# Total Maximum Daily Loads of Polychlorinated Biphenyls in the Elk River Oligohaline and the C&D Canal Oligohaline Tidal Chesapeake Bay Segments in Cecil 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

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## 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 |
| C&D Canal | Chesapeake & Delaware Canal |
| 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 |
| DMR | Daily Monitoring Record |
| DRBC | Delaware River Basin Commission |
| EOF | Edge of Field |
| EOS | Edge of Stream |
| EPA | U.S. Environmental Protection Agency |
| 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 |
| $M^2$ | Square meter |
| $M^3$ | Cubic meter |
| MD | Maryland |

| | |
|---|---|
| MDE | Maryland Department of the Environment |
| MDL | Maximum Daily Load |
| Mg | Milligram |
| MGD | Million gallons per day |
| MOS | Margin of Safety |
| MS4 | Municipal Separate Storm Sewer Systems |
| Ng | Nanogram |
| NOAA | National Oceanic and 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 | Waste Load Allocation |
| WQA | Water Quality Analysis |
| WQBEL | Water Quality Based Effluent Limit |
| WQLS | Water Quality Limited Segment |
| WQS | Water Quality Standard |
| WWTP | Waste Water Treatment Plant |
| µg | Microgram |

## EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for Polychlorinated Biphenyls (PCBs) in the Elk River Oligohaline Tidal Chesapeake Bay Segment (basin numbers 02130601, 02130603, and 02130605) (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-ELKOH) and the C&D Canal Oligohaline Tidal Chesapeake Bay Segment (basin number 02130604) (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-C&DOH), Maryland. Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards (WQSs). For each WQLS, the State is to either establish a TMDL of the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2013a).

Maryland WQSs specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life (COMAR 2013a). The specific designated use of the Elk River Oligohaline Tidal Chesapeake Bay Segment and the Chesapeake & Delaware (C&D) Canal Oligohaline Tidal Chesapeake Bay Segment is Use II – *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2013b). The Maryland Department of the Environment (MDE) has identified the waters of the Elk River Oligohaline Tidal Chesapeake Bay Segment (*Integrated Report* Assessment Unit ID: MD-ELKOH) on the State's 2012 Integrated Report as impaired for nutrients (nitrogen & phosphorous) (1996) and PCBs in fish tissue (2002) (MDE 2012). MDE has identified the waters of the C&D Canal Oligohaline Tidal Chesapeake Bay Segment (*Integrated Report* Assessment Unit ID: MD-C&DOH) on the State's 2012 Integrated Report as impaired by nutrients (nitrogen & phosphorous) (1996), arsenic (1996), cadmium (1996), silver (1996), and PCBs in fish tissue (2002) (MDE 2012). From this point on in the document, the Elk River and the C&D Canal Oligohaline Tidal Chesapeake Bay Segments will simply be referred to as the Elk River and the C&D Canal. The TMDL established herein by MDE will address the total PCB (tPCB) listings, for which a data solicitation was conducted, and all readily available data have been considered. Water Quality Analyses of arsenic, cadmium, and silver in the C&D Canal were approved by the EPA in November 2005 (MDE 2005). The Chesapeake Bay TMDL, which was approved by the EPA in December 2010, has addressed the nutrient listing for the Elk River and the C&D Canal.

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 will cause bioaccumulation within the fatty tissues of humans, which can potentially lead to the development of cancer.

Since the Elk River and the C&D Canal were 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 Elk River and the C&D Canal is supported. However, this TMDL will also ensure the protection of all other applicable designated uses within the area. This objective was achieved via the use of extensive field observations and a water quality model. The model incorporates the influences of tide, atmospheric deposition, freshwater inputs, and exchanges between the water column and bottom sediments, thereby representing realistic dynamic transport within the area.

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 Elk River and the C&D Canal;
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.

The CWA, as recently interpreted by the United States District Court, requires TMDLs to be protective of all the designated uses applicable to a particular waterbody (US District Court for the District of Columbia 2011). Within the Elk River and the C&D Canal, these designated uses, as described previously, include "water contact recreation," "fishing," "the protection of aquatic life," and "marine and estuarine aquatic life and shellfish harvesting." The 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. These endpoint tPCB concentrations are lower than 1) EPA's human health criterion tPCB water column concentration relative to fish consumption, and 2) Maryland's saltwater aquatic life chronic criterion tPCB water column concentration (*i.e.*, water column TMDL endpoint tPCB concentrations < saltwater chronic tPCB criterion). This indicates that the TMDLs are not only protective of the "fishing" designated use but also the "aquatic life" designated use, specifically the protection of "marine and estuarine aquatic life and shellfish harvesting". Lastly, the designated use for "water contact recreation" is not associated with any potential human health risks due to PCB exposure. Dermal contact and consumption of water from activities associated with "water contact recreation" are not a significant pathway for the uptake of PCBs. The EPA human health criterion was developed solely based on organism consumption, as drinking water consumption does not pose any risk for cancer development at environmentally relevant levels. The only human health risk associated with PCB exposure is through the consumption of aquatic organisms, which is addressed by the water column and sediment tPCB endpoint concentrations applied within this TMDL developed to be supportive of the "fishing" designated use.

As part of this analysis, both point and nonpoint sources of PCBs have been identified throughout the Elk River and the C&D Canal. Nonpoint sources in the Elk River include tidal influence from the Chesapeake Bay mainstem, direct atmospheric deposition, runoff from non-regulated watershed areas, the Big Elk Creek tributary, upstream watersheds in Pennsylvania and Delaware, exchanges between the Bohemia River and the Elk River, exchanges between the C&D Canal and the Elk River, and contaminated sites. Nonpoint sources in the C&D Canal include tidal influence at the Maryland/Delaware boundary in the C&D Canal, direct atmospheric deposition, runoff from non-regulated watershed areas, upstream watersheds in Delaware, exchanges between the C&D Canal and the Elk River, and contaminated sites. Point sources in the Elk River include eleven National Pollutant Discharge Elimination System (NPDES) waste water treatment plants (WWTPs), an industrial process water facility and regulated stormwater runoff. Point sources in the C&D Canal include NPDES WWTPs and regulated stormwater runoff. Model estimated tPCB loads from these point and nonpoint sources represent the baseline conditions for the Elk River and the C&D Canal.

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. Under current conditions in the Elk River and C&D Canal, due to elevated particulate tPCB concentrations resultant from PCB adsorption to the organic carbon component of suspended sediment, there is a net transport of PCBs to the bottom sediment from the water column through settling and deposition. The estimated loads to the sediment from the water column in the Elk River and the C&D Canal is 8,282 gram/year (g/year) and 950 g/year, respectively. Even if resuspension and diffusion from bottom sediments served as a source of PCBs to the water column, the load contribution is resultant from other point and nonpoint source inputs (both historic and current) and is not considered to be a directly controllable source. Therefore, it would not be assigned a baseline load or allocation.

The transport of PCBs into the Elk River due to tidal influences from the Chesapeake Bay mainstem serves a major source of PCBs to the system (net transport of 31,662 g/year); however, this load contribution is resultant from other point and nonpoint source inputs (both historic and current) and not considered to be a directly controllable source. Therefore this load will not be assigned a baseline load or allocation within the TMDL. The transport of PCBs due to tidal influences in the C&D Canal at the boundary between Maryland and Delaware results in a net transport of tPCBs out of the system into the Delaware portion of the C&D Canal (18,411 g/year). Thus, through tidal influences, PCBs are being removed from the C&D Canal at the boundary between Maryland and Delaware. Even if the Delaware portion of the C&D Canal served as a source of PCBs to the Maryland portion through the tidal boundary, the load contribution would be resultant from other point and nonpoint source inputs within the Delaware watershed and would not be considered to be a directly controllable source. Therefore it would not be assigned a baseline load or allocation within the TMDL.

The PCB load associated with exchanges at the boundary between the Elk River and the C&D Canal will not be explicitly presented in this TMDL, as the water quality model simulates exchanges at this boundary within the framework of the model. Therefore, the load is accounted for internally within the system and will not be assigned a baseline load or allocation within the TMDL.

The PCB load from the Bohemia River which flows into the Elk River will be accounted for within the TMDL by incorporating a model segment for the Bohemia River within the water quality modeling framework. A TMDL was developed for the Bohemia River and approved by EPA in 2009. Water quality data from this TMDL was used to establish the initial conditions for this model segment within the Elk River and C&D Canal water quality model. The model predicts a net transport of 9,082 g/year from the Elk River to the Bohemia River. This load is not explicitly presented in the TMDL, as the water quality model simulates exchanges at the boundary within the framework of the model. Therefore the load is accounted for internally within the system and is not assigned a baseline load or allocation within the TMDL. In addition, as the Elk River is a source of PCBs to the Bohemia River, reductions assigned within this TMDL demonstrate that water quality within the Bohemia River is also met, thus supporting the previously approved TMDL.

The objective of the TMDLs established herein is to reduce current PCB loads to the Elk River and the C&D Canal 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 2013a). 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.

Summaries of the baseline loads, TMDLs, and Maximum Daily Loads (MDLs) for the Elk River and the C&D Canal are presented in Tables ES-1 and ES-2, respectively. Additionally, the baseline loads and TMDL allocations only consider current sources of PCBs to the area that are deemed to be directly controllable loads. When implemented, these TMDLs will ensure that the resulting tPCB concentrations in the sediment and water column are at levels supportive of the "fishing" designated use in the Elk River and the C&D Canal.

The water quality model developed for simulating ambient sediment and water column tPCB concentrations within the Elk River and the C&D Canal was used to determine the specific load reductions for each controllable source category that would result in simulated tPCB concentrations in the sediment and water column that meet the TMDL endpoints. The results of this scenario establish the load reductions per source category and the associated WLAs and LAs necessary to achieve the TMDLs. Some controllable sources, however, were not assigned a load reduction. Loads from contaminated sites were not reduced from their baseline loads because they have already undergone some degree of remediation in accordance with MDE's Superfund program or Voluntary Cleanup Program (VCP) and their baseline loads constitute a relatively small percentage of the Total Baseline Loads (0.3%) in the Elk River. A reduction to atmospheric deposition is not applied in the Elk River and the C&D Canal. The primary source of PCBs to the atmosphere is from volatilization of PCB contaminated land sources which will be eliminated as these sources are remediated through implementation of the non-regulated watershed runoff LA and NPDES regulated stormwater WLA. A reduction is also not necessary in order to achieve the TMDL. In addition, this will be consistent with the allocations assigned in the Bohemia River tPCB TMDL (MDE 2009a).

In addition, baseline loads from ten of eleven WWTPs located in the Elk River and C&D Canal watershed were not reduced because their loads account for a relatively small percentage of the total baseline load (0.002%), therefore no appreciable environmental benefit would be gained by reducing these loads. Only the Elkton WWTP requires a load reduction in order to achieve the TMDL for the Elk River. The WLA for this facility was assigned based on the water column TMDL endpoint and the facility design flow. There are currently no effluent tPCB limits established in the discharge permit for this WWTP. Inclusion of a WLA in this document does not reflect any determination to impose an effluent limit. The load from a single industrial process water facility was considered *de minimis* under this analysis and no baseline load or WLA was assigned in the TMDL.

In the Elk River, the TMDL modeling scenario was used to develop the load reductions, WLAs, and LAs for non-regulated watershed runoff, the Big Elk Creek tributary, NPDES WWTPs, upstream watersheds in Pennsylvania and Delaware, NPDES regulated stormwater and contaminated site source categories. As previously applied in other PCB TMDLs developed by Maryland in the Chesapeake Bay region (e.g., MDE 2009a, 2009b) the model assumes that water column tPCB concentration decrease at a rate of 6.5% year at the tidal boundary between the Elk River and Chesapeake Bay mainstem. For the open boundary within the C&D Canal between Maryland and Delaware the model assumes a declining rate of 4% per year (derived from DRBC 2011). The resultant TMDL scenario requires load reductions ranging between 49.5% and 50.0% for all watershed sources including those in Pennsylvania and Delaware, and a 93.8% reduction for the Elkton Creek WWTP in order to achieve the sediment and water column TMDL endpoint tPCB concentrations. In the C&D Canal, the load reductions and LAs were developed for the non-regulated watershed runoff, upstream watershed in Delaware, and NPDES regulated stormwater source categories. The resultant TMDL scenario requires a load reduction ranging between 49.4 % and 50.0% for all watershed sources, including those in Delaware, in order to achieve the sediment and water column TMDL endpoint tPCB concentrations.

Federal regulations require that TMDL analysis take into account the impact of critical conditions and seasonality on water quality (CFR 2013a). 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 Elk River and the C&D Canal. Thus, the TMDLs implicitly account for seasonal variations as well as critical conditions.

Once EPA has approved this TMDL, MDE will begin an iterative process of implementation that will: 1) identify specific sources, or areas of PCB contamination, within the Elk River and the C&D Canal watersheds and 2) target remedial action for those sources with the largest impact on water quality, while giving consideration to the relative cost and ease of implementation. The implementation efforts will be periodically evaluated, and if necessary, improved, in order to further progress toward achieving the water quality goals. Given that a number of contaminated sites have already undergone some degree of remediation and their baseline loads constitute a relatively small percentage of the Total Baseline Loads in the Elk River (i.e., 0.3%), these sites are not intended to be targeted during the initial stages of implementation and thus, at this point, were not subjected to any reductions (as discussed previously). However, if in the future it becomes clear that the TMDL goals cannot be achieved without load reductions from these sites, additional reduction measures might need to be considered. 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 Elk River and the C&D Canal.

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

| Source | Baseline Load (g/year) | Baseline Load (%) | TMDL (g/year) | Load Reduction (%) | MDL (g/day) |
|---|---|---|---|---|---|
| Direct Atmospheric Deposition | 58.4 | 17.5% | 58.4 | 0.0% | 0.304 |
| Maryland Non-regulated Watershed Runoff [1] | 115.2 | 34.5% | 58.0 | 49.7% | 0.302 |
| Big Elk Creek Tributary [2] | | | | | |
| Maryland | 33.6 | 10.1% | 16.9 | 49.7% | 0.088 |
| Pennsylvania | 67.6 | 20.2% | 34.0 | 49.7% | 0.177 |
| Delaware Upstream Watershed [2] | 3.2 | 1.0% | 1.6 | 50.0% | 0.008 |
| Pennsylvania Upstream Watershed [2] | 19.8 | 5.9% | 10.0 | 49.5% | 0.052 |
| Contaminated Sites | 0.9 | 0.3% | 0.9 | 0.0% | 0.005 |
| ***Nonpoint Sources*** | ***298.7*** | ***89.4%*** | ***179.8*** | **39.8%** | ***0.936*** |
| WWTPs | 14.5 | 4.3% | 0.9 | 93.8% | 0.008 |
| NPDES Regulated Stormwater [1] | 20.9 | 6.3% | 10.5 | 49.8% | 0.055 |
| ***Point Sources*** | ***35.4*** | ***10.6%*** | ***11.4*** | **67.8%** | ***0.063*** |
| ***MOS*** | - | - | ***10.1*** | - | ***0.052*** |
| **Total** | **334.1** | **100.0%** | **201.3** | **39.7%** | **1.051** |

**Notes:** 1 Load applies to the direct drainage portion of the watershed only.
2 Although these loads are reported here as a single nonpoint source value, they could include both point and nonpoint source loads.

