tidal Influence

The Magothy 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 Magothy River and within the Magothy River embayment, predicts

a gross tPCB input of 6,098 g/year from the bay to the river and a gross tPCB output of 2,339 g/year from the river to the bay. These loads result in a net tPCB transport of 3,759 g/year from the bay to the river. Therefore, currently the Chesapeake Bay mainstem is a major source of tPCBs to the Magothy River embayment (see Table 5, Appendix D, and Appendix E). However, with the attenuation of tPCB concentration in the Chesapeake Bay mainstem, the net transport of PCBs from the bay to the river could shift in the future.

Atmospheric Deposition

PCBs enter the atmosphere through volatilization. There is no recent study of the atmospheric deposition of PCBs to the surface of the Magothy River. 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 conducted by the Delaware River Basin Commission (DRBC) found PCB deposition rates ranging from 1.3 (non urban) to 17.5 (urban) $\mu g/m^2$/year of tPCBs (DRBC 2003). While urban land use accounts for over 60.9% of the Magothy River watershed, the land area is comprised primarily of low and medium density residential land uses. The urban deposition rate defined in CBP's study is a result of more heavily urbanized areas comprised primarily of high density residential, industrial and commercial land uses. The 1.6 $\mu g/m^2$/year tPCB depositional rate for non urban areas resultant from CBP's 1999 study will be applied in the Magothy River watershed. Therefore, the atmospheric deposition load to the direct watershed can be calculated by multiplying 1.6 $\mu g/m^2$/year by the Magothy River watershed area of 92.7 km^2, which results in a load of 148 g/year. However, according to Totten *et al*. (2006), only a portion 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 Magothy River from the watershed is approximately 1.5 g/year. This load is accounted for within the loading from the watershed and is inherently modeled as part of the non-regulated watershed runoff and the National Pollutant Discharge Elimination System (NPDES) Regulated Stormwater loads described below and in Section 4.2.

Similarly, the direct atmospheric deposition load to the surface of the river of 35.9 g/year was calculated by multiplying the surface area of the river (22.4 km^2) and the deposition rate of 1.6 $\mu g/m^2$/year.

Contaminated Sites

'Contaminated sites' refer 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.

Three sites with PCB contamination were identified based on information gathered from the EPA's Superfund database and MDE's Land Restoration Program Geospatial Database (LRP-

FINAL

MAP) (US EPA 2014b; MDE 2014b). These contaminated sites have 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. Table 4 lists these sites and Figure 6 depicts their locations.

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. A sediment delivery ratio was applied to calculate the final edge-of-stream (EOS) load. The contaminated site tPCB baseline load is estimated to be 1.82 g/year. A detailed description of the methodology used to estimate the contaminated site tPCB baseline load is presented in Appendix H.

Table 4: Summary of Contaminated Site tPCB Baseline Loads

Site Name	Site ID	Area (acres)	EOS Load (g/year)
A.S. Pearman	MD-452	3.98	0.48
Green Valley Road Site	MD-178	2.00	0.36
Woods Road Site	MD-192	39.00	0.98
Total		**44.98**	**1.82**

Magothy River PCB TMDL Report
Document version: February 12, 2015

FINAL
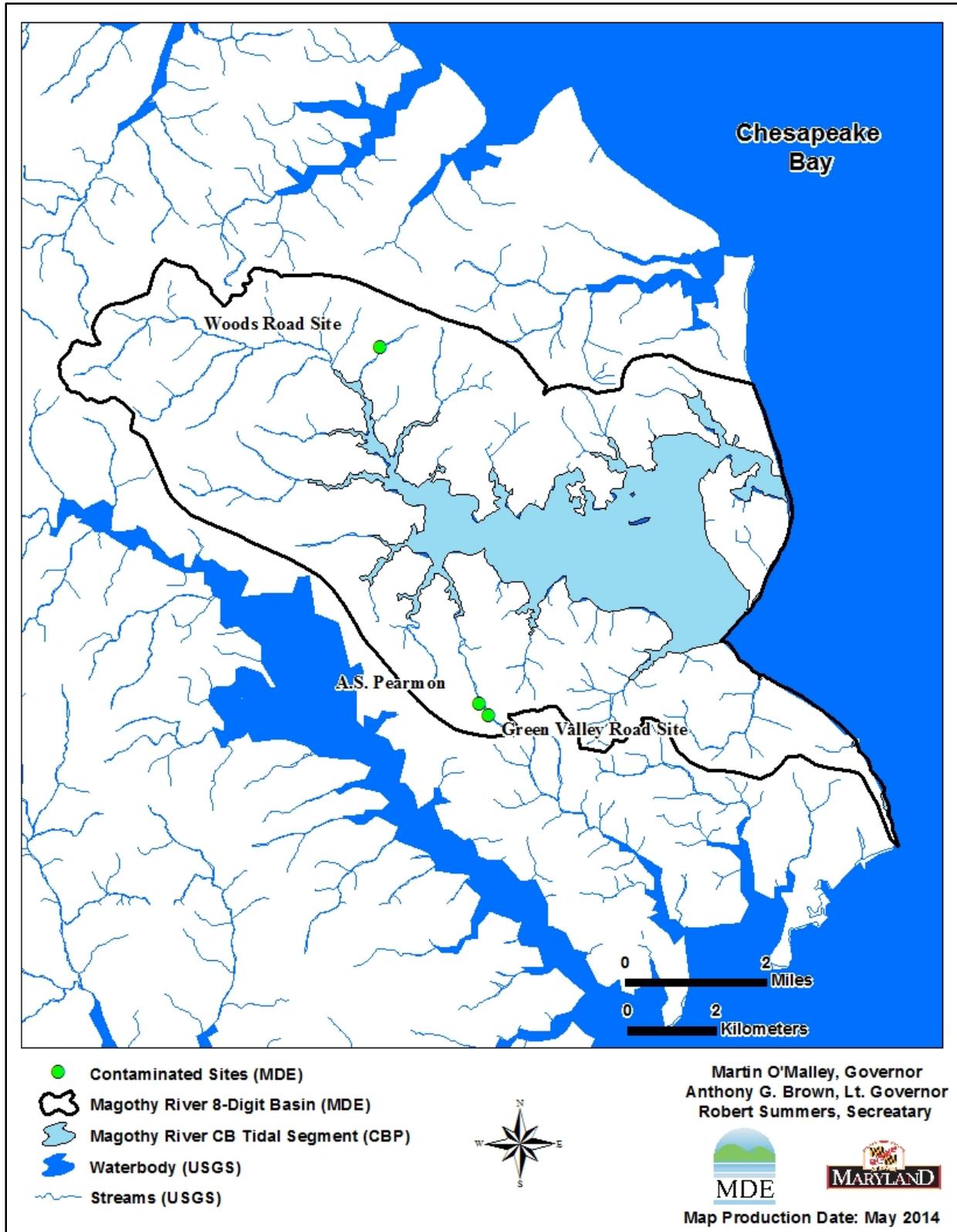
Figure 6: PCB Contaminated Sites in the Magothy River Watershed

18

Magothy River PCB TMDL Report
Document version: February 12, 2015

Watershed Sources: Non-regulated Watershed Runoff

The non-regulated watershed runoff tPCB load corresponds to the non-urbanized areas (*i.e.*, primarily forest and wetland areas) of the watershed. The load associated with the urbanized area of the watershed represents the NPDES Regulated Stormwater tPCB load which is presented in Section 4.2 under Point Sources.

MDE collected water column samples for PCB analysis at three non-tidal watershed monitoring stations and two stormwater monitoring stations in the Magothy River during May, July, October, and November of 2011 and March 2012 (See Appendix J). To calculate the watershed flow, the daily flow rates from May 1, 2000 to May 1, 2014 at the nearest United States Geological Survey (USGS) station located at South Fork Jabez Branch at Millersville (USGS 01589795) (see Figure 4) were averaged. The flow from the Magothy River watershed (25.92 cubic feet per second) was calculated by dividing its closest USGS station mean flow (0.724 cubic feet per second) by the USGS station drainage area (2.59 km^2), and multiplying this quotient by the watershed area (92.7 km^2) (Equation 4.1).

$$\text{Watershed Flow} = \frac{\text{USGS Mean Flow}}{\text{USGS Drainage Area}} \times \text{Watershed Area} \qquad \text{(Equation 4.1)}$$

The Magothy River watershed baseline tPCB loading (13.0 g/year) was calculated by multiplying its average flow and mean measured tPCB concentration (0.561 ng/L). The mean measured tPCB concentration is the average of all the concentration data for the three non-tidal watershed monitoring stations and two stormwater monitoring stations.

As mentioned above, about 1.5 g/year of the Magothy River watershed's baseline load is attributed to atmospheric deposition to the land surface of the direct drainage, and is inherently captured within the total watershed tPCB baseline load of 13.0 g/year.