**Table ES-2: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in the C&D Canal**

| Source | Baseline Load (g/year) | Baseline Load (%) | TMDL (g/year) | Load Reduction (%) | MDL (g/day) |
|---|---|---|---|---|---|
| Direct Atmospheric Deposition | 4.0 | 9.1% | 4.0 | 0.0% | 0.021 |
| Maryland Non-regulated Watershed Runoff [1] | 20.3 | 46.0% | 10.2 | 49.8% | 0.053 |
| Delaware Upstream Watershed [2] | 17.6 | 39.9% | 8.9 | 49.4% | 0.046 |
| ***Nonpoint Sources*** | ***41.9*** | ***95.0%*** | ***23.1*** | ***44.9%*** | ***0.120*** |
| WWTPs | 0.2 | 0.5% | 0.2 | 0.0% | 0.002 |
| NPDES Regulated Stormwater [1] | 2.0 | 4.5% | 1.0 | 50.0% | 0.005 |
| ***Point Sources*** | ***2.2*** | ***5.0%*** | ***1.2*** | ***45.1%*** | ***0.007*** |
| ***MOS*** | - | - | ***1.3*** | - | ***0.007*** |
| **Total** | **44.1** | **100.0%** | **25.6** | **42.0%** | **0.134** |

**Notes:** 1 Load applies to the direct drainage portion of the watershed only.
2 Although these loads are reported here as a single nonpoint source value, they could include both point and nonpoint source loads.

## 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 Elk River Oligohaline Tidal Chesapeake Bay Segment (basin number 02130601, 02130603, and 02130605) (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-ELKOH) and the Chesapeake & Delaware (C&D) Canal Oligohaline Tidal Chesapeake Bay Segment (basin number 02130604) (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-C&DOH), Maryland. Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards (WQSs). For each WQLS, the State is to either establish a TMDL of the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2013a).

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 the protection of aquatic life (COMAR 2013a). The specific designated use of the Elk River Oligohaline Tidal Chesapeake Bay Segment and the C&D Canal Oligohaline Tidal Chesapeake Bay Segment is Use II – *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2013b). The Maryland Department of the Environment (MDE) has identified the waters of the Elk River Oligohaline Tidal Chesapeake Bay Segment (*Integrated Report* Assessment Unit ID: MD-ELKOH) on the State's 2012 Integrated Report as impaired for nutrients (nitrogen & phosphorous) (1996) and PCBs in fish tissue (2002) (MDE 2012). MDE has identified the waters of the C&D Canal Oligohaline Tidal Chesapeake Bay Segment (*Integrated Report* Assessment Unit ID: MD-C&DOH) on the State's 2012 Integrated Report as impaired by nutrients (nitrogen & phosphorous) (1996), arsenic (1996), cadmium (1996), silver (1996), and PCBs in fish tissue (2002) (MDE 2012). From this point on in the document, the Elk River and the C&D Canal Oligohaline Tidal Chesapeake Bay Segments will simply be referred to as the Elk River and the C&D Canal. The TMDL established herein by MDE will address the total PCB (tPCB) listings, for which a data solicitation was conducted, and all readily available data have been considered. Water Quality Analyses of arsenic, cadmium, and silver in the C&D Canal were approved by the EPA in November 2005 (MDE 2005). The Chesapeake Bay TMDL, which was approved by the EPA in December 2010, has addressed the nutrient listing for the Elk River and the C&D Canal.

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

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

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

The waters of the Elk River and the C&D Canal were originally identified as impaired by PCBs in fish tissue on Maryland's 2002 Integrated Report based on fish tissue PCB data from MDE's monitoring program that exceeded the tPCB fish tissue listing threshold of 39 ng/g, or ppb – (wet weight) (MDE 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 Elk River: Atlantic Croaker, Brown Bullhead, Channel Catfish, Common Carp, Spot, Striped Bass, Yellow Perch, and White Perch. The recreational fish consumption advisories suggest limiting the consumption of the following fish species caught in the C&D Canal: Atlantic Croaker, Channel Catfish, Common Carp, Spot, Striped Bass, and White Perch (MDE 2014a).

# 2.0 SETTING AND WATER QUALITY DESCRIPTION

## 2.1 General Setting

**Location**

The Elk River watershed is located in Cecil County in the Upper Eastern Shore region of the Chesapeake Bay watershed. Watersheds which drain directly into the tidal portion of the Elk River include Little Elk Creek (MD 8-digit Code 02130605), Lower Elk River (MD 8-digit Code 02130601), and Upper Elk River (MD 8-digit Code 02130603). The northernmost portion of the Little Elk Creek watershed extends into Pennsylvania. The easternmost portion of the Upper Elk River watershed extends into Delaware. The Big Elk Creek (MD 8-digit Code 02130601) watershed is located east of the Little Elk Creek with its northern most portion extending into Pennsylvania, flows directly into the non-tidal portion of the Upper Elk River watershed and will therefore be considered a tributary of the Elk River within the framework of this TMDL. The Bohemia River flows into the lower tidal portion of the Elk River for which a PCB TMDL was developed and approved by EPA in 2009 (MDE 2009a). A model segment has been created for the Bohemia River within the water quality model for the Elk River and the C&D Canal to account for exchanges between the Bohemia River and the Elk River. Load reductions assigned in the Elk River and the C&D Canal TMDL will also demonstrate that water quality within the Bohemia River is met, thus supporting the previously approved TMDL. The location of the Elk River watershed is displayed in Figure 1.

The C&D Canal is located within the Back Creek watershed (MD 8-digit Code 02130604) in Cecil County in the upper Eastern Shore region of the Chesapeake Bay watershed, with the easternmost portion extending into Delaware. For consistency and to avoid confusion as the impairment listings is for the C&D Canal, from this point on in the document the Back Creek watershed will be referred to as the C&D Canal watershed. The 14-mile-longC&D Canal was constructed in 1829 to create a shipping lane between the Chesapeake Bay and Delaware River. The Canal is currently operated by the U.S. Army Corp of Engineers and is the only major commercial shipping canal operating in the U.S. today. It has been reported that 90% of the flow in the C&D Canal is from the Chesapeake Bay to Delaware Bay (Ward *et al*. 2009). The location of the C&D Canal watershed is also displayed in Figure 1.

**Land Use**

According to the United States Geological Survey's (USGS) 2006 land cover data (USGS 2013), which was specifically developed to be applied within the Chesapeake Bay Program's (CBP) Phase 5.3.2 watershed model, land use in both the Elk River watershed and the C&D Canal watershed is predominantly forest and agriculture. The land use distribution in the Elk River watershed includes the Big Elk Creek watershed and upstream watersheds in Delaware and Pennsylvania. The land use distribution in the C&D Canal watershed includes the upstream watershed in Delaware. In the Elk River, forest land use occupies approximately 41.7%, while 34.1% is agriculture, 15.5% is urban, and 8.7% is water/wetlands. In the C&D Canal, agriculture land use occupies approximately 46%, while 23.8% is forest, 19% is urban, and 11.2% is water/wetlands. The land use distribution is displayed in Figures 2 and 3 as well as Table 1.