The non-regulated watershed runoff tPCB baseline load (5.1 g/year) was estimated by multiplying the percentage of non-urban land use (39.1 %) within the watershed by the total watershed baseline load (13.0 g/year). As all three contaminated sites are located within the non-urbanized area, their total tPCB load (1.8 g/year) is subtracted from the Magothy River total load, resulting in a non-regulated watershed runoff tPCB baseline load of 3.3 g/year for the Magothy River.

Resuspension and Diffusion from Bottom Sediments

The transport of PCBs from bottom sediments to the water column through resuspension and diffusion can be a major source of PCBs in estuarine systems; however, under the framework of this TMDL it is not considered a non-point source. The water quality model developed for this TMDL simulates conditions within the water column and sediment as a single system therefore exchanges between the sediment and water column are considered an internal loading. Only external sources to the system are assigned a baseline load within a TMDL. As PCBs bind to the organic carbon fraction of suspended sediment in the water column and settle onto the

embayment floor, a large portion of the tPCB loads delivered from various point and non-point sources to the embayment deposits within the bottom sediments. This accumulation of PCBs can subsequently become a significant source of PCBs to the water column via the disturbance and resuspension of sediments. Dissolved tPCB concentrations in sediment pore water will also diffuse into the water column. The tidal prism model, applying observed tPCB concentrations in the water column and sediment, predicts a gross tPCB load of 3,345 g/year from bottom sediment to the water column through resuspension and diffusion and a gross tPCB load of 3,141 g/year from water column to the bottom sediment through settling. This results in a net tPCB transport of 204 g/year from the bottom sediment of the Magothy River to the water column under baseline conditions.

Although the transport of PCBs to the river from bottom sediment via resuspension and diffusion is currently estimated to be the major source of PCBs, this load contribution is resultant from other point and nonpoint source inputs (both historic and current) and is not considered to be directly controllable source. Therefore, this load will not be presented as a baseline load.

4.2   Point Sources

Point Sources in the Magothy River watershed only include stormwater discharges regulated under Phase I and Phase II of the NPDES stormwater program. No NPDES regulated WWTPs or industrial process water facilities were identified within the watershed. This section provides detailed explanations regarding the calculation of the point source tPCB baseline loads.

NPDES Regulated Stormwater

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 Magothy River watershed that could potentially convey tPCB loads to the river is presented in Appendix I.

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 Magothy River watershed is entirely located within Anne Arundel County, Maryland. The NPDES stormwater permits within the watershed include: (i) the area covered under Anne

Arundel County's Phase I jurisdictional MS4 permit, (ii) the State Highway Administration's Phase I MS4 permit, (iii) state and federal general Phase II MS4's, (iv) industrial facilities permitted for stormwater discharges, and (v) construction sites (see Appendix I for a list of all NPDES regulated stormwater permits).

The NPDES Regulated Stormwater tPCB Baseline Load (7.9 g/year) was estimated by multiplying the percentage of urban land use (60.9%) of the direct drainage by the total direct drainage baseline load (13.0 g/year).

4.3 Source Assessment Summary

From this source assessment all point and nonpoint sources of PCBs to the Magothy River watershed have been identified and characterized. Nonpoint sources of PCBs have been identified: 1) Chesapeake Bay mainstem tidal influence, 2) direct atmospheric deposition to the river, and 3) contaminated sites, and 4) runoff from non-regulated watershed areas. Point sources only include NPDES regulated stormwater runoff. No NPDES regulated WWTPs or industrial process water facilities were identified within the watershed. Estimated tPCB loads from these point and nonpoint sources represent the baseline conditions for the watershed.

A summary of the tPCB baseline loads for the Magothy River is presented in Table 5. The total tPCB load to the Magothy River embayment is 3,807.9 g/year (3.81 kg/year). In order to address the long term PCB load variation, the loads for this model are calculated using a 14-year mean flow from May 1, 2000 to May 1, 2014 (PCB data was taken in 2011 and 2012).

As explained in Section 4.1, since the loads from resuspension and diffusion from bottom sediments are not considered directly controllable (reducible) and are considered as internal loads within the modeling framework of the TMDL, they are not included in the tPCB baseline load summaries.

Magothy River PCB TMDL Report
Document version: February 12, 2015

Table 5: Summary of tPCB Baseline Loads in the Magothy River

Source	Baseline Load (g/year)	Baseline Load (%)
Chesapeake Bay Mainstem Tidal Influence	3,759.0	98.7%
Direct Atmospheric Deposition	35.9	0.9%
Maryland Non-regulated Watershed Runoff	3.3	0.1%
Contaminated Sites	1.8	0.0%
Nonpoint Sources	*3,800.0*	*99.8%*
NPDES Regulated Stormwater	7.9	0.2%
Point Sources	*7.9*	*0.2%*
MOS	*-*	*-*
Total	**3,807.9**	**100.0%**

5.0   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 2014a):

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

This section describes how the tPCB TMDL and the corresponding LAs and WLAs have been developed for the Magothy River watershed. 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 5.7.

5.2 Analysis Framework

A tidal prism model that incorporates the influences of both fresh water discharge and tidal flushing was used to simulate the dynamic interactions between the water column and bottom sediments within the Magothy River embayment and the Chesapeake Bay mainstem (MDE 2005, Kuo et al.2005). Within the Magothy River embayment, the tidal exchange with the Chesapeake Bay mainstem, freshwater discharge, 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 observed average tPCB concentrations in the water column and sediment (2011, 2012) were used to characterize the initial (baseline) model conditions. Based on the study of Ko and Baker (2004), on average the tPCB concentrations in the Upper Chesapeake Bay are decreasing at a rate of 6.5% per year. As a conservative estimation, this study assumes a PCB attenuation rate of 5.0% per year at the boundary between the Magothy River and the Chesapeake Bay mainstem as used in the Back River PCB TMDL study (MDE, 2011b). All other model inputs (i.e., fresh water discharge, tidal exchange rates, sediment and water column exchange rates, atmospheric deposition, and burial rate) were kept constant.

The model was initially run for a simulation period of 30,000 days to predict the time needed for the water column tPCB concentration to meet the site-specific tPCB water column TMDL endpoint. The results indicated that when the site-specific water column TMDL endpoint (0.41 ng/L) was met after 7,878 days (21.6 years), the tPCB sediment concentration was still higher than the site-specific sediment TMDL endpoint (1.97 ng/g). Consequently, the model was run again to predict the time needed for the sediment concentrations to reach the TMDL endpoint. Figure 7 shows the simulated results: after 15,845 days (about 43.4 years) the tPCB sediment concentration reached 1.97 ng/g, at which time the water column tPCB concentration was equal to 0.13 ng/L. If the model inputs for freshwater discharge (i.e., tPCB watershed load) and atmospheric deposition are reduced by 100% the time it takes to achieve the TMDL endpoints is only reduced by 579 days (1.6 years). Figure 8 shows the simulated results: after15,266 days (about 41.8 years) the tPCB sediment concentration reached 1.97 ng/g, at which time the water colum tPCb concentration was equal to 0.12 ng/L.
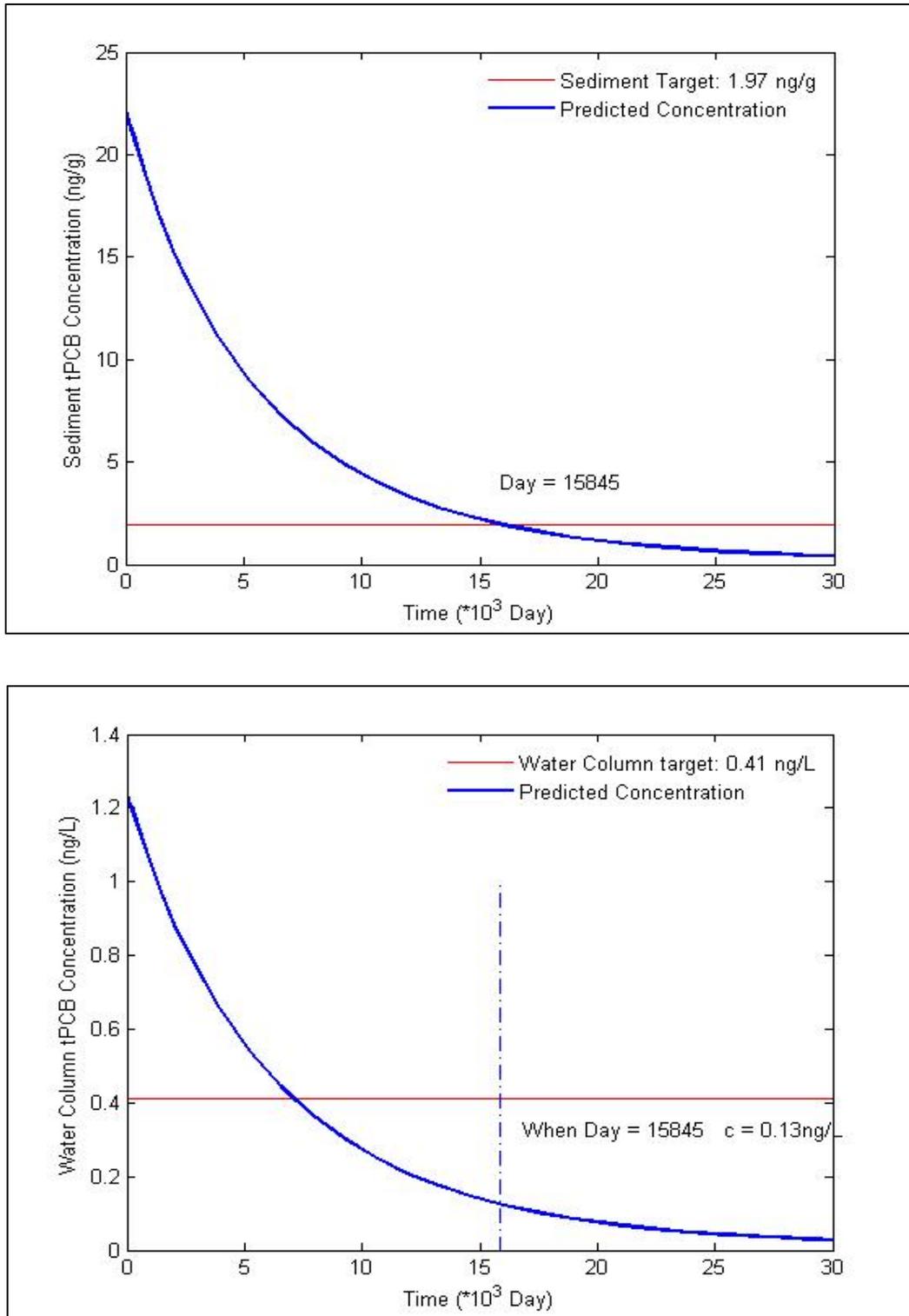
Figure 7: Change of Bottom Sediment and Water Column tPCB Concentrations with Time within the Magothy River (Natural Attenuation Only)
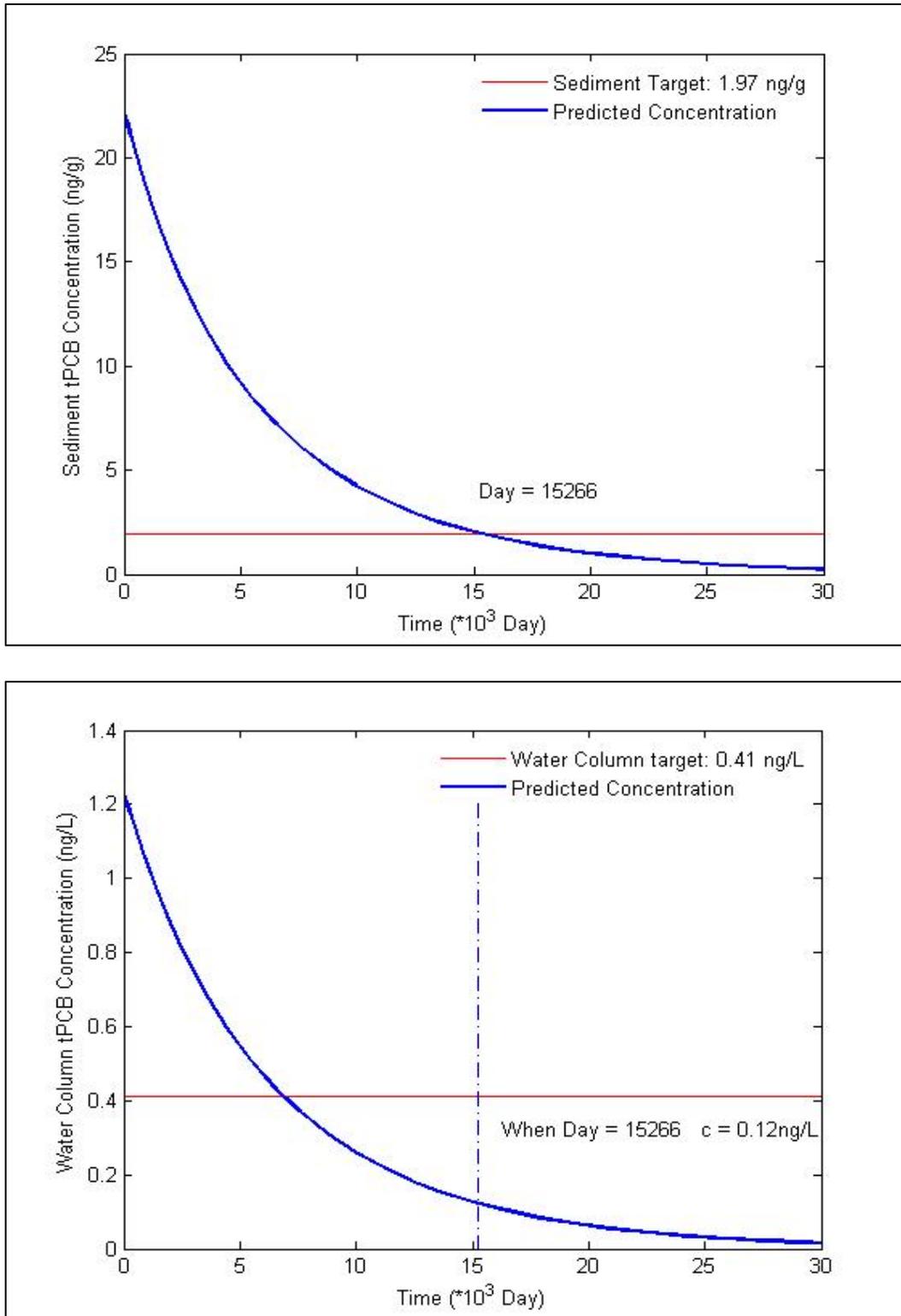
25

Figure 8: Change of Bottom Sediment and Water Column tPCB Concentrations with Time within the Magothy River (100% Reduction to Watershed Load & Atmospheric Deposition)

26

As stated in Section 4, the Chesapeake Bay mainstem tidal influence and resuspension and diffusion from the bottom sediments are the two primary sources of tPCB baseline loads resulting in the PCB impairment in the Magothy River embayment. However, the loads from resuspension and diffusion from bottom sediments are not considered to be directly controllable (reducible) loads and it is considered as an internal load within the modeling framework of the TMDL, therefore they are not included in the tPCB baseline load and TMDL allocation. Attainment of the site-specific tPCB water quality TMDL endpoints is expected to take place over time as the Chesapeake Bay mainstem tPCB concentrations continue to decline, which also results in the natural attenuation of tPCB levels in the legacy sediments (i.e., the covering of contaminated sediments with newer, less contaminated materials, flushing of sediments during periods of high stream flow, and biodegradation). Assuming that the tPCB concentrations in the Chesapeake Bay mainstem will continue to decline, at or above the current rate of 5% per year, the water column and sediment tPCB TMDL endpoints will be met after 15,845 days (about 43.4 years) thus meeting the "fishing" designated use in the Magothy River embayment. A reduction to model inputs for freshwater discharge (i.e., tPCB watershed load) and atmospheric deposition is not required as it will only reduce the time it takes to achieve the TMDL endpoints by 579 days (1.6 years).

5.3 Critical Condition and Seasonality

Federal regulations require TMDL analysis to take into account the impact of critical conditions and seasonality on water quality (CFR 2014a). The intent of this requirement is to ensure that water quality is protected when it is most vulnerable.

This TMDL is protective of human health at all times; thus, it implicitly accounts for seasonal variations as well as critical conditions. Achievement of the TMDL endpoints for sediment and water column through the implementation of load reductions will result in PCB levels in fish tissue acceptable for human consumption without posing a risk for development of cancer. Bioaccumulation of PCBs in fish is driven by long-term exposure through respiration, dermal contact, and consumption of lower order trophic level organisms. The critical condition defined by acute exposure to temporary fluctuations in PCB water column concentrations during storm events is not a significant pathway for uptake of PCBs. Monitoring of PCBs was conducted on a quarterly basis to account for seasonal variation in establishing the baseline condition for ambient water quality in the Magothy River and estimation of watershed loadings. 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 Magothy River. Furthermore, the water column TMDL endpoint is also supportive of the "protection of aquatic life" designated use at all times as it is more stringent than the freshwater and salt water chronic tPCB criteria.

27

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 2014b). 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 Magothy River. These allocations are also supportive of the 'protection of aquatic life" designated use as explained above.