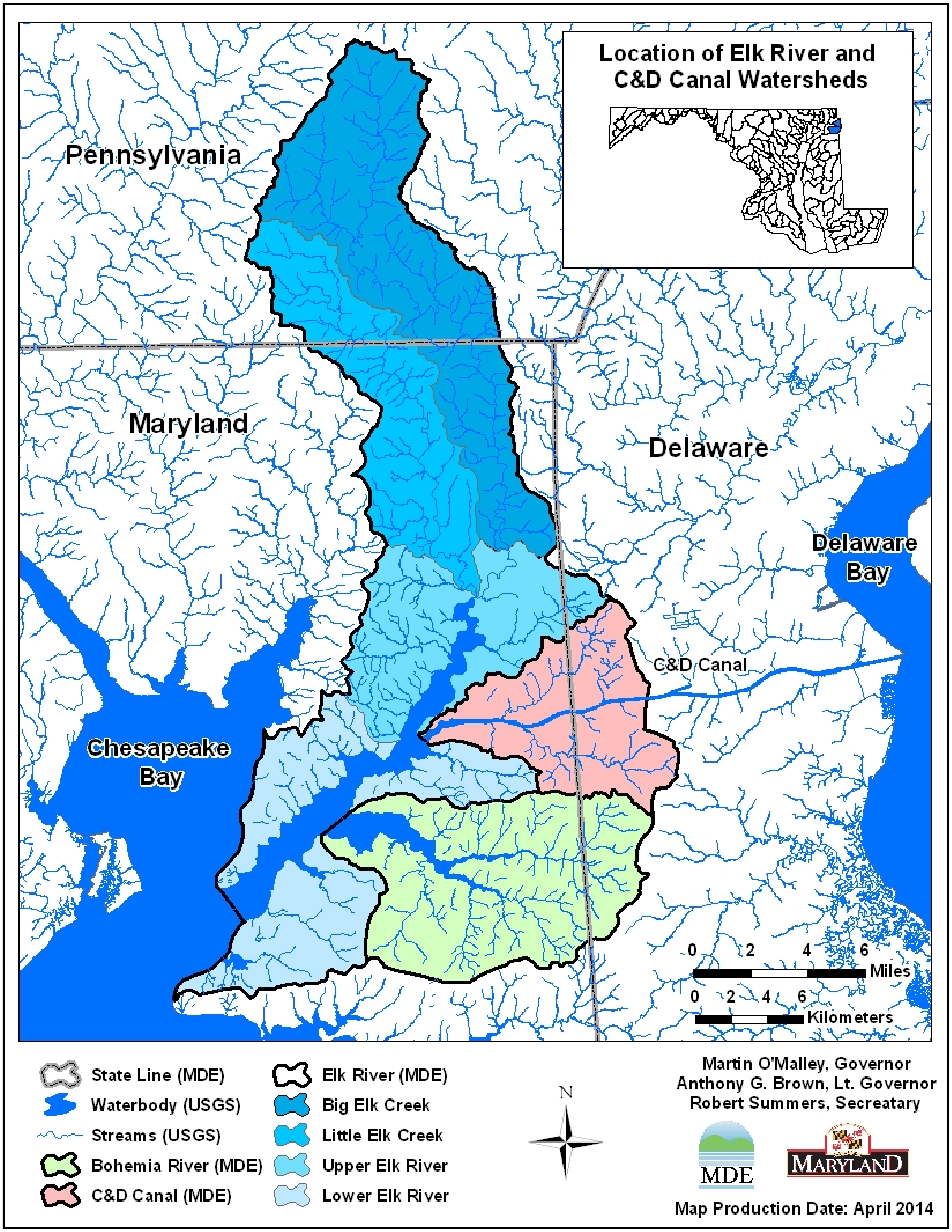


**Figure 1: Location Map of the Elk River and the C&D Canal Watersheds.**

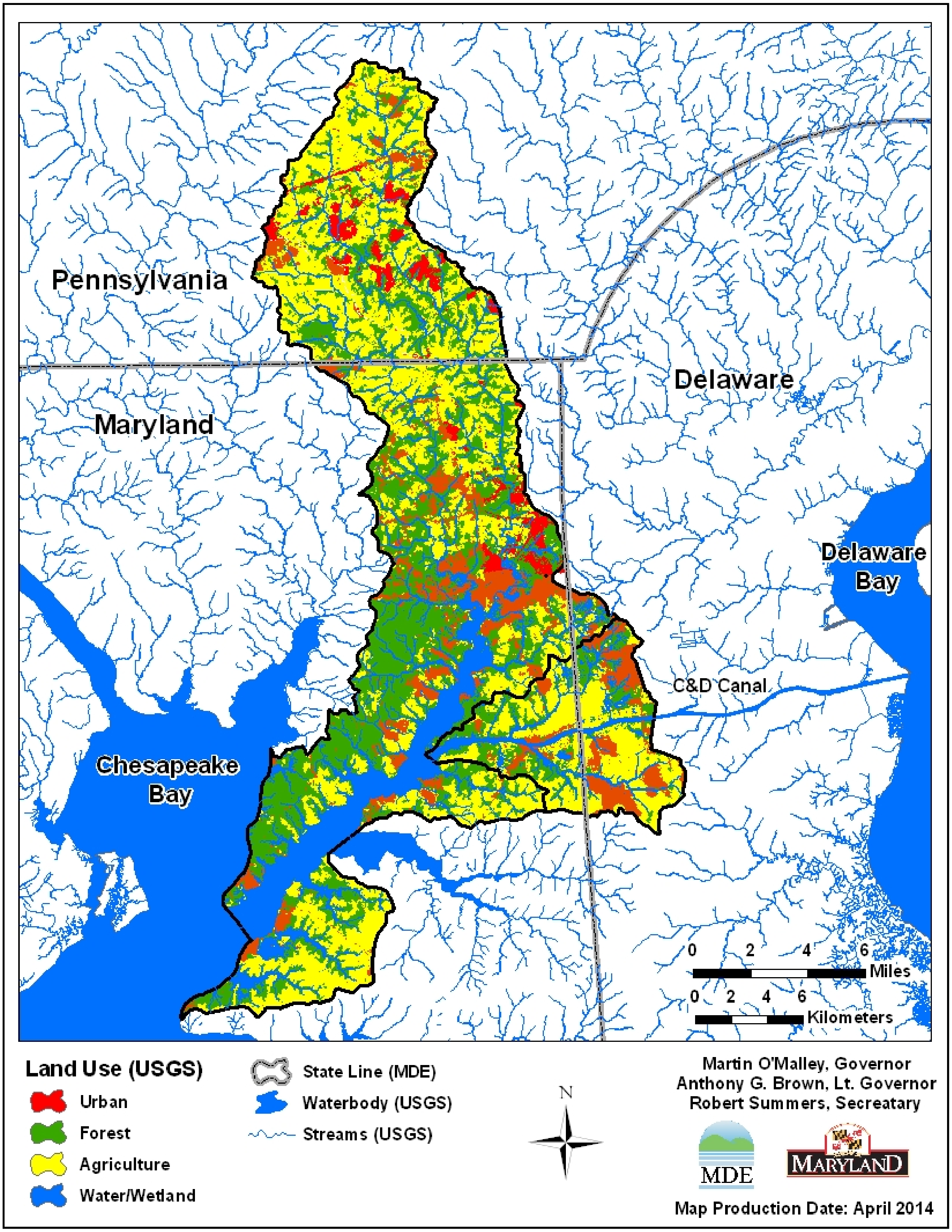


**Figure 2: Land Use of the Elk River and the C&D Canal Watersheds**

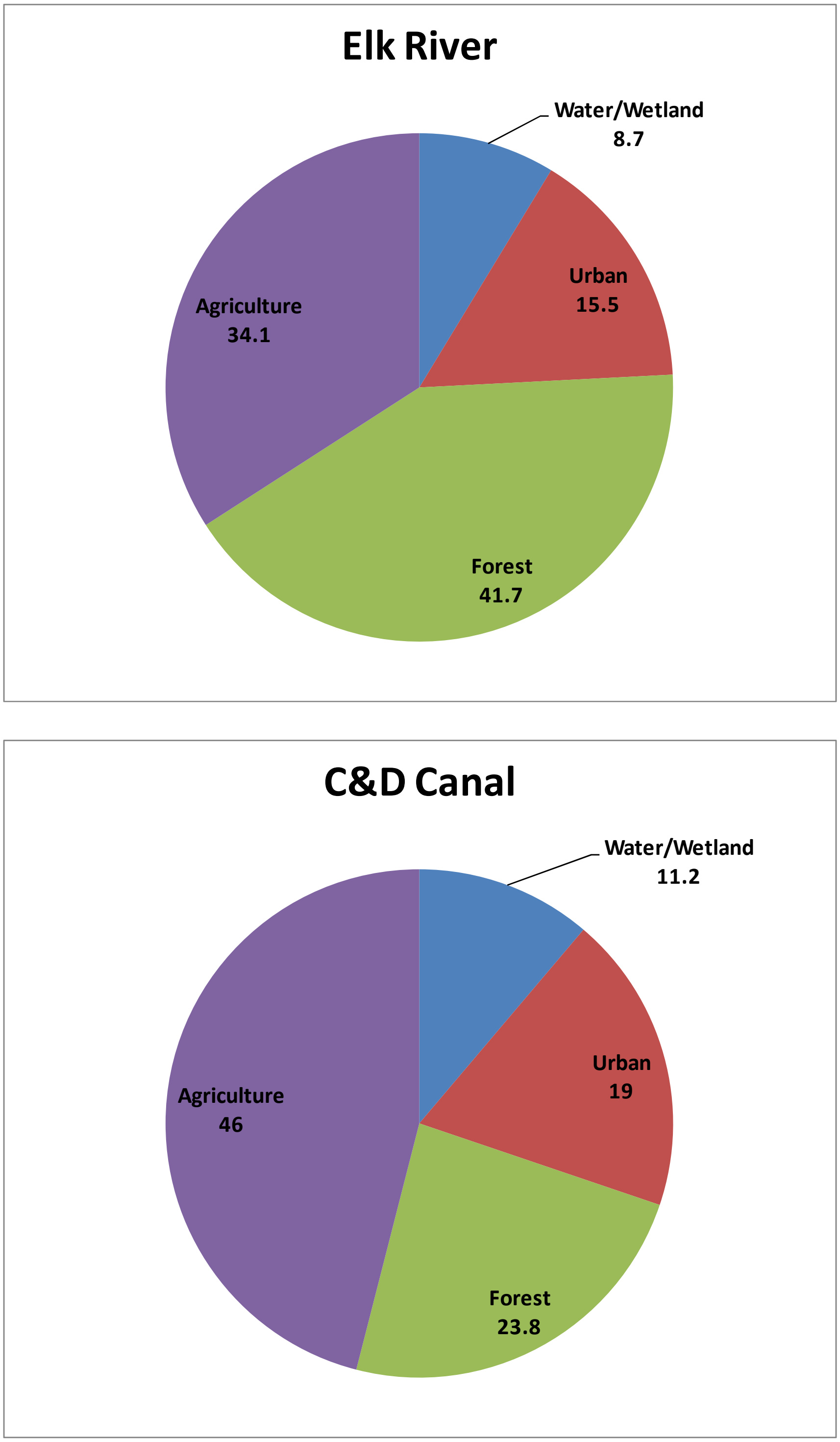


**Figure 3: Land Use Distribution in the Elk River and the C&D Canal Watersheds**

**Table 1: Land Use Distributions in the Elk River and the C&D Canal Watersheds**

| Watershed | Land Use | Water/Wetland | Urban | Forest | Agriculture | Total |
|---|---|---|---|---|---|---|
| **Elk River** | **Area ($km^2$)** | 23.9 | 42.2 | 113.9 | 93 | **273** |
| | **Percent (%)** | 8.7 | 15.5 | 41.7 | 34.1 | **100** |
| **C&D Canal** | **Area ($km^2$)** | 7.5 | 12.7 | 16 | 30.9 | **67** |
| | **Percent (%)** | 11.2 | 19 | 23.8 | 46 | **100** |
| **Total** | **Area ($km^2$)** | 31.4 | 54.9 | 129.9 | 123.9 | **340** |
| | **Percent (%)** | 9.2 | 16.2 | 38.2 | 36.4 | **100** |

## 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 2013a). The specific designated use of the Elk River and the C&D Canal is Use II – *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2013b). There are no "high quality", or Tier II, stream segments (Benthic Index of Biotic Integrity [BIBI] and Fish Index of Biotic Integrity [FIBI] aquatic life assessment scores > 4 [scale 1-5]) located within the direct drainage portions of the Elk River or the C&D Canal watersheds (COMAR 2011b). Within the Big Elk Creek watershed, an upstream tributary of the Elk River, there are currently two stream segments identified as Tier II waters, Gramies Run and Big Elk Creek. These streams require the implementation of Maryland's anti-degradation policy to ensure protection of water quality (COMAR 2011b; MDE 2010).

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 Elk River and C&D Canal are tidal systems, 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 2013c, US EPA 2013a). 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 cancer slope factor is used to estimate the risk of cancer associated with exposure to a carcinogenic substance (i.e. PCBs). A bioconcentration factor 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 2013c, US EPA 2013a).

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 a tPCB fish tissue listing threshold of 39 ng/g, 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). Maryland's Integrated Report listing methodology requires tPCB fish tissue concentration data from a minimum of five fish (individual or composite [i.e., samples composited from the tissue of several individual fish] of the same resident species) in order to establish an impairment for PCBs in fish tissue in a given waterbody (MDE 2014b). Fish that comprise a composite sample must also be within the same size class (i.e., the smallest fish must be within seventy-five percent of the total length of the largest fish) (MDE 2014b).

MDE collected several composite and individual fish tissue samples for PCB analysis in the Elk River and the C&D Canal in 1999, 2000, 2002, 2004, and 2006 (119 total fish (27 composites and 2 individual) in the Elk River and 146 total fish (36 composites and 2 individual)8 in the C&D Canal). The tPCB concentrations for all fish tissue samples (several species of fish including American eel, brown bullhead, channel catfish, largemouth bass, striped bass, white perch, and yellow perch were collected) exceed the listing threshold, demonstrating that a PCB impairment exists within the listed waters. The tPCB fish tissue concentration data including the number of fish per composite, average length, and average weight are presented in Appendix I. The water column tPCB criteria and tPCB fish tissue listing threshold are displayed in Table 2.

**Table 2: 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) |

In 1993, 2003, and 2010, monitoring surveys were conducted by MDE to measure water column tPCB concentrations at tidal and non-tidal monitoring stations in the Elk River and the C&D Canal. Sediment samples were also collected at tidal stations to characterize tPCB sediment concentrations. Non-tidal tPCB water column concentration data is required to characterize loadings from the watershed.

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, Konietcka 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.

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. The congener distribution is representative of all congeners present in the industrially produced Aroclor mixtures. A list of congeners detected under this analytical method is presented in Appendix A.

Table 3 summarizes the tPCB data for fish tissue, water column, and sediment samples that were applied in developing this TMDL. Appendix I contains maps of the monitoring station locations for tidal and non-tidal water column samples, sediment samples, and fish tissue collection and tables containing all of the tPCB water quality data.

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

| Watershed | Sample Media | Sample Type | Units | Sample Years | Sample Size | tPCB Concentration | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean | Max. | Min. |
| Elk River | Fish Tissue | Tidal | ng/g | 1999/2000/2006 | 119* | 382.4 | 1,327.2 | 70.7 |
| C&D Canal | | | | 1999/2000/2002/ 2004/2006 | 146* | 463.2 | 1,501.6 | 90.9 |
| Elk River | Sediment | Tidal | ng/g | 1993/2003 | 12 | 32.28 | 51.97 | 5.42 |
| C&D Canal | | | | 2003/2010 | 10 | 49.86 | 192.92 | 0.58 |
| Elk River | Water Column | Tidal | ng/L | 1993/2003 | 32 | 3.62 | 7.82 | 0.44 |
| | | Non-Tidal | | 2003/2010 | 23 | 1.25 | 4.78 | ND** |
| C&D Canal | | Tidal | | 2003/2010 | 20 | 4.24 | 9.58 | 0.76 |
| | | Non-Tidal | | 2010 | 11 | 0.86 | 3.14 | ND* |

***Total fish tissue samples**
****Not detected**

The mean water column tPCB concentration for tidal samples in the Elk River and the C&D Canal exceed the human health criterion of 0.64 ng/L; however, none of the tidal water column samples in the Elk River and the C&D Canal exceed the salt water chronic aquatic life tPCB criterion of 30 ng/L.

## 3.0 WATER COLUMN AND SEDIMENT TMDL ENDPOINTS

As described in Section 2.2, MDE evaluates whether a tidal waterbody meets PCB related WQSs based on three criteria: 1) the tPCB Integrated Report fish tissue listing threshold (39 ng/g, or ppb), 2) the human health tPCB water column criterion (0.64 ng/L, or ppt), or 3) thesaltwater chronic tPCB criterion for protection of aquatic life (30 ng/L, or ppt). Since the Elk River and the C&D Canal were 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 two waterbodies, is supported. However, this TMDL will also ensure the protection of all other applicable designated uses within the two areas.

Since the Elk River and the C&D Canal are listed separately for PCB impairments in fish tissue, their respective water column and sediment TMDL endpoints were calculated separately. The tPCB fish tissue listing threshold was translated into an associated tPCB water column concentration to provide a water column TMDL endpoint that is protective of the "fishing" designated use as the water quality model only simulates tPCB water column and sediment concentrations 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 280,520 L/kg for the Elk River and 276,678 L/kg for the C&D Canal, the derivations of which follows the method applied within the Potomac River PCB TMDLs (Haywood and Buchanan, 2007). A total Bioaccumulation Factor (tBAF) is calculated per fish species, and subsequently the tBAFs are normalized by the median species lipid content and median dissolved tPCB water column concentration in their home range to produce the Adj-tBAF per species (see Appendix B for further details regarding the calculation of the Adj-tBAF). The most environmentally conservative of the Adj-tBAFs is then selected to calculate the TMDL endpoint water column concentration. This final water column tPCB concentration was subsequently compared to the water column tPCB criteria concentrations, as described in Section 2.2, to ensure that all applicable criteria would be attained within the impaired waters (Calculations 3.1 and 3.2).

$$\text{tPCB Water Column Concentration} = \frac{\text{tPCB Fish Tissue Concentration Listing Threshold}}{\text{Adj-tBAF} \times \text{Unit Conversion}} \quad \text{(Equation 3.1)}$$

Substituting 39 ng/g into the equation results in:

For the Elk River:

$$\text{tPCB Water Column Concentration} = \frac{39\text{ ng/g}}{280{,}520\text{ L/kg} \times 1{,}000\text{ g/kg}} = 0.14\text{ ng/L} \quad \text{(Calculation 3.1)}$$

For the C&D Canal:

$$\text{tPCB Water Column Concentration} = \frac{39\text{ ng/g}}{276{,}678\text{ L/kg} \times 1{,}000\text{ g/kg}} = 0.14\text{ ng/L} \quad \text{(Calculation 3.2)}$$

Based on this analysis, the water column tPCB concentration of 0.14 ng/L for the Elk River and the C&D Canal derived from the fish tissue listing threshold, is more stringent than the human health criterion (0.64 ng/L) and saltwater chronic aquatic life tPCB criterion (30 ng/L). Therefore a water column tPCB concentration of 0.14 ng/L will be applied as the water column TMDL endpoint for the Elk River and the C&D Canal.

Similarly, the tPCB fish tissue listing threshold was also translated into an associated tPCB sediment concentration to provide a sediment TMDL endpoint that is protective of the "fishing" designated use within the Elk River and the C&D Canal (tPCB sediment concentrations were derived from the tPCB fish tissue listing threshold [see Equation 3.2 and Calculations 3.3 and 3.4]). This was done using the Adjusted Sediment Bioaccumulation Factor (Adj-SediBAF) of 33.9 (unitless) for the Elk River and 41.8 for the C&D Canal, the derivation of which follow the method applied within the Potomac River PCB TMDLs (Haywood and Buchanan 2007). 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.

$$\text{tPCB Sediment Concentration} = \frac{\text{tPCB Fish Tissue Concentration Listing Threshold}}{\text{Adj - SediBAF}} \qquad \text{(Equation 3.2)}$$

Substituting 39 ng/g into the equation results in:

For the Elk River:

$$\text{tPCB Sediment Concentration} = \frac{39\ \text{ng/g}}{33.9} = 1.15\ \text{ng/g} \qquad \text{(Calculation 3.3)}$$

For the C&D Canal:

$$\text{tPCB Sediment Concentration} = \frac{39\ \text{ng/g}}{41.8} = 0.93\ \text{ng/g} \qquad \text{(Calculation 3.4)}$$

Based on this analysis, the sediment tPCB concentrations of 1.15 ng/g for the Elk River and 0.93 ng/g for the C&D Canal derived from the fish tissue listing threshold will be applied as the sediment TMDL endpoints.

The CWA, as recently interpreted by the United States District Court, requires TMDLs to be protective of all the designated uses applicable to a particular waterbody (US District Court for the District of Columbia 2011). In addition to the "fishing" designated use, the TMDL presented herein is also supportive of the other applicable designated uses within the 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, shellfish, etc…) 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 SOURCES ASSESSMENT

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

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

The linkage between the “fishing” designated use and PCB concentrations in the water column is via the uptake and bioaccumulation of PCBs by aquatic organisms. Bioaccumulation occurs when the combined uptake rate of a given chemical from food, water, and/or sediment by an organism exceeds the organisms’ ability to remove the chemical through metabolic functions, dilution, or excretion, resulting in excess concentrations of the chemical being stored in the body of the organism. 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 Elk River and the C&D Canal, following the direction of the major flow, is diagramed in Figure 4. PCB sources, resulting primarily from historical uses of these compounds and potential releases to the environment as described above, include point and nonpoint sources. This section provides a summary of these existing nonpoint and point sources that have been identified as contributing tPCB loads to the impaired waters.