As stated in Section 4.3, the PCB load from the Chesapeake Bay mainstem is the major sources for the Magothy River embayment, which accounts for about 98.7% of the total baseline load to the river. In Section 5.2, model simulation results show that both the water column and sediment PCB targets will be met in about 43.4 years with only natural attenuation of tPCB concentration at the Chesapeake Bay mainstem. Loads from the watershed, including non-point and point sources, and atmospheric deposition only account for 1.3% of the total tPCB baseline load. If these loads were reduced by 100% it would only reduce the time necessary to achieve the water column and sediment tPCB TMDL endpoints by 579 days (1.6 years). Therefore, no reductions to these loads are necessary in order to achieve the TMDL. When the TMDL endpoints are met, the tPCB load from the Chesapeake Bay mainstem will be reduced about 92.3% of its baseline load, including an explicit 5% Margin of Safety (Table 6).

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 Chesapeake Bay mainstem, as well as the initial condition of mean tPCB concentrations that was selected for the model. 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 Maximum Daily Loads

All TMDLs must include maximum daily loads (MDLs) consistent with the average annual TMDL. For this TMDL, tPCB MDLs are developed for each source category by converting daily time-series loads into TMDL values consistent with available EPA guidance on generating daily loads for TMDLs (US EPA 2007). 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 and considers a daily load level of a resolution based on specific data for each source category. The detailed calculation of MDLs is reported in Appendix G and the results are shown on Table 6.

5.7 TMDL Summary

Table 6 summarizes the tPCB baseline loads, TMDL allocations, load reductions, and maximum daily loads (MDLs) (see Appendix G for further details regarding MDL calculations) for the Magothy River.

Table 6: Summary of tPCB Baseline Loads, TMDL Allocations, MDL, and Associated Percent Reductions

Source	Baseline Load (g/year)	Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Chesapeake Bay Mainstem Tidal Influence	3,759.0	98.7%	289.4	92.3%	1.139
Direct Atmospheric Deposition	35.9	0.9%	35.9	0.0%	0.141
Maryland Non-regulated Watershed Runoff	3.3	0.1%	3.3	0.0%	0.013
Contaminated Sites	1.8	0.05%	1.8	0.0%	0.007
Nonpoint Sources	*3,800.0*	*99.8%*	*330.4*	*91.3%*	**1.300**
NPDES Regulated Stormwater	7.9	0.2%	7.9	0.0%	0.031
Point Sources	*7.9*	*0.2%*	*7.9*	*0.0%*	**0.031**
MOS	-	-	*17.8*	-	**0.070**
Total	**3,807.9**	**100.0%**	**356.1**	**90.6%**	**1.402**

6.0   ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurance that the tPCB TMDL for the Magothy River will be achieved and maintained.

As discussed in the previous sections, the Chesapeake Bay mainstem tidal influence and resuspension and diffusion from the bottom sediments have been identified as the two major sources of PCBs to the Magothy River embayment. However, the loads from resuspension and diffusion from bottom sediments are not considered to be directly controllable (reducible) loads and are considered as internal loads within the modeling framework of the TMDL, so they are not included in the tPCB baseline load and TMDL allocation.

Given that PCBs are no longer manufactured, and their use has been substantially restricted, it is reasonable to expect that with time tPCB concentrations in the aquatic environment will decline. In this study, it is assumed that the tPCB concentrations in the Chesapeake Bay mainstem are decreasing at a rate of 5% per year as used in the Back River PCB TMDL study (MDE, 2011b). Given this rate of decline, the tPCB levels in the Magothy River embayment are expected to decline over time. Processes, such as the burial of contaminated sediments with newer, less contaminated materials, flushing of sediments during periods of high stream flow, and biodegradation will contribute to this natural attenuation. Model scenario predict that with the natural attenuation of tPCB concentrations in the Chesapeake Bay mainstem the tPCB TMDL endpoints in both water column and sediment of the Magothy River embayment will be met in about 43.4 years. Loads from the watershed, including non-point and point sources, and atmospheric deposition only account for 1.3% of the total tPCB baseline load. If these loads were reduced by 100% it would only reduce the time necessary to achieve the water column and sediment tPCB TMDL endpoints by 579 days (1.6 years). Therefore, no reductions to these loads are necessary in order to achieve the TMDL.

A new Chesapeake Bay Watershed Agreement was signed on June 16, 2014 which includes goals and outcomes for toxic contaminants including PCBs (CBP 2014). The toxic contaminant goal is to "ensure that the Bay and its rivers are free of effects of toxic contaminants on living resources and human health." Objectives for the toxic contaminant outcomes regarding PCBs include 1) characterizing the occurrence, concentrations, sources and effects of PCBs, 2) identifying best management practices (BMPs) that may provide benefits for reducing toxic contaminants in waterways, 3) improving practices and controls that reduce and prevent the effects of toxic contaminants, and 4) building on existing programs to reduce the amount and effects of PCBs in the Bay and watershed. Implementation of the toxic contaminant goal and outcomes under the new Bay agreement as well as discovering and minimizing any existing PCB land sources throughout the Chesapeake Bay watershed via future TMDL development and implementation efforts could further help to meet water quality goals in the Magothy River.

Aside from the processes of natural attenuation, an alternative approach that can assist in reducing the tPCB concentrations in the water column so as to meet WQSs is the physical

removal of the PCB-contaminated sediments (*i.e.*, dredging). This process would minimize one of the primary, potential sources of tPCBs to the water column. When considering dredging as an option, the risk versus benefit must be weighed as the removal of contaminated sediment may potentially damage the habitat and health of the existing benthic community. 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 during dredging operations. In addition, the resuspension of contaminated sediments causes additional exposure of PCBs to aquatic organisms. In the case of the Magothy River, by allowing for natural attenuation of PCBs in the sediment, water quality supportive of the "fishing" designated use will be achieved within 43.4 years while avoiding disturbance of the benthic habitat.

MDE's Environmental Assessment and Standards Program will periodically monitor and evaluate concentrations of contaminants in recreationally caught fish, shellfish, and crabs throughout Maryland. This information will be used to evaluate the PCB impairment in the Magothy River embayment on an ongoing basis. 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 within Maryland, 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. Similar approaches may be applicable for all upstream jurisdictions with regards to PCB monitoring and stakeholder collaboration.

Under certain conditions, EPA's NPDES regulations allow the use of 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 2014c). 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 Magothy River, will also contribute toward tPCB load reductions and meeting PCB water quality goals. Implementation of similar restoration measures within upstream jurisdictions would also contribute additional reductions to PCB loadings from the Chesapeake Bay mainstem and provide progress towards achieving the TMDL. Other BMPs that focus on PCB source tracking and elimination at the source rather than end-of-pipe controls are also warranted.

Numerous stormwater dischargers are located in the 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 I of this document to view the current list of known NPDES stormwater dischargers).

An example of one jurisdiction with a PCB TMDL implementation plan is Montgomery County. The current Montgomery County Phase I MS4 permit requires that the jurisdiction develop implementation plans to meet its assigned NPDES Regulated Stormwater WLAs. In this TMDL, because its load was estimated at only 0.2% of the total PCB baseline load, the Anne Arundel County Phase I MS4 permit was not assigned a reduction and therefore no PCB implementation plan will be required.   Development of implementation plans by regulated stormwater dischargers within jurisdictions discharging to tidal waters north of the Magothy River would also contribute additional reductions to PCB loadings from the Chesapeake Bay and provide progress towards achieving the TMDL.

MDE regulates contaminated sites under Subtitle 14 of the Environment Article within COMAR which 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 2014e). 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 2014), 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 the contaminated site baseline load constitutes a relatively small percentage of the Total Baseline Load (0.05%) for the Magothy River watershed and no reduction to the total watershed load is required to meet the TMDL, further remediation of these sites will also not be required.

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. MDE will continue to monitor PCB levels in fish and evaluate the PCB impairment in the Magothy River embayment on an ongoing basis.

FINAL

7.0 REFERENCES

Ayris, S., Currado, G. M., Smith, D., and Harrad, S. 1997. GC/MS Procedures for the Determination of PCBs in Environmental Matrices. *Chemosphere* 35(5): 905-917.

Ashley, J. T. F., and J. E. Baker. 1999. Hydrophobic Organic Contaminants in Surficial Sediments of Baltimore Harbor: Inventories and Sources. *Environmental Toxicology and Chemistry* 18(5): 838-849.

CBP (Chesapeake Bay Program). 2014. Chesapeake Bay Watershed Agreement. http://www.chesapeakebay.net/documents/FINAL_Ches_Bay_Watershed_Agreement.withsignatures-HIres.pdf (Accessed July 2014).

CFR (Code of Federal Regulations). 2014a. 40 CFR 130.2. http://www.gpo.gov/fdsys/pkg/CFR-2002-title40-vol18/pdf/CFR-2002-title40-vol18-sec130-2.pdf (Accessed April, 2014).

_____. 2014b. 40 CFR 130.7. http://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol22/pdf/CFR-2011-title40-vol22-sec130-7.pdf (Accessed April, 2014).