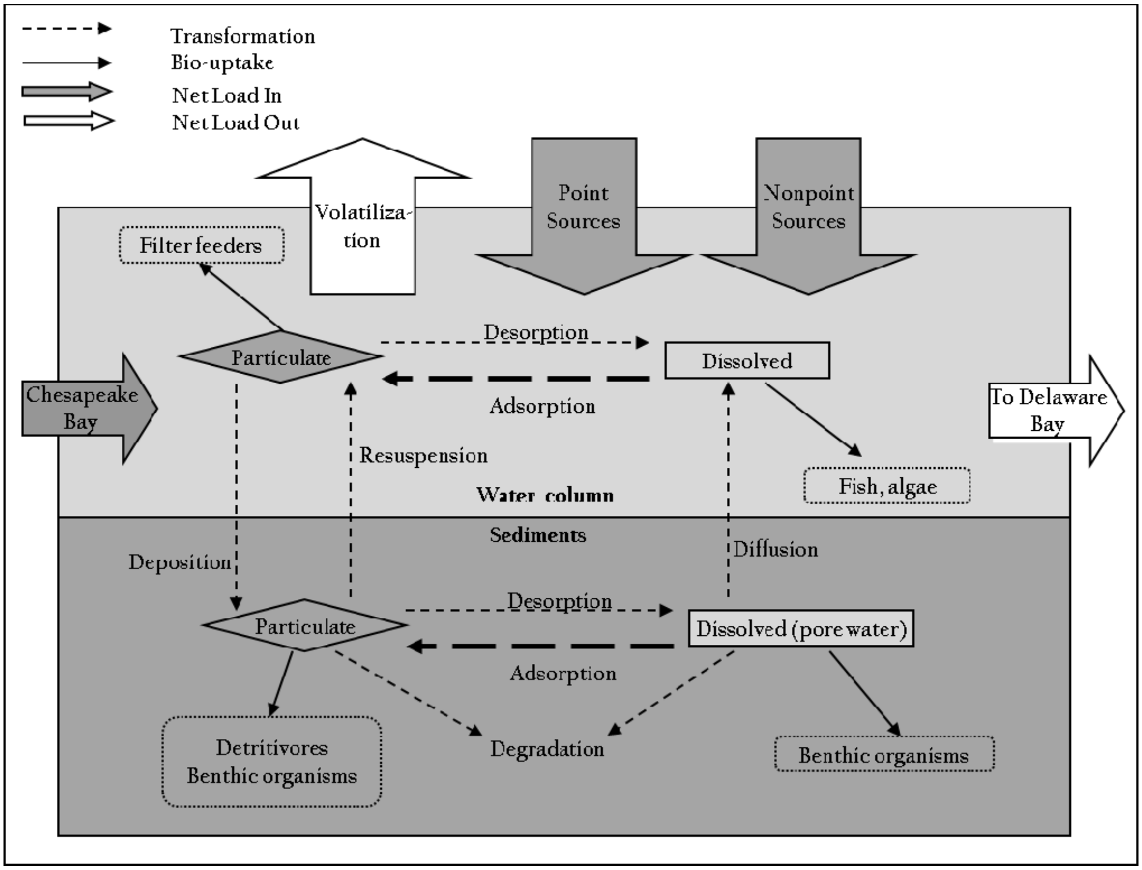


**Figure 4: Conceptual Model of the Key Transport and Transformation Processes of PCBs in Surface Water and Bottom Sediments of the Elk River and the C&D Canal, and Entry Points to the Food Chain**

### 4.1 Nonpoint Sources

For the purpose of the TMDLs, under current conditions, the following nonpoint sources of PCBs have been identified for the Elk River: 1) tidal influence from the Chesapeake Bay mainstem, 2) direct atmospheric deposition, 3) runoff from non-regulated watershed areas, 4) Maryland tributaries (outside of the direct drainage area), 5) Pennsylvania and Delaware upstream watersheds, 6) exchanges between the Bohemia River and the Elk River, 7) exchanges between the C&D Canal and the Elk River, and 8) contaminated sites (areas with known PCB soil contamination, as documented by state or federal hazardous waste cleanup programs). The following nonpoint sources have been identified for the C&D Canal: 1) tidal influence at the Maryland/Delaware boundary in the C&D Canal, 2) direct atmospheric deposition, 3) runoff from non-regulated watershed areas, 4) exchanges between the C&D Canal and the Elk River, and 5) Delaware upstream 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. 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.

**Tidal Influence from the Chesapeake Bay Mainstem**

The water quality model, applying the observed tPCB concentrations measured near the mouth of the Lower Elk River, predicts a gross tPCB input of 79,322 g/year from the Chesapeake Bay to the Elk River and a gross tPCB output of 47,660 g/year from the Elk River to the Bay. These loads result in a net tPCB transport of 31,662 g/year from the Bay to the Elk River. Even though tidal influence from the Chesapeake Bay mainstem serves as a source of PCBs to the Elk River, the load contribution is resultant from other point and nonpoint source inputs (both historic and current) from throughout the Upper Chesapeake Bay watershed and is not considered to be a directly controllable (reducible) source. Therefore this load will not be assigned a baseline load or allocation within the TMDL.

**Tidal Influence at the Maryland/Delaware Boundary in the C&D Canal**

The water quality model, applying the observed tPCB concentrations at the boundary between Maryland and Delaware within the C&D Canal, predicts a gross tPCB input of 22,713 g/year from Delaware to Maryland and a gross tPCB input of 41,123 g/year from Maryland to Delaware. These loads result in a net tPCB transport of 18,411 g/year from Maryland to Delaware at the State boundary within the C&D Canal. Thus, through tidal influences, PCBs are being removed from the C&D Canal at the boundary between Maryland and Delaware. Even if the Delaware portion of the C&D Canal served as a source of PCBs to the Maryland portion through the tidal boundary, the load contribution would be resultant from other point and nonpoint source inputs within the Delaware watershed and not considered to be a directly controllable source. Therefore this load would not be assigned a baseline load or allocation within the TMDL.

**Exchange between the C&D Canal and the Elk River**

The water quality model, applying the observed tPCB concentrations at the boundary between the Elk River and the C&D Canal, predicts a net tPCB transport of 15,570 g/year from the Elk River to the C&D Canal. Even though the Elk River serves as a source of PCBs to the C&D Canal, this load will not be explicitly presented in the TMDL, as the water quality model simulates exchanges at the boundary within the framework of the model. Therefore the load is accounted for internally within the system and will not be assigned a baseline load or allocation within the TMDL.

**Exchanges between the Bohemia River and the Elk River**

The Bohemia River flows into the lower portion of the Elk River. A tPCB TMDL was developed for the Bohemia River and approved by EPA in 2009 (MDE 2009a). A model segment has been created for the Bohemia River within the water quality model for the Elk River and the C&D Canal to account for exchanges between the Bohemia River and the Elk River. Water quality data from the Bohemia River TMDL was applied to establish the initial conditions for the model segment. The water quality model predicts a net transport of 9,082 g/year from the Elk River to the Bohemia River. This load is not explicitly presented in the TMDL, as the water quality model simulates exchanges at the boundary within the framework of the model. Therefore the load is accounted for internally within the system and is not assigned a baseline load or allocation within the TMDL. In addition, as the Elk River is a source of PCBs to the

Bohemia River, reductions are assigned in this TMDL to ensure that water quality within the Bohemia River is also met, thus supporting the previously approved TMDL.

**Atmospheric Deposition**

PCBs enter the atmosphere through volatilization. There is no recent study of the atmospheric deposition of PCBs to the surface of the Elk River and the C&D Canal. CBP's Atmospheric Deposition Study (US EPA 1999) estimated a net deposition of 16.3 micrograms/square meter/year (µg/m$^2$/year) of tPCBs for urban areas and a net deposition of 1.6 µg/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) µg/m$^2$/year of tPCBs (DRBC 2003). Since urban land use comprises less than one fifth of the Elk River and the C&D Canal watersheds (see Table 1), the 1.6 µg/m$^2$/year tPCB depositional rate for non-urban areas resultant from CBP's 1999 study is appropriate. Therefore, this value was used in the development of this TMDL. The direct atmospheric deposition loads to the surfaces of the Elk River (58.2 g/year) and the C&D Canal (4.0 g/year) were calculated by multiplying the total surface areas of the Elk River (36.4 km$^2$) and the C&D Canal (2.5 km$^2$), and the deposition rate of 1.6 µg/m$^2$/year.

Similarly, the atmospheric deposition load to the direct drainage watershed (Maryland part only) can be calculated by multiplying 1.6 µg/m$^2$/year by the watershed areas of 277.50 km$^2$ (MD part of the Elk River) and 36.24 km$^2$ (MD part of the C&D Canal) which result in loads of 444.0 g/year and 58.0 g/year respectively. 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) of approximately 1%, the atmospheric deposition loads to the Elk River and the C&D Canal, from the Maryland part of the direct drainage watershed, is approximately 4.4 g/year and 0.6 g/year, respectively. This load is accounted for within the loading from the watershed and is inherently modeled as part of the non-regulated watershed runoff/National Pollutant Discharge Elimination System (NPDES) Regulated Stormwater loads described below and in Section 4.2.

**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.

These sites were identified based on information gathered from the EPA's Superfund database and MDE's Land Restoration Program Geospatial Database (LRP-MAP) (US EPA 2013b; MDE 2013). Only twelve sites within the Elk River watershed have been identified with PCB soil concentrations at or above method detection levels, as determined via soil sample results contained within MDE Land Management Administration's (LMA) contaminated site survey and investigation records. In the C&D Canal watershed no sites have been identified. Table 4 lists these sites and Figure 5 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 0.87 g/year. A detailed description of the methodology used to estimate the contaminated site tPCB baseline load is presented in Appendix G.

**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 or allocation 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. Under current conditions, due to elevated particulate tPCB concentrations resultant from PCB adsorption to the organic carbon component of suspended sediment in the water column, when compared to tPCB concentrations in the bottom sediment, there is a net transport of PCBs to the bottom sediment from the water column in the Elk River and the C&D Canal through settling and deposition. The water quality model, applying observed tPCB concentrations in the water column and sediment, predicts a net tPCB transport of 8,282 g/year and 950 g/year from the water column to the bottom sediment in the Elk River and the C&D Canal, respectively. Even if resuspension and diffusion from bottom sediments served as a source of PCBs to the water column, the load contribution is resultant from other point and nonpoint source inputs (both historic and current) and is not considered to be a directly controllable (reducible) source. Therefore, it would not be assigned a baseline load or allocation.

**Table 4: Summary of Contaminated Site tPCB Baseline Loads**

| Site Name | Watershed | Area (acres) | EOS Load (g/year) |
|---|---|---|---|
| Childs Property | Elk River | 1.67 | 0.0015 |
| Dwyer Property | Elk River | 72.86 | 0.16 |
| IP Inc. (Isocyanate Products, Inc) | Elk River | 5.64 | 0.072 |
| Herron Area 3 | Elk River | 90.94 | 0.2 |
| Herron Area 4 | Elk River | 88.19 | 0.073 |
| Former PECO Elkton Service Building | Elk River | 9.3 | 0.0014 |
| RMR/JMR Corporation | Elk River | 3.96 | 0.014 |
| Reginald Thompson Property | Elk River | 13 | 0.06 |
| Old Elkton Dump | Elk River | 2.7 | 0.17 |
| New Jersey Fireworks and Route 7 Dump | Elk River | 46.5 | 0.023 |
| Patriotic Fireworks | Elk River | 33.7 | 0.093 |
| Globe Fireworks / Bacon Hill | Elk River | 0.004 | 0.00078 |
| **Total** | | **368.5** | **0.9** |

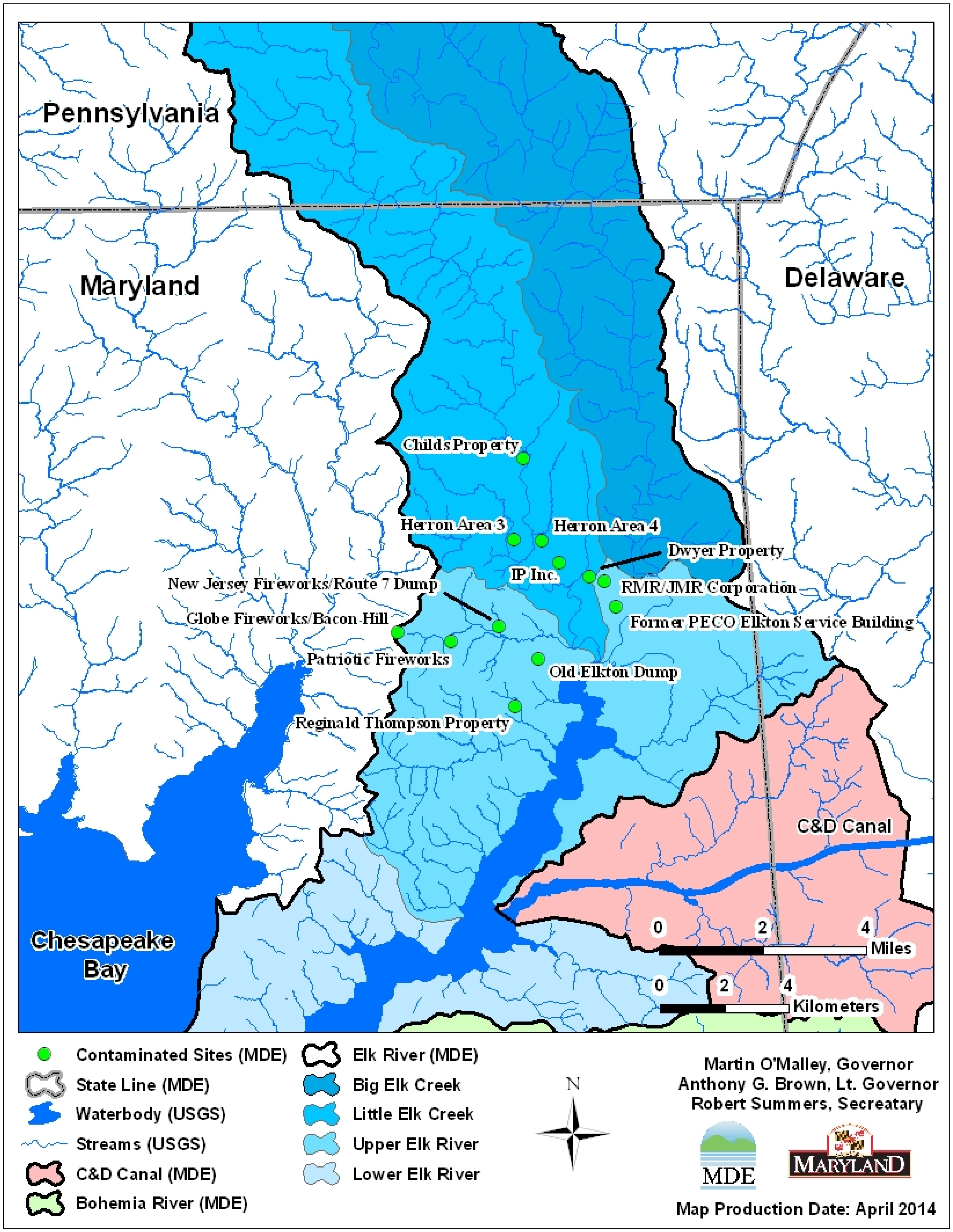


**Figure 5: Locations of PCB Contaminated Sites with PCB Soil Concentrations**

## Watershed Sources

### Non-regulated Watershed Runoff

The non-regulated watershed runoff tPCB load corresponds to the non-urbanized areas (*i.e.*, primarily forest and agricultural areas) of the direct drainage watershed. The load associated with the urbanized area of the direct drainage 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 10 watershed monitoring stations in the direct drainage of the Elk River and the C&D Canal in March and April of 2003, and in January, May, July, and October of 2010 (See Appendix C). Additionally, 10-year daily flows (2003-2012) from a USGS gage (USGS 1495000, Figure C-1) were obtained and the mean flow was calculated. The USGS daily flow was also obtained for each sample date. A tPCB load for each sample was then calculated based on the observed tPCB concentration and the flow, and the relationship between loads and flows was developed via regression analysis. With this relationship, the tPCB load corresponding to any flow can be estimated. The load calculation is described in further detail in Appendix C. The total direct drainage watershed tPCB baseline loads of the Elk River and the C&D Canal are 137.0 g/year and 22.3 g/year, respectively.

As mentioned above, about 4.4 g/year and 0.6 g/year of the Elk River and the C&D Canal watershed's tPCB baseline load, respectively, are attributed to atmospheric deposition to the land surfaces of the watersheds, and are inherently captured within their total direct drainage watershed tPCB baseline loads of 137.0 g/year and 22.3 g/year.