_____. 2014c. 40 CFR 122.44(k). http://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol22/pdf/CFR-2011-title40-vol22-sec122-44.pdf (Accessed April, 2014).

Chapra, S.C. 1997. Surface Water-Quality Modeling. McGraw-Hill, New York, USA, pp. 844.

COMAR (Code of Maryland Regulations). 2014a. 26.08.02.07. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.07.htm (Accessed April, 2014).

_____. 2014b. 26.08.02.08 B(2)(a). http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.08.htm (Accessed April, 2014).

_____. 2014c. 26.08.02.04-1. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.04-1.htm (Accessed April, 2014).

_____. 2014d. 26.08.02.03-2 G (4). http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.03-2.htm (Accessed April, 2014).

_____. 2014e. 26.14.02.03. http://www.dsd.state.md.us/comar/getfile.aspx?file=26.14.02.03.htm (Accessed April, 2014).

De Bruijn, J., Busser, F., Seinen, W. and Hermens, J. 1989. Determination of Octanol/Water Partition Coefficients for Hydrophobic Organic Chemicals with the "Slow-Stirring" Method. *Environmental Toxicology and Chemistry* 8(6): 499-512.

DRBC (Delaware River Basin Commission). 2003. PCB Water Quality Model for Delaware Estuary (DELPCB). West Trenton, NJ: Delaware River Basin Commission.

33

Haywood, H. C., and Buchanan, C. 2007. Total Maximum Daily Loads of Polychlorinated Biphenyls (PCBs) for Tidal Portions of the Potomac and Anacostia Rivers in the District of Columbia, Maryland, and Virginia. Rockville, MD: Interstate Commission on the Potomac River Basin.

Hoke, R. A., Ankley, G. T., Cotter, A. M., Goldstein, T., Kosian, P. A., Phipps, G. L. and VanderMeiden, F. M. 1994. Evaluation of Equilibrium Partitioning Theory for Predicting Acute Toxicity to Field Collected Sediments Contaminated with DDT, DDE and DDD to the Amphipod Hyalella Azteca. *Environmental Toxicology and Chemistry* 13(1): 157-166.

Ko F. C., and Baker, J. E. 2004. Seasonal and Annual Loads of Hydrophobic Organic Contaminants from the Susquehanna River Basin to the Chesapeake Bay. *Marine Pollution Bulletin* 48(9-10): 840–851.

Konieczka, P., and Namiesnik, J. 2008. Determination of PCBs in Marine Sediment Using Pressurised Liquid Extraction-Gas Chromatography-Isotope Dilution Mass Spectrometry-Method Validation. *Chemical Analysis* 53(6): 785-796.

Kuo, A., K. Park, S. Kim, and J. Lin. 2005. A tidal Prism Water Quality Model for Small Coastal Basins. *Coastal Management* 33: 101-117.

MDE (Maryland Department of the Environment). 2005. *Total Maximum Daily Loads of Fecal Coliform for Restricted Shellfish Harvesting Areas in the Wicomico River Watershed Basin (Charleston Creek and Chaptico Bay) in Charles and St. Mary's Counties, Maryland*. Baltimore, MD: Maryland Department of the Environment.

_____. 2011a. Total Maximum Daily Loads of Polychlorinated Biphenyls in Baltimore Harbor, Curtis Creek/Bay, and Bear Creek Portions of Patapsco River Mesohaline Tidal Chesapeake Bay Segment, Maryland. Baltimore, MD: Maryland Department of the Environment.

_____. 2011b. Total Maximum Daily Loads of Polychlorinated Biphenyls in Back River Oligohaline Tidal Chesapeake Bay Segment, Maryland. Baltimore, MD: Maryland Department of the Environment.

_____. 2012. The 2012 Integrated Report of Surface Water Quality in Maryland. Baltimore, MD: Maryland Department of the Environment. Also Available at: http://www.mde.maryland.gov/programs/water/tmdl/integrated303dreports/pages/2012_ir.aspx. (Accessed April 2014)

_____. 2014a. Statewide Fish Consumption Guidelines for All Ages: Table. http://mde.maryland.gov/programs/Marylander/CitizensInfoCenterHome/Documents/Fish%20Consumption%20Docs/Maryland_Fish_Advisories_2014_Web_bluecatedit.pdf (Accessed April, 2014)

_____. 2014b. Land Restoration Program's Geospatial Database (LRP-MAP). Baltimore, MD: Maryland Department of the Environment. http://167.102.241.76/mde_lrp (Accessed April, 2014).

Magothy River PCB TMDL Report
Document version: February 12, 2015

Mydlova-Memersheimerova, J., Tienpont, B., David, F., Krupcik, J., and Sandra, P. 2009. Gas Chromatography of 209 Polychlorinated Biphenyl Congeners on An Extremely Efficient Nonselective Capillary Column. *Journal of Chromatography A* 1216(32): 6043-6062.

QEA (Quantitative Environmental Analysis, LLC). 1999. PCBs in the Upper Hudson River – Volume I, Historical Perspective and Model Overview. Albany, NY: Quantitative Environmental Analysis, LLC.

RETEC (The RETEC Group, Inc.). 2002. Remedial Investigation Report Lower Fox River and Green Bay, Wisconsin - Prepared for Wisconsin Department of Natural Resources.

Thomann R. V., and Mueller, J. A. 1987. Principles of Surface Water Quality Modeling and Control. New York City, NY: Harper & Row.

Totten, L. A., Panangadan, M., Eisenreich, S. J., Cavallo, G. J. and Fikslin, T. J. 2006. Direct and Indirect Atmospheric Deposition of PCBs to the Delaware River Watershed. Environmental Science and Technology. 40(7): 2171-2176.

US District Court for the District of Columbia. 2011. Anacostia Riverkeeper Inc., *et al.*, Plaintiffs, v. Lisa Jackson, Administrator, United States Environmental Protection Agency, *et al.*, Defendants: Order and Judgment. Washington, DC: US District Court of the District of Columbia.

US EPA (US Environmental Protection Agency). 1991. Technical Support Document (TSD) for Water Quality-based Toxics Control. Washington, DC: U.S. Environmental Protection Agency. Also Available at http://www.epa.gov/npdes/pubs/owm0264.pdf.

_____. 1999. Chesapeake Bay Basin Toxics Load and Release Inventory. Annapolis, MD: U.S. Environmental Protection Agency with Chesapeake Bay Program.

_____. 2002. Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs. Washington, DC: U.S. Environmental Protection Agency.

_____. 2003. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. Washington, DC: U.S. Environmental Protection Agency.

_____. 2004. The Incidence and Severity of Sediment Contamination in Surface Waters of the United States: National Sediment Quality Survey, 2nd Edition. Washington, D.C: US EPA, Office of Science and Technology.

_____. 2007. *Options for Expressing Daily Loads in TMDLs*. U.S. Environmental Protection Agency, Office of Wetlands, Oceans & Watersheds. http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/2007_06_26_tmdl_draft_daily_loads_tech-2.pdf (Accessed April, 2014).

_____. 2014a. National Recommended Water Quality Criteria. Washington, D.C: U.S. Environmental Protection Agency, Office of Science and Technology. http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm (Accessed April, 2014)

FINAL

_____. 2014b. Superfund Site Information Database. http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm (Accessed April, 2014).

USGS (United States Geological Survey). 2014. 2006 National Land Cover Dataset Chesapeake Bay Area, Modified Version 2.0. Annapolis, MD: United States Geological Survey, Chesapeake Bay Program Office.

Magothy River PCB TMDL Report
Document version: February 12, 2015

Appendix A: List of Analyzed PCB Congeners

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 GC-MS detection (Ayris *et al*. 1997, Holwell *et al*. 2007, Konietckka and Namiesnik 2008, Mydlová-Memersheimerová *et al* 2009). This method is based on EPA method 8082 which was developed in 1996. Since that time the extraction protocols have been enhanced to fall in line with those of EPA method 1668a. 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 and ten C13 labeled standards). Based on this method, upwards of 100 chromatographic peaks can be quantified. Some of the peaks contain one PCB congener, while many are comprised of two or more co-eluting congeners. PCB congeners identified under this method are displayed in Table A-1. 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 tPCB TMDL (Haywood and Buchanan 2007).

I. Data Description

The observation-based Adj-tBAF and Adj-SediBAF were calculated for the fish species within the Magothy River 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 (#)	Trophic Level (Description)	Home Range (miles)
White Perch	*Morone americana*	4	Predator	10
Brown Bullhead	*Ameiurus nebulosus*	3	Benthivore-Generalist	5
Spot	*Leiostomus xanthurus*	3	Benthivore-Generalist	10
Yellow Perch	*Perca flavescens*	3	Benthivore-Generalist	2
Pumpkinseed Sunfish	*Lepomis gibbosus*	3	Benthivore-Generalist	2

II. Total BAFs

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

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

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 (2003):

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

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):

$$\%fd = \frac{1}{1 + POC \times K_{ow} + DOC \times 0.08 \times K_{ow}} \tag{B-3}$$

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 showing in 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:

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

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:

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

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.