As mentioned above, the non-regulated watershed runoff tPCB load only corresponds to the non-urbanized areas (*i.e.*, primarily forest and agricultural areas) within the direct drainage portion of the Elk River and the C&D Canal watersheds. The loads associated with the urbanized area of the Elk River and the C&D Canal watersheds represent the NPDES Regulated Stormwater tPCB baseline loads. The non-regulated watershed runoff tPCB baseline loads were estimated by multiplying the percentage of non-urban land use (88.7% for the Elk River and 91% for the C&D Canal) within the direct drainage portion of the watersheds by the total direct drainage watershed tPCB baseline loads for the Elk River and the C&D Canal. The non-regulated watershed runoff tPCB baseline loads for the Elk River and the C&D Canal watersheds are 115.9 g/year and 20.3 g/year respectively. As five of the contaminated sites (Dwyer Property, Herron Area 3, Herron Area 4, Reginald Thompson Property, and Old Elkton Dump) are located within the non-urbanized area, their total tPCB load (0.66 g/year) is subtracted from the Elk River total load, resulting in a non-regulated watershed runoff tPCB baseline load of 115.2 g/year for the Elk River.

### Big Elk Creek Tributary

The Big Elk Creek watershed flows directly into the non-tidal portion of the Upper Elk River watershed and will therefore be considered a tributary of the Elk River within the framework of this TMDL. A portion of this tributary also extends into Pennsylvania. The TMDL will present this loading from Pennsylvania under the tributary load for Big Elk Creek. The baseline tPCB load from Big Elk Creek (101.2 g/year) for the Maryland portion is estimated based on the same methodology used to calculate the non-regulated watershed runoff tPCB baseline load. The load is presented as a single value, representing the total tPCB load at the outlet of the individual basin. However, it could include both point and nonpoint sources, but for the purposes of this analysis, will be treated as a single nonpoint source load. The baseline tPCB load from the Pennsylvania portion of the tributary is estimated based on an average tPCB concentration from data collected at a monitoring station near the state line between Pennsylvania and Maryland and the average flow for this portion of the watershed.

**Delaware and Pennsylvania Upstream Watersheds**

A portion of the direct drainage area to the Elk River extends into Delaware and Pennsylvania and a portion of the direct drainage area to the C&D Canal extends into Delaware. Upstream watershed loads from these jurisdictions are assigned a baseline load. These loads will be reported as a non-point source, even though it may include both point and non-point sources. The baseline tPCB loads from the Delaware upstream portion of the Elk River and the C&D Canal direct drainage area are 3.2 g/year and 17.6 g/year, respectively. The baseline tPCB load from the Pennsylvania upstream portion of the Elk River is 19.8 g/year. The baseline tPCB loads are estimated based on an average tPCB concentration from data collected at monitoring stations near the state lines for Delaware and Pennsylvania and average flows for the upstream watersheds.

Tables 5 and 6 summarize the nonpoint source watershed loads to the Elk River and the C&D Canal (i.e., Non-regulated watershed runoff, tributary sources, and upstream watershed sources from Delaware and Pennsylvania).

**Table 5: Summary of the Nonpoint Source Watershed Loads to the Elk River**

| Source | Baseline Load (g/year) |
|---|---|
| Maryland Non-regulated Watershed Runoff [1] | 115.2 |
| Big Elk Creek Tributary [2] | |
| Maryland | 33.6 |
| Pennsylvania | 67.6 |
| Delaware Upstream Watershed [2] | 3.2 |
| Pennsylvania Upstream Watershed [2] | 19.8 |
| **Total** | **239.4** |

**Notes**: [1] Although these loads are reported here as a single nonpoint source value, it could include both point and nonpoint source loads.
[2] Load applies to the direct drainage portion of the watershed only.

**Table 6: Summary of the Nonpoint Source Watershed Loads to the C&D Canal**

| Source | Baseline Load (g/year) |
|---|---|
| Maryland Non-regulated Watershed Runoff [1] | 20.3 |
| Delaware Upstream Watershed [2] | 17.6 |
| **Total** | **37.9** |

**Notes**: [1] Although the load is reported here as a single nonpoint source value, it could include both point and nonpoint source loads.
[2] Load applies to the direct drainage portion of the watershed only.

## 4.2 Point Sources

Point Sources in the Elk River and the C&D Canal watersheds include eleven waste water treatment plants (WWTPs), one industrial process water discharger, and stormwater discharges regulated under Phase II of the NPDES stormwater program.

**Municipal WWTPs**

There are eleven WWTPs within the Elk River and the C&D Canal watersheds. Two of the facilities' outfalls, Elkton and Harbour View, were sampled by MDE for PCB analysis. As no tPCB effluent concentration data is available for the remaining facilities, their concentrations were estimated based on the median tPCB effluent concentration from 13 WWTPs monitored by MDE in the Chesapeake Bay watershed (MDE 2006). Their baseline tPCB loadings were calculated based on their daily monitoring record (DMR) average discharge flows and the estimated median tPCB concentration. Table 7 provides information on the data used in calculating the baseline loads, and Figure 6 depicts the WWTP locations.

**Table 7: Summary of Municipal WWTP tPCB Baseline Loads**

| Facility Name | NPDES ID | Watershed | Average Concentration (ng/L) | Average Flow (MGD*) | Baseline Load (g/year) |
|---|---|---|---|---|---|
| Corps Of Engineers Chesapeake City | MD0020206 | C&D Canal | 0.91 | 0.001 | 0.001 |
| Chesapeake City South | MD0020397 | C&D Canal | 0.91 | 0.068 | 0.086 |
| Chesapeake City North | MD0020401 | C&D Canal | 0.91 | 0.05 | 0.063 |
| **Total WWTP Load of the C&D Canal Watershed** | | | | | **0.2** |
| Ceco Utilities | MD0023108 | Elk River | 0.91 | 0.024 | 0.031 |
| Triumph Industrial Park | MD0024929 | Elk River | 0.91 | 0.036 | 0.045 |
| Cherry Hill | MD0052825 | Elk River | 0.91 | 0.076 | 0.096 |
| Forest Green Court Mobile Home Park | MD0053279 | Elk River | 0.91 | 0.017 | 0.021 |
| Elkton WWTP | MD0020681 | Elk River | 5.51 | 1.86 | 14.19 |
| Bohemia Manor High School | MD0023469 | Elk River | 0.91 | 0.007 | 0.009 |
| Elk Neck State Park | MD0023833 | Elk River | 0.91 | 0.021 | 0.026 |
| Harbour View | MD0024023 | Elk River | 1.79 | 0.021 | 0.053 |
| **Total WWTP tPCB Load of the Elk River Watershed** | | | | | **14.5** |

***Million gallons per day**

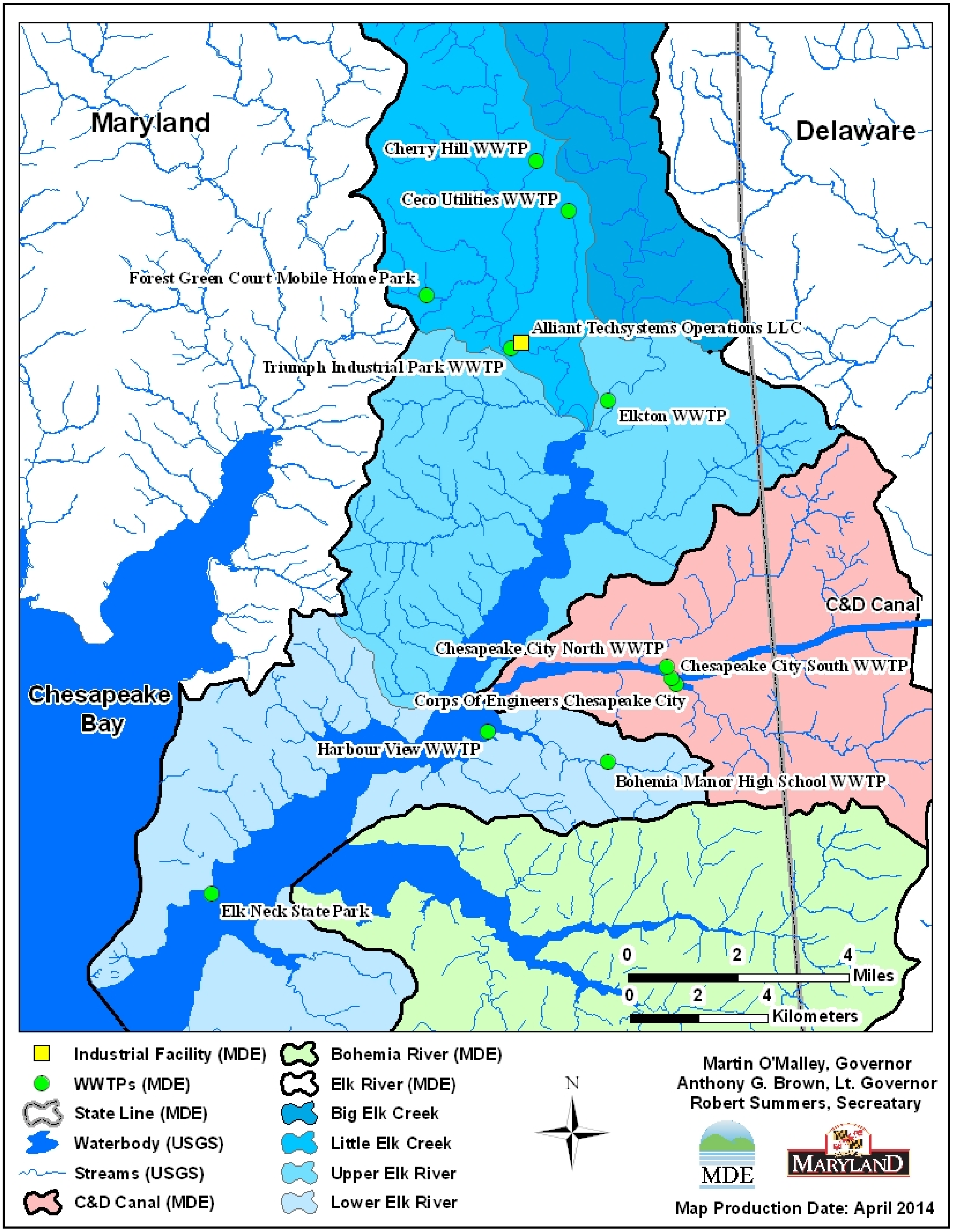


**Figure 6: Location of Municipal WWTPs and Industrial Process Water Facility in the Elk River and the C&D Canal Watersheds**

**Industrial Process Water Facility**

Industrial process water facilities are included in Maryland's tPCB TMDL analyses if: 1) they are located within the applicable watershed and 2) they have the potential to discharge PCBs. As per the guidance developed by Virginia (VA) for monitoring point sources in support of TMDL development, specific types of industrial and commercial operations are more likely than others to discharge PCBs based on historic or current activities. The State identified specific types of permitted industrial and municipal facilities based on their Standard Industrial Classification (SIC) codes as having the potential to contain PCBs within their process water discharge (VADEQ 2009). This methodology has been previously applied within MD's Baltimore Harbor tPCB TMDL, which has been approved by the EPA (MDE 2011a).

The Alliant Techsystems Operations LLC (NPDES MD0000078, Figure 6), with an SIC code defined in the VA guidance as having the potential to discharge PCBs, was identified within the Elk River watershed. However, the facility was considered *de minimis* under this analysis, as its average flow (0.064 Million Gallons per Day [MGD]) was well below 1 MGD. Therefore no baseline load or allocation is assigned within this TMDL.

**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 Phase 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 Elk River and the C&D Canal watersheds that could potentially convey tPCB loads to the impoundment is presented in Appendix H. This section provides detailed explanations regarding the calculation of the point source tPCB baseline loads.

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 Maryland portion of the Elk River and the C&D Canal watersheds are located in Cecil County. The NPDES stormwater permits within the watersheds include: (i) the area covered under Cecil County's Phase II jurisdictional MS4 permit, (ii) the State Highway Administration's Phase II MS4 permit, (iii) the town of Elkton Phase II MS4 permit, (iv) state and federal general Phase II MS4's, (v) industrial facilities permitted for stormwater discharges, and (vi) construction sites).

The NPDES regulated stormwater tPCB baseline loads of the two watersheds (21.1 g/year for the Elk River and 2.0 g/year for the C&D Canal) were estimated by multiplying the percentages of urban land use (11.3 % for the Elk River and 9 % for the C&D Canal) within the direct drainage portion of the watersheds by the total direct drainage watershed tPCB baseline loads. Since two of the identified contaminated sites (Child's Property and IP Inc.) are located within the urban land use area of the Little Elk Creek watershed, and five of the identified contaminated sites (RMR/JMR Corporation, Former PECO Elkton Service Building, Globe Fireworks/Bacon Hill, Patriotic Fireworks, and New Jersey Fireworks/Route 7 Dump) are located within the urban land use area of the Upper Elk River watershed, their total load of 0.21 g/year is subtracted, giving a final NPDES Regulated Stormwater tPCB baseline load of 20.9 g/year for the Elk River watershed. Table 8 lists the aggregate NPDES Regulated Stormwater tPCB Baseline Loads by watershed.

**Table 8: Summary of NPDES Regulated Stormwater tPCB Baseline Loads**

| Watershed | Jurisdiction | tPCB Baseline Load (g/year) |
|---|---|---|
| Elk River | Cecil County | 20.9 |
| C&D Canal | Cecil County | 2.0 |
| **Total** | | **22.9** |

### 4.3 Source Assessment Summary

From this source assessment all point and nonpoint sources of PCBs to the Elk River and the C&D Canal have been identified and characterized. For the Elk River, the following nonpoint sources of PCBs have been identified: 1) tidal influence from the Chesapeake Bay mainstem, 2) direct atmospheric deposition, 3) runoff from non-regulated watershed areas, 4) Big Elk Creek tributary, 5) Pennsylvania and Delaware upstream watershed, 6) exchanges between the Bohemia River and the Elk River, 7) exchanges between the C&D Canal and the Elk River, and 8) contaminated sites. Point sources include WWTPs and NPDES regulated stormwater runoff. Though one industrial facility was identified with the potential to discharge PCBs to the watershed, it is considered *de minimis* as its average discharge flow was below 1 MGD. Estimated tPCB loads from these point and nonpoint sources represent the baseline conditions.

For the C&D Canal, the following nonpoint sources of PCBs have been identified: 1) tidal influence at the Maryland/Delaware boundary in the C&D Canal, 2) direct atmospheric deposition, 3) runoff from non-regulated watershed areas, 4) exchanges between the C&D Canal and the Elk River, and 5) the Delaware upstream watershed. Point sources include WWTPs and NPDES regulated stormwater runoff. Estimated tPCB loads from these point and nonpoint sources represent the baseline conditions.

As explained in Section 4.1, loads associated with resuspension and diffusion from sediments, tidal influences from the Chesapeake Bay mainstem and the Maryland/Delaware boundary in the

C&D Canal are not considered to be directly controllable (reducible) within the framework of the TMDL and are thus not assigned baseline loads or allocations. Exchanges between the Elk River and the C&D Canal are accounted for internally within the modeling framework and are thus not assigned baseline loads or allocations. In addition, the load associated with exchanges between the Bohemia River and the Elk River was defined by a previously approved PCB TMDL, and is thus not assigned a baseline load or allocation in this TMDL. A summary of the tPCB baseline loads for the Elk River and the C&D Canal are presented in Tables 9 and 10.