According to the data requirement for listing a waterbody as impaired by PCBs in fish tissue (http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Pages/Programs/WaterPrograms/TMDL/maryland%20303%20dlist/ir_listing_methodologies.aspx), the minimum data requirement is 5 fish (individual or composite of the same resident species) for a given waterbody and all fish that comprise a composite sample must be within the same size class (i.e., the smallest fish must be within 75% of the total length of the largest fish). The lowest tPCB water column threshold concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the "fishing" designated use (Table B-3). In the Magothy River, the lowest threshold concentration (0.41 ng/L) is associated with White Perch. There are four fish composites for White Perch with three composed of five fish and one composed of four fish. The length and weight for these fish are shown in Table B-4. For Magothy River the water column tPCB threshold concentration of 0.41 ng/L for White Perch was selected as the water column tPCB TMDL endpoint.

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

Species Name	Number of Fish (Composites)	tBAF (L/kg)	Baseline BAF (L/kg)	Adj-tBAF (L/kg)	Water Column tPCB Threshold Concentration (ng/L)
Brown Bullhead	11 (3)	33236	493552	22009	1.77
Pumpkinseed Sunfish	5 (1)	46494	421389	32957	1.18
White Perch	19 (4)	80401	404381	94881	**0.41**
Yellow Perch	13 (3)	72817	1280187	74871	0.52
Spot	5 (1)	38187	256882	34246	1.14

Table B-4: Individual Fish Lengths and Weights in the Yellow Perch Composites

Station ID	Sample ID	Sample Date	Fish Species	Fish/ Composite (#)	Fish ID	Length (cm)	Weight (g)	Sex
MAG	Mag-A	9/16/2011	White Perch	4	MAG-A-01	23.8	202	F
					MAG-A-02	21.7	173	M
					MAG-A-03	22.5	178	F
					MAG-A-04	21.1	152	M
MAG	MAG-E	3/7/2012	White Perch	5	MAG-E-01	27	309	F
					MAG-E-02	25	232	M
					MAG-E-03	24	218	F
					MAG-E-04	24	217	F
					MAG-E-05	23	204	F
MAG	MAG-F	3/7/2012	White Perch	5	MAG-F-01	23	187	F
					MAG-F-02	23.9	201	F
					MAG-F-03	23	194	M
					MAG-F-04	23	215	M
					MAG-F-05	22.7	185	F
MagRa	MAGO-A	9/17/2009	White Perch	5	MAGO-A-01	22.8	175	-
					MAGO-A-02	23.5	170	-
					MAGO-A-03	21.9	144	-
					MAGO-A-04	21	141	-
					MAGO-A-05	20	120	-

V. Biota-Sediment Accumulation Factors and Adjusted Sediment BAFs

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

$$\text{BSAF} = \frac{\text{tPCB}_{tissue}/\,\%\,\text{Lipid}}{\text{tPCB}_{sediment}/\,\%\,\text{Oraganic Carbon}} \qquad \text{(B-6)}$$

> 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:

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

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 threshold concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the "fishing" designated use (Table B-5). In the Magothy River, the lowest concentration (1.97 ng/g) is associated with White Perch and will be selected as the sediment TMDL endpoint.

Table B-5: BSAF, Adj-SedBAF, and Sediment TMDL Endpoint tPCB Concentrations

Species Name	BSAF	Adj-SedBAF	Sediment tPCB Threshold Concentration (ng/g)
Brown Bullhead	6.21	4.58	8.51
Pumpkinseed Sunfish	7.23	7.23	5.40
White Perch	15.01	19.76	**1.97**
Yellow Perch	11.32	16.42	2.37
Spot	7.13	7.13	5.47

Appendix C: Method Used to Estimate Watershed tPCB Load

In May, July, October, and November of 2011 and March 2012, MDE collected water column samples for PCB analysis at three non-tidal watershed monitoring stations and two stormwater monitoring stations in the Magothy River (Stations MAG-6, MAG-7, MAG-8, MAG-10 and MAG-12) (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 daily average flow rates from May 1, 2000 to May 1, 2014 of the closest USGS Station 01589795 located at Magothy Fork Jabez Branch at Millersville (Figure C1) were used to generate the flow duration curves. The flows for the dates on which the watershed samples were collected were identified on the flow duration curve (Figure C-2). This comparison indicates that the PCB samples are mainly located in the medium to high flow region. It was therefore not justifiable to use the regression method applied in the Back River tPCB TMDL (MDE 2011b) to the Magothy River.

To calculate the watershed flow, the daily flow rates of the USGS Station 1589795 were averaged. The Magothy River watershed flow (25.92 cubic feet per second) was calculated by dividing the USGS station mean flow (0.724 cubic feet per second) by the USGS drainage area (2.59 km^2), and multiplying by the Magothy River watershed area (92.7 km^2). The Magothy River watershed baseline tPCB loading (13.0 g/year) was calculated by multiplying the average flow and mean measured tPCB concentration (0.561 ng/L) of the three non-tidal watershed and two stormwater monitoring stations.
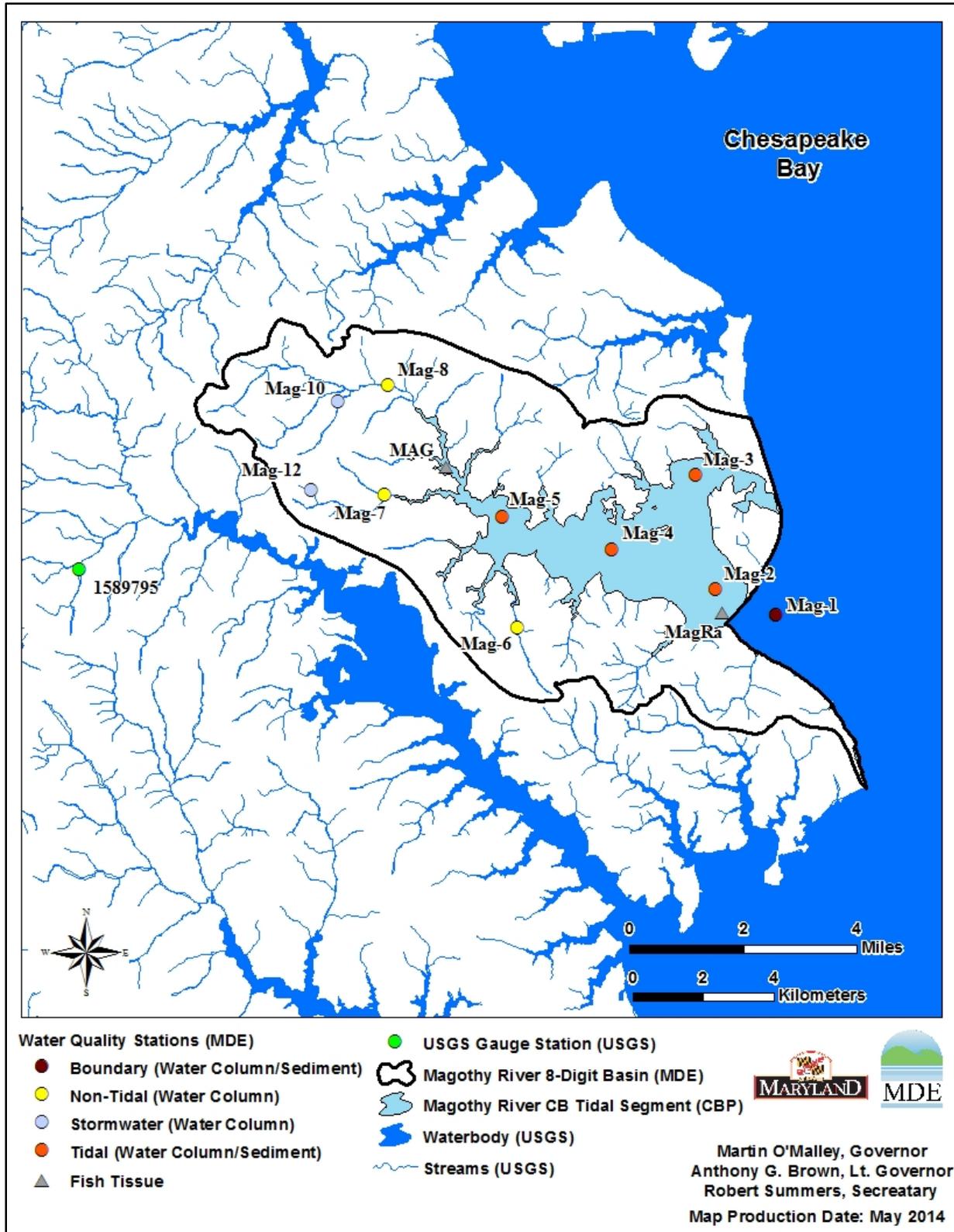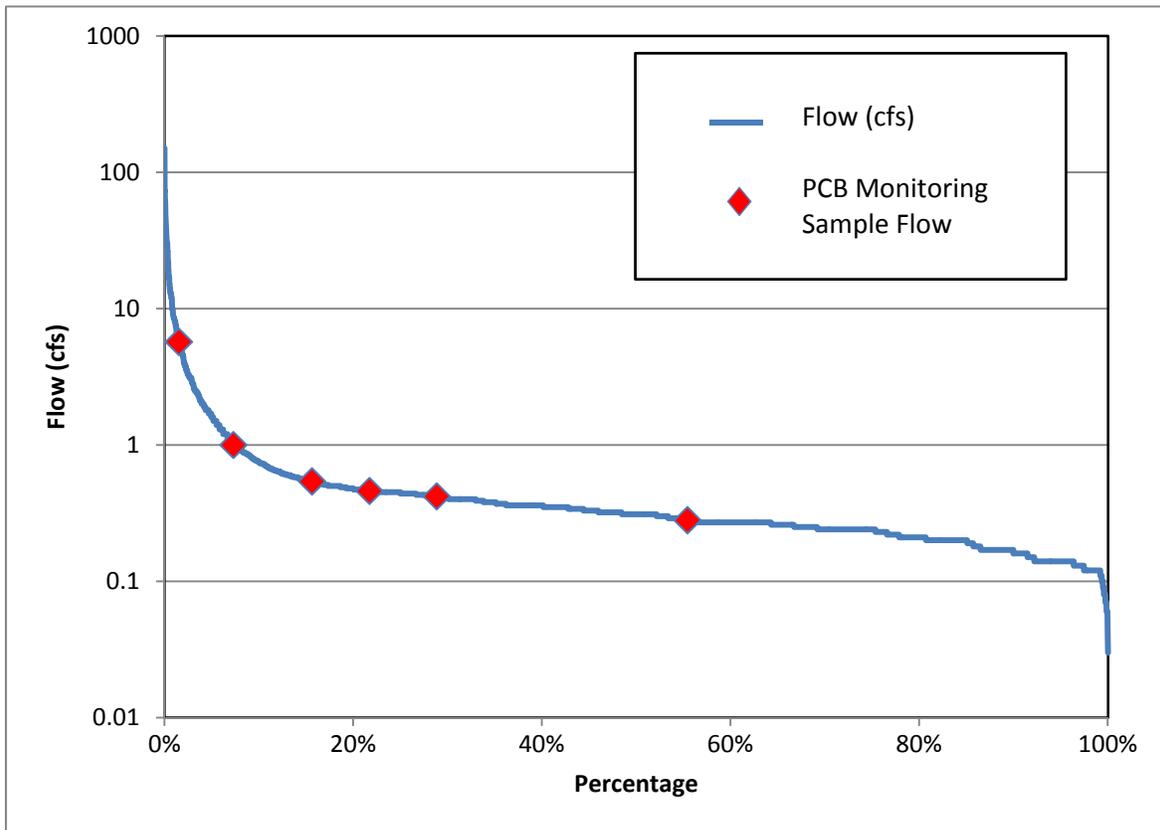
Figure C-1: PCB Water Quality Monitoring Stations/ USGS Station in the Magothy River Watershed