**Table 9: Summary of tPCB Baseline Loads in the Elk River**

| Source | Baseline Load (g/year) | Baseline Load (%) |
|---|---|---|
| Direct Atmospheric Deposition | 58.4 | 17.5% |
| Maryland Non-regulated Watershed Runoff [1] | 115.2 | 34.5% |
| Big Elk Creek Tributary [2] | | |
| Maryland | 33.6 | 10.1% |
| Pennsylvania | 67.6 | 20.2% |
| Delaware Upstream Watershed [2] | 3.2 | 1.0% |
| Pennsylvania Upstream Watershed [2] | 19.8 | 5.9% |
| Contaminated Sites | 0.9 | 0.3% |
| ***Nonpoint Sources*** | ***298.7*** | ***89.4%*** |
| WWTPs | 14.5 | 4.3% |
| NPDES Regulated Stormwater [1] | 20.9 | 6.3% |
| ***Point Sources*** | ***35.4*** | ***10.6%*** |
| **Total** | **334.1** | **100.0%** |

**Notes:** 1 Load applies to the direct drainage portion of the watershed only.
2 Although these loads are reported here as a single nonpoint source value, they could include both point and nonpoint source loads.

**Table 10: Summary of tPCB Baseline Loads in the C&D Canal**

| Source | Baseline Load (g/year) | Baseline Load (%) |
|---|---|---|
| Direct Atmospheric Deposition | 4.0 | 9.1% |
| Maryland Non-regulated Watershed Runoff [1] | 20.3 | 46.0% |
| Delaware Upstream Watershed [2] | 17.6 | 39.9% |
| ***Nonpoint Sources*** | ***41.9*** | ***95.0%*** |
| WWTPs | 0.2 | 0.5% |
| NPDES Regulated Stormwater [1] | 2.0 | 4.5% |
| ***Point Sources*** | ***2.2*** | ***5.0%*** |
| **Total** | **44.1** | **100.0%** |

**Notes:** 1 Load applies to the direct drainage portion of the watershed only.
2 Although these loads are reported here as a single nonpoint source value, they could include both point and nonpoint source loads.

# 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 2011a):

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

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

## 5.2 Analysis Framework

A tidally averaged multi-segment one-dimensional transport model was applied to simulate the tPCB dynamic interactions between the water column and bottom sediments within the Elk River, the C&D Canal, the Chesapeake Bay, and the Maryland/Delaware Boundary of the C&D Canal. The Elk River and the C&D Canal were modeled as one system as they are closely connected to each other. The system was divided into 20 segments (Figure D-2) and the watershed into 20 subwatersheds (Figure C-1). As previously stated, 90% of the total flow across the segments in the C&D Canal is from the Chesapeake Bay to the Delaware Bay (Ward *et al.*, 2009) other than the freshwater input from the watershed. In general, tidal waters are exchanged through their connecting boundaries. Within the system, the dominant processes affecting the transport of PCBs throughout the water column include: the dispersion induced by tide, the concentration gradients between the Chesapeake Bay and the Elk River and between the Delaware Bay and the C&D Canal, the freshwater discharge, the atmospheric exchange due to volatilization and deposition, and the exchange with the bottom sediments (through diffusion, resuspension, and settling). Burial to the deeper inactive layers and the exchange with the water column (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 Appendix D.

### Baseline Conditions

The average observed tPCB concentrations in each segment were used as the model input representing baseline conditions. If the segment did not have any PCB observation, the linear interpolation of the most adjacent up- and down-stream segments' tPCB concentrations were used. The model predicts the time required for the water column/sediment tPCB concentrations of the Elk River and the C&D Canal to meet their respective TMDL water column/sediment endpoints. The results indicate that under the current conditions, approximately 51 years (18,597 days) and approximately 42 years (15,154 days) are required for the Elk River (Figure 7) and the C&D Canal (Figure 8), respectively.

As described in Section 4.1, the load from the Chesapeake Bay main stem due to tidal influence is the largest source of PCBs to the Elk River, and the load from the Elk River is the largest source of PCBs to the C&D Canal. Therefore, the Chesapeake Bay plays the most important role on the PCB dynamics of both the Elk River and the C&D Canal. As previously applied in other PCB TMDLs developed by Maryland in the Chesapeake Bay region (e.g., MDE 2009a, 2009b), it is assumed that water column tPCB concentrations decrease at a rate of 6.5% per year at the tidal boundary of the Elk River with the Chesapeake Bay mainstem. For the other open boundary (Delaware/Maryland boundary in the C&D Canal), the model adopts the water column tPCB concentration declining rate in the C&D Canal of 4% per year (derived from DRBC 2011).

**TMDL Scenarios**

To determine what percent reduction of the total load is necessary for both the Elk River and the C&D Canal to meet their respective water quality and sediment TMDL endpoints, different scenario runs were conducted with various open boundary conditions (Appendix J). It was demonstrated that a minimum reduction of 43% is required to the baseline load in order to achieve the TMDL when the Bay boundary water column concentration is set at the TMDL endpoint of 0.14 ng/l. Therefore, it is applied as the reduction goal while both of the boundary concentrations were set at their respective initial condition and declined based on the 6.5% (MD) and 4% (DE) reduction rates. The simulation results show that for the Elk River, with a reduction ranging between 49.5% and 50.0% for all watershed source including those of Delaware and Pennsylvania, it will take approximately 43 years (15,679 days) to meet the TMDL endpoints and thus be supportive of its designated use (Figure 9). For the C&D Canal, with a reduction ranging between 49.4% and 50.0% for all watershed sources including those in Delaware, it will take approximately 40 years (14,481 days) to meet the TMDL endpoints and thus be supportive of its designated use (Figure 10).

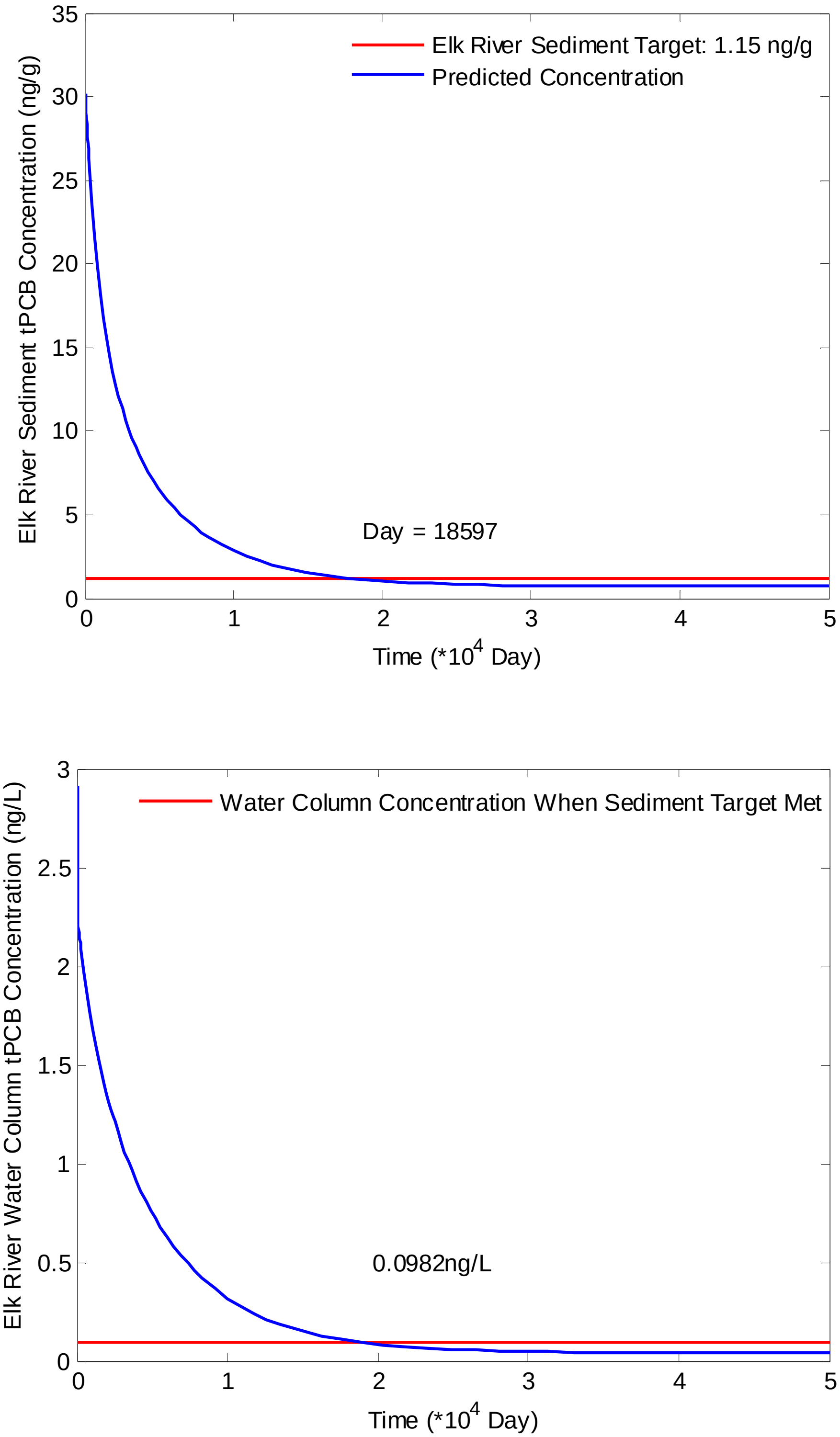


**Figure 7: Change of Average Bottom Sediment and Water Column tPCB Concentrations over Time for the Elk River (Baseline Conditions)**

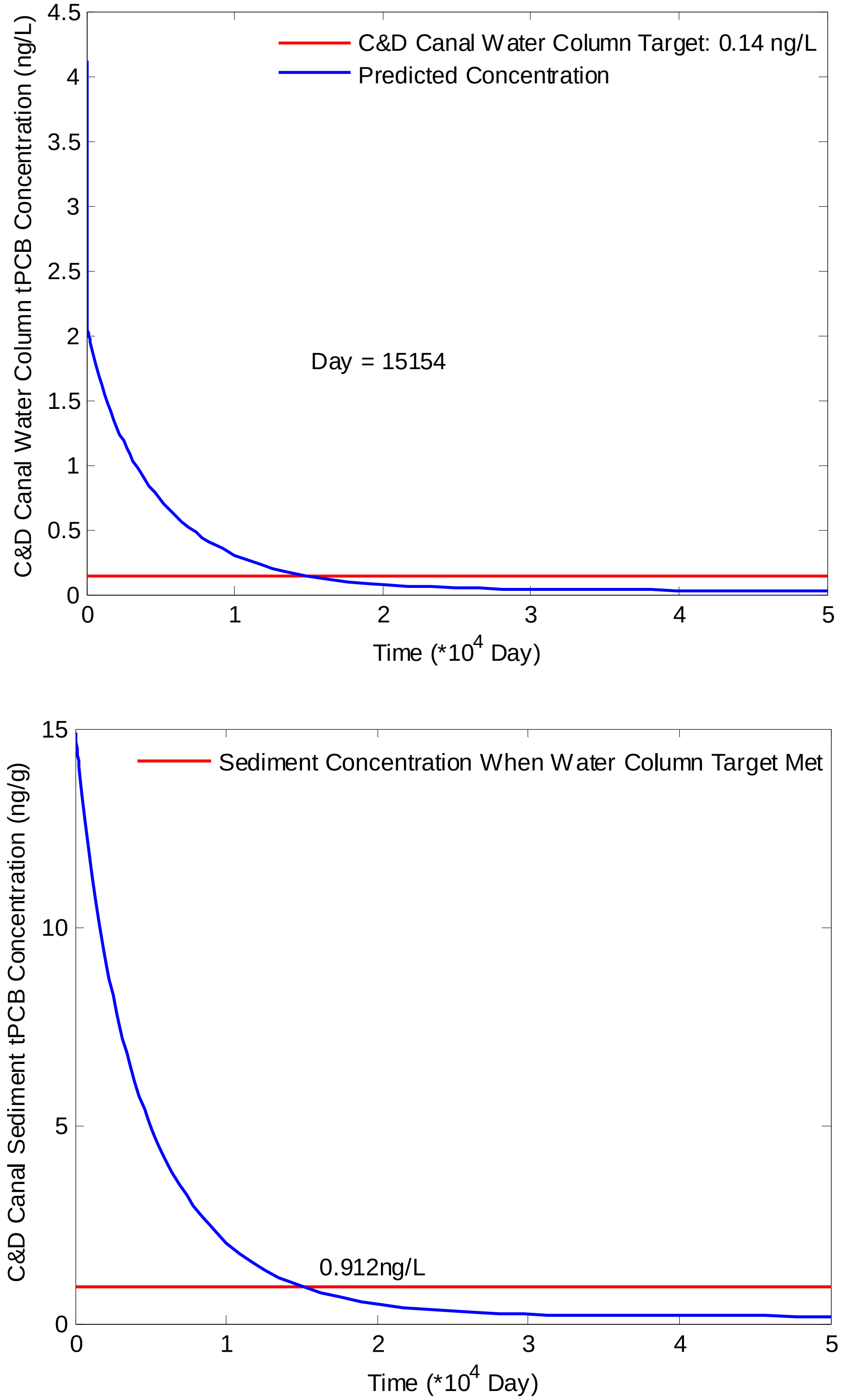


**Figure 8: Change of Average Water Column and Bottom Sediment tPCB Concentrations over Time for the C&D Canal (Baseline Conditions)**

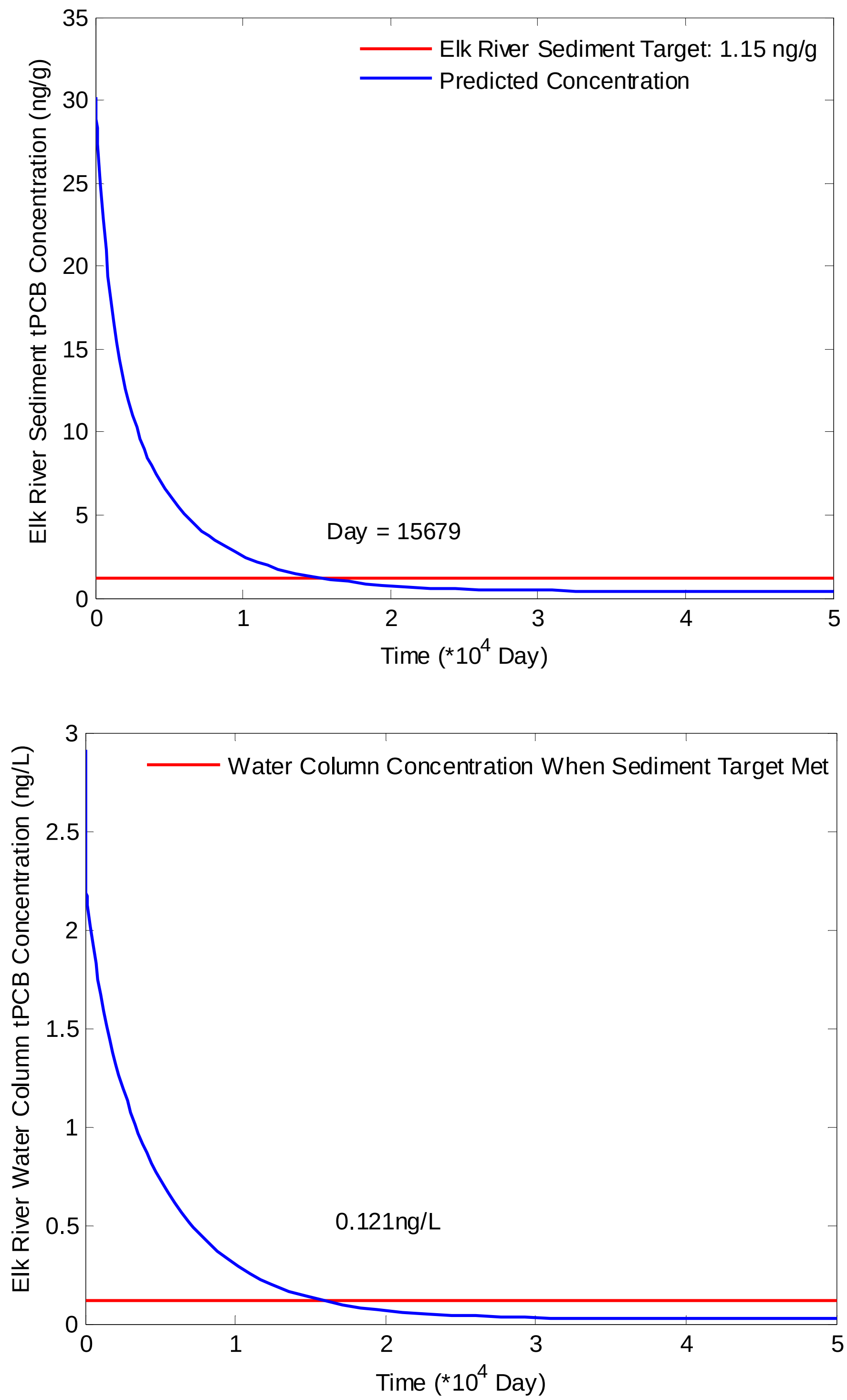


**Figure 9: Change of Average Bottom Sediment and Water Column tPCB Concentrations over Time for the Elk River (43% Total Load Reduction)**