Note: The red points represent the non-tidal water quality monitoring and stormwater
monitoring sample flows

**Figure C-2: Relative Locations of PCB Water Column Measurement Station Sampling
Date Flow on the Flow Duration Curve**

Appendix D: Tidal Prism Model

A description of the tidal prism model applied in the development of the Magothy River embayment PCB 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_rAC_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 ($V_rAC_2$), 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:

$$\frac{dV_1C_1}{dt} = L_f - V_vAF_{do1}C_1 + (1-\alpha)Q_0C_0 - Q_bC_1 + V_rAC_2 - V_sAF_{p1}C_1 + V_dA(F_{do2}C_2 - F_{do1}C_1) \qquad \text{(D-1)}$$

$$\frac{dV_2C_2}{dt} = -V_rAC_2 + V_sAF_{p1}C_1 - V_dA(F_{do2}C_2 - F_{do1}C_1) - V_bAC_2 \qquad \text{(D-2)}$$

Where:
L_f =   PCB load from upstream (point and nonpoint sources) and direct atmosphere deposition and the load from the atmosphere to the river surface;
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);
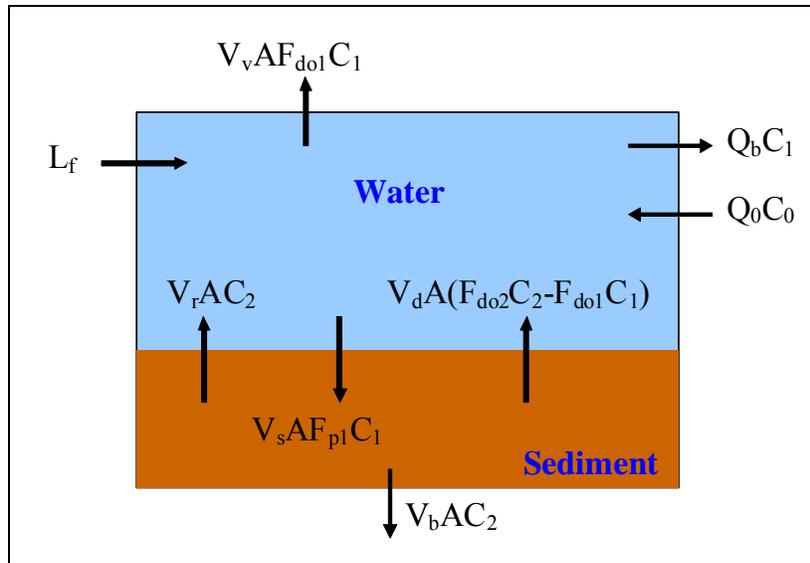V_s = rates of settling (m/d);
V_b = rates of burial (m/d).

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

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

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

L_f = 133,880 µg/day. It was obtained by summing all the upstream point and nonpoint source loads and the load from the atmosphere to the river surface.

V_v = 91.6 m/year = 0.251 m/day [derived using the method of Chapra (1997), assuming a wind speed of 1 m/s and a temperature of 10℃]

α = 0.5 (return ratio varies from 0.1 to 0.9)

A = 22,419,610 (m^2).

Q_0 = A × Tidal range ÷ Tidal circle×24 hours = 22,419,610×0.296÷12.42×24 = 12,823,584 (m^3/d).

Q_b = Q_f (Volume of water entering the embayment from the watershed) + Q_0×(1-α) = 63,407 + 12,823,584 ×(1-0.5) = 6,475,199 (m^3/d) (Q_f is the estimated daily watershed flow)

C_0 = 1.303×(0.95)^t (ng/L) (The measurement at the station STH-1 was used as the baseline boundary condition of the model. The TMDL methodology assumes that on average the tPCB concentrations at the Magothy River boundary are decreasing at a rate of 5% per year

C_1 = 0.990 (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 = 22.23×2,500×(1-0.80) ÷ 0.9983 = 11,132 (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 = 70,016,441 (m^3) (average depth of 3.12 meters)

V_2 = A × Active sediment layer thickness = 22,419,610 ×0.10=2,241,961 (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 × 0.8× (305.6)$^{-2/3}$ ÷ 365 = 0.00335 (m/d; Thomann and Mueller 1987)

F_{p1} = 0.3879; F_{do1} = 0.6121; F_{do2} = 0.00171 (see Appendix F for derivation)

V_s = 1 (m/d) (a default value of settling rate normally used in literature)

V_b = 3.935×10^{-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:

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

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:

$$V_r = \frac{V_s \times TSS}{\rho \times (1-\varphi)} - V_b = \frac{1 \times 17.56}{2500000 \times (1-0.80)} - 3.935 \times 10^{-6} = 3.12 \times 10^{-5} (m/d) \tag{E-2}$$

FINAL

Appendix F: Calculation of Fractions of Different PCB Forms

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

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

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

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

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.

Magothy River PCB TMDL Report
Document version: February 12, 2015

Appendix G: 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 Magothy River. 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 Magothy River.

Level of Resolution

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 Magothy River:

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.

Probability Level

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 95th percentile value would result in a MDL that would be exceeded 5% of the time.

V. Selected Approach

The approach selected for defining a Magothy River 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 Magothy River 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 tPCB TMDL, and the coefficient of variation (CV) of the initial condition for ambient water column tPCB concentrations in the Magothy River. 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 99th 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 Magothy River. The resulting CV of 0.418 was calculated using the following equation:

$$CV = \frac{\beta}{\alpha}$$ (Equation G-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:

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

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 0.418, and consistent units, the resulting dimensionless conversion factor from long-term average loads to a maximum daily value is 1.44. The average annual tPCB TMDL in the Magothy River is reported in g/year, and the conversion from g/year to a maximum daily load in g/day is 0.0039 (*e.g.* 1.44/365).