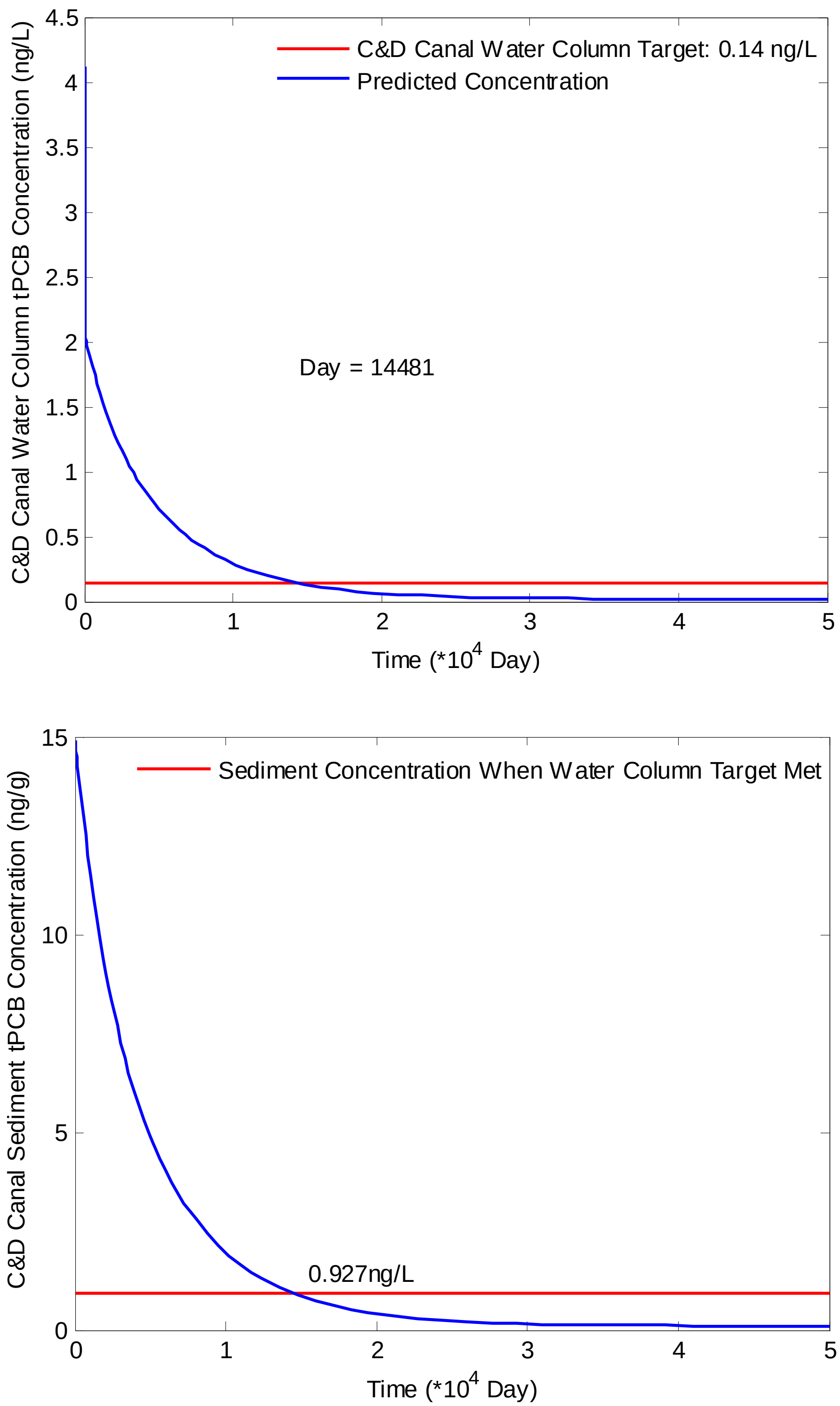


**Figure 10: Change of Average Bottom Sediment and Water Column tPCB Concentrations over Time for the C&D Canal (43% Total Load Reduction)**

## 5.3 Critical Condition and Seasonality

Federal regulations require TMDL analysis take into account the impact of critical conditions and seasonality on water quality (CFR 2013a). 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 approximately on a quarterly basis to account for seasonal variation in establishing the baseline condition for ambient water quality 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 area. 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 saltwater chronic tPCB criterion.

## 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 2013b). 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 Elk River and the C&D Canal. However, as explained above, these allocations are also supportive of the ‘protection of aquatic life” designated use.

### 5.4.1 Load Allocations

LAs have been assigned to the following nonpoint sources in order to support the “fishing” designated use in: 1) the Elk River: non-regulated watershed runoff from the direct drainage portion of the watershed, Big Elk Creek tributary, Pennsylvania and Delaware upstream watersheds, and contaminated sites; and 2) the C&D Canal: non-regulated watershed runoff from the direct drainage portion of the watershed and Delaware upstream watershed. The model demonstrates that in order to support the “fishing” designated use in the Elk River and the C&D Canal, a total tPCB load reduction ranging between 49.4% and 50.0% from these sources is required to achieve the TMDL. Given that the contaminated site baseline load constitutes a relatively small percentage of the Total Baseline Load (0.3%), it is currently not subjected to any reductions. In addition, contaminated sites have already undergone some degree of remediation in accordance with MDE’s Superfund program or Voluntary Cleanup Program (VCP). A reduction to atmospheric deposition is also not applied in the Elk River and the C&D Canal. The primary source of PCBs to the atmosphere is from volatilization of PCB contaminated land sources which will be eliminated as these sources are remediated through implementation of the non-regulated watershed runoff LA and NPDES regulated stormwater WLA. A reduction is also not necessary in order to achieve the TMDL. In addition, this will be consistent with the allocations assigned in the Bohemia River tPCB TMDL.

As explained in Section 4.1, loads associated with resuspension and diffusion from sediments, tidal influences from the Chesapeake Bay mainstem and the Maryland/Delaware boundary in the C&D Canal are not considered to be directly controllable (reducible) within the framework of the TMDL and are thus not assigned baseline loads or allocations. Exchanges between the Elk River and the C&D Canal are accounted for internally within the modeling framework and thus not assigned a baseline load or allocation. In addition, the load associated with exchanges between the Bohemia River and the Elk River was defined by a previously approved PCB TMDL, and is thus not assigned a baseline load or allocation in this TMDL. The water quality model demonstrates that reductions required to achieve the TMDL for the Elk River and the C&D Canal result in water column and sediment concentrations (0.12 ng/L and 0.95 ng/g) within the model segment for the Bohemia River meeting the TMDL endpoints (0.18 ng/L and 1.5 ng/g) established in the Bohemia River PCB TMDL.

### 5.4.2 Wasteload Allocations

**Municipal WWTPs and Industrial Process Water Facility**

There are eleven WWTPs within the Elk River and the C&D Canal watersheds. The estimated WWTP tPCB baseline loadings for the Elk River and the C&D Canal are 14.47 and 0.15 g/year, respectively. The WWTP tPCB baseline load for ten of the WWTPs only accounts for 0.002% of the total baseline load and was therefore considered insignificant as no appreciable environmental benefit would be gained by reducing these loads. The WLA for these facilities will be equivalent to the baseline load. The only WWTP that requires a reduction in order to achieve the TMDL is the Elkton WWTP, which has a tPCB baseline load of 14.19 g/year. Its WLA is calculated by multiplying the water column TMDL endpoint tPCB concentration of 0.14 ng/L by its design flow of 3.2 MGD, resulting in a WLA of 0.62 g/year (Table 11). The elevated tPCB concentrations in wastewater are believed to be primarily due to external sources (e.g., source water, atmospheric deposition, and stormwater runoff) infiltrating into the wastewater collection system through broken sewer lines and connections.

**Table 11: Summary of Elkton WWTP tPCB WLA, Baseline Load, and Load Reduction**

| Facility Name | NPDES # | Water Column Endpoint(ng/L) | Design Flow (MGD) | Baseline Load (g/year) | WLA (g/year) | Load Reduction (%) |
|---|---|---|---|---|---|---|
| Elkton WWTP | MD0020681 | 0.14 | 3.2 | 14.19 | 0.62 | 95.6 |

The Baseline Load and the WLA for the Elkton WWTP are based on effluent samples collected by MDE in 2006. The facility has recently been upgraded to an Enhanced Nutrient Removal (ENR) process and, as a result, additional effluent monitoring data from the facility will be necessary to determine the actual PCB Load Reduction required to meet its assigned WLA. Relative to industrial process water facilities, these facilities are included in Maryland's PCB TMDL analyses if: 1) they are located within the applicable watershed, and 2) they have the potential to discharge PCBs. The only facility identified within the watersheds, the Alliant Techsystems Operations LLC, was considered *de minimis* under this analysis, as its average flow (0.064 MGD) was below 1 MGD. Therefore, no baseline load or WLA is assigned.

**<u>NPDES Regulated Stormwater</u>**

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

As the Elk River and the C&D Canal are connected, and their PCB dynamics were simulated using the same water quality model, their respective NPDES Regulated Stormwater loads are reduced by nearly the same percentage. The NPDES Regulated Stormwater WLA was established by reducing the NPDES Regulated Stormwater Baseline Loads proportionally to the Non-regulated Watershed Runoff Baseline Load, after the WLAs for the remaining source sectors were set, until the TMDL was achieved. For more information on methods used to calculate the NPDES Regulated Stormwater PCB Baseline Load, please see Section 4.2. The NPDES Regulated Stormwater WLA may include any or all of the NPDES stormwater discharges listed in Section 4.2 (see Appendix H for a complete list of stormwater permits). As stormwater assessment and/or other program monitoring efforts result in a more refined source assessment, MDE reserves the right to revise the current NPDES Regulated Stormwater WLA provided the revisions are protective of the "fishing" designated use in the Elk River and the C&D Canal.

The NPDES Regulated Stormwater Baseline Load requires a 49.8% and 50.0% reduction for the Elk River and the C&D Canal, respectively. Table 12 lists the aggregate NPDES Regulated Stormwater WLA.

**Table 12: Summary of the NPDES Regulated Stormwater tPCB Baseline Load, WLA, and Load Reduction by Watershed**

| Watershed | Baseline Load (g/year) | WLA (g/year) | Load Reduction (%) |
|---|---|---|---|
| Elk River | 20.9 | 10.5 | 49.8% |
| C&D Canal | 2.0 | 1.0 | 50.0% |

### 5.5 Margin of Safety

All TMDLs must include a MOS to account for any 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 and at the Maryland/Delaware boundary in the C&D Canal, 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 ensure 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 is reported in Appendix F.

### 5.7 TMDL Summary

Tables 13 and 14 summarize the tPCB baseline loads, TMDL allocations, load reductions, and MDLs (see Appendix F for further details regarding MDL calculations).

**Table 13: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in the Elk River**

| Source | Baseline Load (g/year) | Baseline Load (%) | TMDL (g/year) | Load Reduction (%) | MDL (g/day) |
|---|---|---|---|---|---|
| Direct Atmospheric Deposition | 58.4 | 17.5% | 58.4 | 0.0% | 0.304 |
| Maryland Non-regulated Watershed Runoff [1] | 115.2 | 34.5% | 58.0 | 49.7% | 0.302 |
| Big Elk Creek Tributary [2] | | | | | |
| Maryland | 33.6 | 10.1% | 16.9 | 49.7% | 0.088 |
| Pennsylvania | 67.6 | 20.2% | 34.0 | 49.7% | 0.177 |
| Delaware Upstream Watershed [2] | 3.2 | 1.0% | 1.6 | 50.0% | 0.008 |
| Pennsylvania Upstream Watershed [2] | 19.8 | 5.9% | 10.0 | 49.5% | 0.052 |
| Contaminated Sites | 0.9 | 0.3% | 0.9 | 0.0% | 0.005 |
| ***Nonpoint Sources*** | ***298.7*** | ***89.4%*** | ***179.8*** | **39.8%** | ***0.936*** |
| WWTPs | 14.5 | 4.3% | 0.9 | 93.8% | 0.008 |
| NPDES Regulated Stormwater [1] | 20.9 | 6.3% | 10.5 | 49.8% | 0.055 |
| ***Point Sources*** | ***35.4*** | ***10.6%*** | ***11.4*** | **67.8%** | ***0.063*** |
| ***MOS*** | **-** | **-** | ***10.1*** | **-** | ***0.052*** |
| **Total** | **334.1** | **100.0%** | **201.3** | **39.7%** | **1.051** |

**Notes:** 1 Load applies to the direct drainage portion of the watershed only.
2 Although these loads are reported here as a single nonpoint source value, they could include both point and nonpoint source loads.

**Table 14: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in the C&D Canal**

| Source | Baseline Load (g/year) | Baseline Load (%) | TMDL (g/year) | Load Reduction (%) | MDL (g/day) |
|---|---|---|---|---|---|
| Direct Atmospheric Deposition | 4.0 | 9.1% | 4.0 | 0.0% | 0.021 |
| Maryland Non-regulated Watershed Runoff [1] | 20.3 | 46.0% | 10.2 | 49.8% | 0.053 |
| Delaware Upstream Watershed [2] | 17.6 | 39.9% | 8.9 | 49.4% | 0.046 |
| ***Nonpoint Sources*** | ***41.9*** | ***95.0%*** | ***23.1*** | ***44.9%*** | ***0.120*** |
| WWTPs | 0.2 | 0.5% | 0.2 | 0.0% | 0.002 |
| NPDES Regulated Stormwater [1] | 2.0 | 4.5% | 1.0 | 50.0% | 0.005 |
| ***Point Sources*** | ***2.2*** | ***5.0%*** | ***1.2*** | ***45.1%*** | ***0.007*** |
| ***MOS*** | - | - | ***1.3*** | - | ***0.007*** |
| **Total** | **44.1** | **100.0%** | **25.6** | **42.0%** | **0.134** |

**Notes:** 1 Load applies to the direct drainage portion of the watershed only.
2 Although these loads are reported here as a single nonpoint source value, they could include both point and nonpoint source loads.