VIII. Approach for WWTPs

The TMDL also considers contributions from NPDES permitted WWTPs that discharge quantifiable concentrations of tPCBs to the Magothy River. No WWTPs were identified in the Magothy River Watershed.

IX. Results of Approach

Table G-1 lists the results of the selected approach to define the Magothy River MDLs.

Table G-1: Summary of tPCB Maximum Daily Load

Source	TMDL (g/year)	MDL (g/day)
Chesapeake Bay Mainstem Tidal Influence	289.4	1.139
Direct Atmospheric Deposition	35.9	0.141
Maryland Non-regulated Watershed Runoff	3.3	0.013
Contaminated Sites	1.8	0.007
Nonpoint Sources	***330.4***	***1.300***
NPDES Regulated Stormwater [1]	7.9	0.031
Point Sources	***7.9***	***0.031***
MOS	***17.8***	***0.070***
Total	**356.1**	**1.402**

FINAL

Appendix H: Contaminated Site Load Calculation Methodology

The term PCB 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. MDE has identified three contaminated sites within the Magothy River watershed with PCB soil concentrations at or above method detection levels. These sites (see Table H-1) were identified based on information gathered from MDE's LRP-MAP database (MDE 2014b), 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.

The tPCB EOF load from the site has been calculated, and subsequently, the EOF load would usually be converted to EOS load using methods applied within Maryland's nontidal sediment TMDLs. The modeling assumption behind the conversion to EOS load is that not all of the contaminated site tPCB loads are expected to reach the impaired waterbody. Thus, EOS load is thought to be a more accurate representation of tPCB loads from the site. Various delivery factors were applied.

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

I. tPCB Soil Concentration Data Processing

The Contaminated Site tPCB Baseline Load was only characterized for sites (contained within MDE's LRP-MAP database and located within the Magothy River 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. Three properties (See Table H-1) were identified as PCB contaminated sites. 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 values of the tPCB concentrations from these sites were calculated.

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 the 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 (e.g.,

---

[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.

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. If the site has a 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.

5. **Management:** 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 pervious 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 concentration of the identified site was converted to pounds of tPCBs per pound of soil (lbs/lb). The EOF contaminated site tPCB load is reported in Table H-1 in g/year.

IV. Calculating EOS tPCB loads

The EOF load is expected to be delivered to the system with some losses expected to occur over land. Various delivery factors have been applied to different sites to the EOF loads. The resultant EOS loads are listed in Table H-1.

Table H-1: Summary of Contaminated Site Soil Loss Value and EOS tPCB Loads

Site Name	Site ID	Median tPCB (μg/kg)	Soil Loss (lbs/year)	EOF Load (g/year)	Delivery Factor	EOS Load (g/year)
A.S. Pearman	MD-452	3100.00	575.86	0.60	0.60	0.48
Green Valley Road Site	MD-178	990.00	977.54	0.44	0.81	0.36
Woods Road Site	MD-192	718.75	3011.26	0.98	1.00	0.98
Total			**4564.66**	**2.02**	–	**1.82**

V. Contaminated Site Baseline Load Summary

The total Contaminated Site tPCB Baseline Load from the identified sites in the Magothy River watershed is estimated to be 1.82 g/year.

Appendix I: List of NPDES Regulated Stormwater Permits

Table I-1: NPDES Regulated Stormwater Permit Summary for the Magothy River Watershed[1]

MDE Permit	NPDES	Facility	City	County	Type	TMDL
-	MD0068276	State Highway Administration (MS4)	State-wide	All Phase I (Anne Arundel)	WMA6	Stormwater WLA
09-GP-0000	MDR100000	MDE General Permit to Construct	All	All		Stormwater WLA
04-DP-3316	MD0068306	Anne Arundel Phase 1 MS4	County-wide	Anne Arundel	WMA6	Stormwater WLA
02SW1910	MDR001910	A-A Recycle & Sand, Inc.	Pasadena	Anne Arundel	WMA5	Stormwater WLA
02SW1584	MDR001584	Anne Arundel County School Transportation Garage	Pasadena	Anne Arundel	WMA5	Stormwater WLA
02SW1039	MDR001039	Chesapeake Charter, Inc.	Annapolis	Anne Arundel	WMA5	Stormwater WLA
02SW1932	MDR001932	Clark Auto Parts, Inc.	Pasadena	Anne Arundel	WMA5	Stormwater WLA
02SW1454	MDR001454	Redmonds Auto Parts	Pasadena	Anne Arundel	WMA5	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 J: Total PCB Concentrations and Locations of the PCB Monitoring Stations

Tables J-1 through J-3 list the tPCB concentrations for sediment, fish tissue, and water column samples collected in the Magothy River.

Table J-1: Sediment tPCB Concentrations (ng/g) in the Magothy River

Station	Date	Station Type	Concentration (ng/g)
MAG-1	5/3/2011	Tidal (Boundary)	2.28
MAG-1	11/9/2011	Tidal (Boundary)	15.53
MAG-2	5/3/2011	Tidal	1.70
MAG-2	11/9/2011	Tidal	3.41
MAG-3	5/3/2011	Tidal	33.35
MAG-3	11/9/2011	Tidal	13.96
MAG-4	5/3/2011	Tidal	0.17
MAG-4	11/9/2011	Tidal	30.52
MAG-5	5/3/2011	Tidal	0.22
MAG-5	11/9/2011	Tidal	94.49

Table J-2: Fish Tissue tPCB Concentrations (ng/g) in the Magothy River

Station	Date	Fish Species	Fish/ Composite (#)	Mean Length (cm)	Mean weight (g)	Concentration (ng/g)
MagRa	9/17/2009	Brown Bullhead	3	29.00	367.33	30.0
MAG	9/16/2011	Brown Bullhead	3	27.3	277.0	29.8
MAG	3/7/2012	Brown Bullhead	5	27.2	243.0	10.7
MAG	9/16/2011	Pumpkinseed Sunfish	5	13.6	56.0	33.0
MagRa	9/17/2009	Spot	5	18.50	104.00	34.2
MagRa	9/17/2009	White Perch	5	21.90	150.00	43.3
MAG	9/16/2011	White Perch	4	22.3	176.3	125.3
MAG	3/7/2012	White Perch	5	24.6	236.0	69.5
MAG	3/7/2012	White Perch	5	23.1	196.4	74.7
MAG	9/16/2011	Yellow Perch	3	18.5	74.7	40.5
MAG	3/7/2012	Yellow Perch	5	27.1	227.8	51.6
MAG	3/7/2012	Yellow Perch	5	25.1	181.6	74.9

Table J-3: Water Column tPCB Concentrations (ng/L) in the Magothy River

Date	Station	Station Type	Conc. (ng/L)	Date	Station	Station Type	Conc. (ng/L)
05/03/11	MAG-1	Tidal (Boundary)	1.41	05/03/11	MAG-10	Stormwater	0.639
07/25/11	MAG-1	Tidal (Boundary)	0.63	10/20/11	MAG-10	Stormwater	0.700
11/09/11	MAG-1	Tidal (Boundary)	1.35	05/03/11	MAG-12	Stormwater	0.338
03/15/12	MAG-1	Tidal (Boundary)	1.83	10/20/11	MAG-12	Stormwater	0.555
5/3/2011	MAG-2	Tidal	1.252	05/03/11	MAG-6	Non-Tidal	0.242
7/25/2011	MAG-2	Tidal	0.677	07/25/11	MAG-6	Non-Tidal	0.829
11/9/2011	MAG-2	Tidal	0.760	11/09/11	MAG-6	Non-Tidal	1.161
3/15/2012	MAG-2	Tidal	1.603	03/15/12	MAG-6	Non-Tidal	1.742
5/3/2011	MAG-3	Tidal	0.843	05/03/11	MAG-7	Non-Tidal	0.374
7/25/2011	MAG-3	Tidal	0.433	07/25/11	MAG-7	Non-Tidal	0.218
11/9/2011	MAG-3	Tidal	1.315	11/09/11	MAG-7	Non-Tidal	0.082
3/15/2012	MAG-3	Tidal	1.703	03/15/12	MAG-7	Non-Tidal	0.308
5/3/2011	MAG-4	Tidal	0.933	05/03/11	MAG-8	Non-Tidal	0.285
7/25/2011	MAG-4	Tidal	0.572	07/25/11	MAG-8	Non-Tidal	0.294
11/9/2011	MAG-4	Tidal	1.234	11/09/11	MAG-8	Non-Tidal	0.369
3/15/2012	MAG-4	Tidal	1.248	03/15/12	MAG-8	Non-Tidal	0.847
5/3/2011	MAG-5	Tidal	0.616				
7/25/2011	MAG-5	Tidal	0.304				
11/9/2011	MAG-5	Tidal	1.324				
3/15/2012	MAG-5	Tidal	1.018				