## 6.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurance that the tPCB TMDLs for the Elk River and the C&D Canal will be achieved and maintained.

The TMDL presented in this report calls for substantial reductions in tPCB loads from diffuse sources present throughout the Elk River and the C&D Canal watersheds. A portion of the direct drainage area to the Elk River and C&D Canal falls within the upstream watersheds of Delaware and Pennsylvania. In future implementation a multi-stage cooperative effort may be necessary in order to achieve the reductions established by this TMDL. The following implementation measures may apply to the Elk River and the C&D Canal watersheds as well as the upstream watersheds in Delaware and Pennsylvania. Given that PCBs are no longer manufactured, and their use has been substantially restricted, it is reasonable to expect that with time PCB concentrations in the aquatic environment will decline. The tPCB levels in the Elk River and the C&D Canal are expected to decline over time due to natural attenuation, such as the burial of contaminated sediments with newer, cleaner materials and through biodegradation.

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. If PCB-contaminated sediments were removed, load reductions would still be required under the TMDL, though water quality supportive of the “fishing” designated use would be achieved in a much shorter time frame. 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 Elk River and the C&D Canal, by implementing load reductions required under the TMDL and allowing for natural attenuation of PCBs in the sediment, water quality supportive of the “fishing” designated use will be achieved within 43 years while avoiding disturbance of the benthic habitat.

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

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

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

Any future monitoring should include congener specific analytical methods. Ideally, the most current version of EPA Method 1668 should be used, or other equivalent methods capable of providing low-detection level, congener specific results. In establishing the necessity and extent of data collection, MDE will collaborate with the affected stakeholders, and take into account data that is already available, as well as the proper characterization of intake (or pass through) conditions, consistent with NPDES program "reasonable potential" determinations and the applicable provisions of the Environment Article and COMAR for permitted facilities. 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 non-numeric, BMP water quality based effluent limits (WQBELs). BMP WQBELs can be used where "numeric effluent limitations are infeasible; or the practices are reasonably necessary to achieve effluent limitations and standards or to carry out the purposes and intent of the CWA" (CFR 2013c).

In addition, impervious surface restoration efforts have been known to result in total suspended solids (TSS) reduction efficiencies. Since PCBs are known to adsorb to sediments and their concentrations correlate with TSS concentrations, any significant restoration requirements, which will lead to a reduction in sediment loads entering the Elk River and the C&D Canal, will also contribute toward tPCB load reductions and meeting PCB water quality goals. Other BMPs that focus on PCB source tracking and elimination at the source rather than end-of-pipe controls are also warranted.

Where necessary, the source characterization efforts will be followed with pollution minimization and reduction measures that will include BMPs for reducing runoff from urban areas, identification and termination of ongoing sources (*e.g.*, industrial uses of equipment that contain PCBs), etc. The identified NPDES regulated WWTP and stormwater control agency permits will be expected to be consistent with the WLAs presented in this report. Numerous stormwater dischargers are located in the Elk River and the C&D Canal watershed including a Municipal Phase II MS4, the SHA Phase II MS4, a city Phase II, industrial facilities, State and

Federal Phase II MS4s, and any construction activities on area greater than 1 acre (see Appendix H of this document to view the current list of known NPDES stormwater dischargers).

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 2013c). 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 2013), 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 (0.3%) for the Elk River watershed and thus was not subjected to any reduction, it is not intended to be targeted during the initial stages of implementation. However, if in the future it becomes clear that the TMDL goals cannot be achieved without load reductions from these sites, additional reduction measures might need to be considered. No sites with PCB contamination were identified in the C&D Canal watershed.

Given the persistent nature of PCBs, the difficulty in removing them from the environment and the significant reductions necessary in order to achieve water quality goals in the Elk River and the C&D Canal, effectiveness of the implementation effort will need to be reevaluated throughout the process to ensure progress is being made towards reaching the TMDLs. MDE also periodically monitors and evaluates concentrations of contaminants in recreationally caught fish, shellfish, and crabs throughout Maryland. MDE will use these monitoring programs to evaluate progress towards meeting the "fishing" designated use.

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## *Appendix A: List of Analyzed PCB Congeners*

PCB analytical services were provided by 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, Konietcka 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 PCB TMDL (Haywood and Buchanan 2007).

## I. Data Description

The observation-based Adj-tBAF and Adj-SediBAF were calculated for the fish species within the Upper and Lower Elk River, and the C&D Canal from the available fish tissue, water column, and sediment tPCB data. The Elk River (Upper and Lower) and the C&D Canal Adj-tBAFs and Adj-SediBAFs were calculated separately as they are listed separately. Each fish species was assigned a trophic level and a home range (see Table B-1). The Adj-tBAF and Adj-SediBAF were calculated based on the geometric mean tPCB concentrations of all the samples within the home range for each species.

**Table B-1: Species Trophic Levels and Home Ranges**

| Common Name | Scientific Name | Trophic Level | Home Range (miles) |
|---|---|---|---|
| American Eel[2] | *Anguilla rostrata* | Predator | 5 |
| Brown Bullhead[1] | *Ameiurus nebulosus* | Benthivore-Generalist | 5 |
| Channel Catfish1[1,2] | *Ictalurus punctatus* | Benthivore-Generalist | 5 |
| Striped Bass[1] | *Morone saxatilis* | Predator | 10 |
| White Perch[1,2] | *Morone americana* | Predator | 10 |
| Yellow Perch[1] | *Perca flavescens* | Benthivore-Generalist | 2 |

1 Fish caught in the Elk River; 2. Fish caught in the C&D Canal.

## 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 (2000):

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

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):

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

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

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

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

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

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

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

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

## IV. Adjusted Total BAFs

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

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

The tPCB fish tissue listing threshold of 39 ng/g can then be divided by the median Adj-tBAF for each species to translate an associated tPCB water column threshold concentration. Maryland's Integrated Report listing methodology requires tPCB fish tissue concentration data from a minimum of five fish (individual or composite of the same resident species) in order to establish an impairment for PCBs in fish tissue in a given waterbody. Fish that comprise a composite sample must also be within the same size class (i.e., the smallest fish must be within seventy-five percent of the total length of the largest fish) (MDE 2014b). These requirements are also applied in establishing the TMDL endpoints. 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 (Tables B-3 and B-4). In the Elk River, the lowest threshold concentration (0.14 ng/L) is associated with white perch which is calculated based on tPCB fish tissue concentration data from 55 fish (11 composites) satisfying the minimum data requirement of five fish (individual or composite)Therefore, this value is selected as the water column TMDL endpoint. In the C&D Canal, the lowest concentration (0.07 ng/L) is associated with American eel. However, as the American eel is a migratory species and travels outside of the C&D Canal it cannot be determined from what waterbody the species has bioaccumulated the majority of its PCBs. Therefore, the next lowest concentration (0.14 ng/L) associated with channel catfish is selected as the water column TMDL endpoint. The threshold is calculated based on tPCB concentrations from 92 fish (24 composites and 2 individual) of channel catfish satisfying the minimum data requirement of five fish (individual or composite).

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

| Species Name | Number of Fish (Composites) | tBAF (L/kg) | Baseline BAF (L/kg) | Adj-tBAF (L/kg) | Water Column Threshold tPCB Concentration (ng/L) |
|---|---|---|---|---|---|
| Brown Bullhead | 4 (1) | 27,216 | 7,148,289 | 28,512 | 1.37 |
| Channel Catfish | 54 (11) | 136,756 | 11,245,324 | 138,811 | 0.28 |
| Striped Bass | 1 (0) | 86,235 | 24,326,168 | 88,614 | 0.44 |
| **White Perch** | **55 (11)** | **125,839** | **25,714,688** | **280,520** | **0.14** |
| Yellow Perch | 5 (1) | 72,080 | 62,086,598 | 67,733 | 0.58 |

**Table B-4: tBAF, Baseline BAF, Adj-tBAF, and Water Column TMDL Endpoint tPCB Concentrations for Each Species in the C&D Canal**

| Species Name | Number of Fish (Composites) | tBAF (L/kg) | Baseline BAF (L/kg) | Adj-tBAF (L/kg) | Water Column Threshold tPCB Concentration (ng/L) |
|---|---|---|---|---|---|
| American Eel | 3 (1) | 517,196 | 47,503,025 | 553,687 | 0.07 |
| **Channel Catfish** | **92 (24)** | **266,568** | **18,411,382** | **276,678** | **0.14** |
| White Perch | 51 (11) | 208,074 | 26,265,334 | 232,129 | 0.17 |

## V. Biota-Sediment Accumulation Factors and Adjusted Sediment BAFs

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

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

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

Since there is no available % Organic Carbon information for most of the study sites, a default value 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:

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

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 concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the "fishing" designated use (Tables B-5 and B-6). In the Elk River, the lowest concentration (1.15 ng/g) is associated with white perch and will be selected as the sediment TMDL endpoint. In the C&D Canal, the lowest concentration (0.57 ng/g) is associated with American eel. However, since the American eel is a migratory species the next lowest concentration associated with channel catfish (0.93 ng/L) is selected as the sediment TMDL endpoint. As stated previously these thresholds are calculated using tPCB fish tissue concentration data from 55 fish (11 composites) and 92 fish (24 composites) of white perch and channel catfish, respectively.

**Table B-5: BSAF, Adj-SedBAF, and Sediment Target tPCB Concentrations in the Elk River**

| Species Name | BSAF | Adj-SedBAF | Sediment Threshold tPCB Concentration (ng/g) |
|---|---|---|---|
| Brown Bullhead | 4.3 | 5.4 | 7.22 |
| Channel Catfish | 5.4 | 21.9 | 1.78 |
| Striped Bass | 7.6 | 8.7 | 4.50 |
| **White Perch** | **9.0** | **33.9** | **1.15** |
| Yellow Perch | 19.0 | 9.3 | 4.18 |

**Table B-6: BSAF, Adj-SedBAF, and Sediment Target tPCB Concentrations in the C&D Canal**

| Species Name | BSAF | Adj-SedBAF | Sediment Threshold tPCB Concentration (ng/g) |
|---|---|---|---|
| American Eel | 18.6 | 68.4 | 0.57 |
| **Channel Catfish** | **8.9** | **41.8** | **0.93** |
| White Perch | 10.7 | 32.2 | 1.21 |

### *Appendix C: Method Used to Estimate Watershed tPCB Load*

In 2003 (March, April, and July) and 2010 (January, May, July, and October), MDE collected water column PCB measurements at the 10 watershed stations in the Elk River and the C&D Canal watersheds. In order to assess whether or not these samples covered all flow ranges so that they could be used to calculate watershed loads, the closest USGS station (USGS 01495000) was identified (see Figure C-1), and its daily average flow rates from January 2003 to November 2012 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 (see Figure C-2). This comparison indicates that the PCB samples span the full range of flows. It was therefore justified to apply the regression method used in the Back River PCB TMDL (MDE 2011b) to the Elk River and the C&D Canal.

Using the average daily flow at USGS Station 01495000 and the ratio of watershed stations' drainage areas to the USGS station drainage area, the flow corresponding to each sampling date at each station was calculated. The tPCB load was calculated as the flow multiplied by the measured tPCB concentration. Then, the relationship between flow and tPCB loads was generated, as shown in Figure C-3. The linear regression with the highest correlation coefficient ($R^2$) was selected.

The whole Elk River and the C&D Canal watershed was delineated into 20 subwatersheds according to the locations of streams and roads. The average daily flow for the past 10 years (2003-2012) at USGS Station 01495000 was converted to the flow of each subwatershed, based on the ratio of their corresponding drainage areas. Then, the converted flow was fit to the linear regression in order to predict the subwatershed tPCB load.

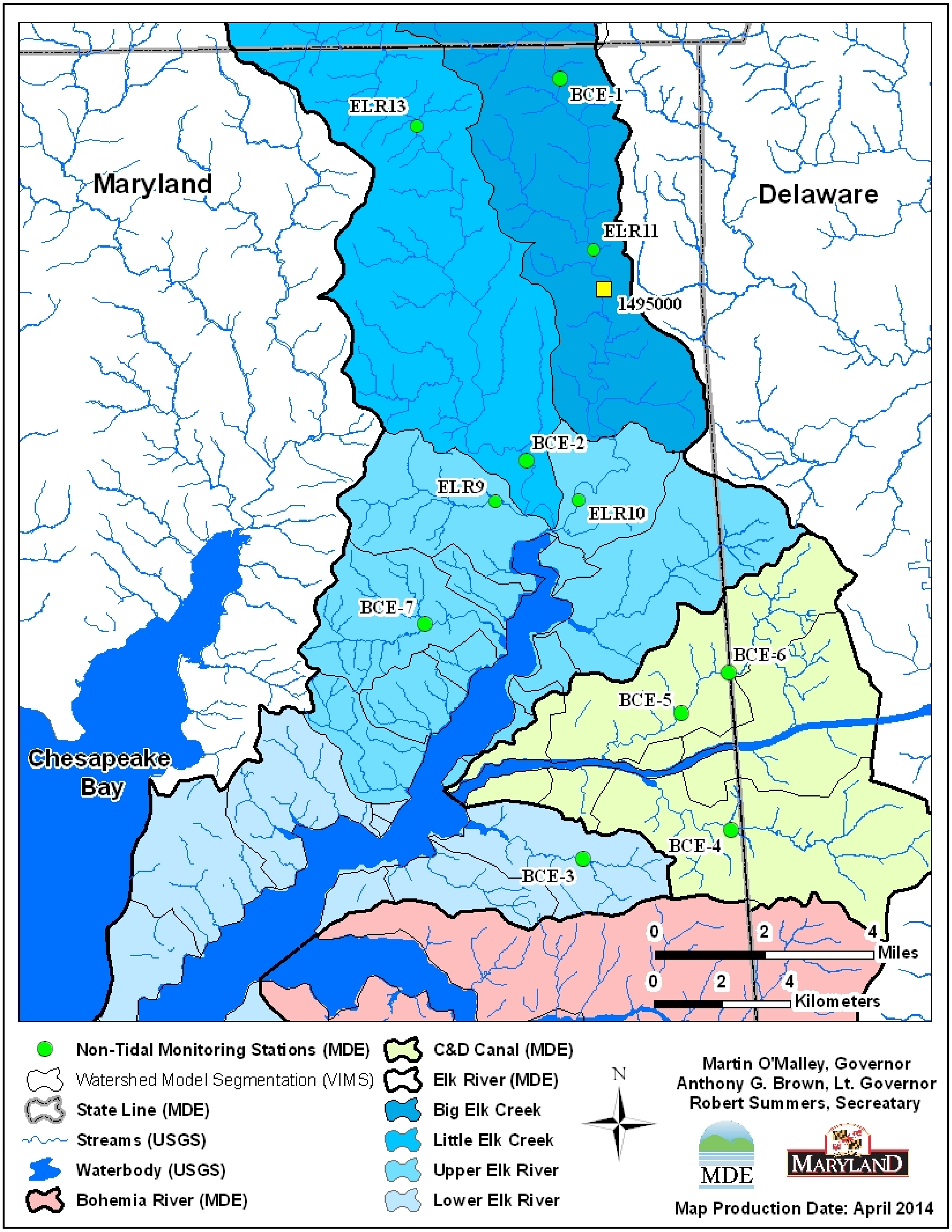
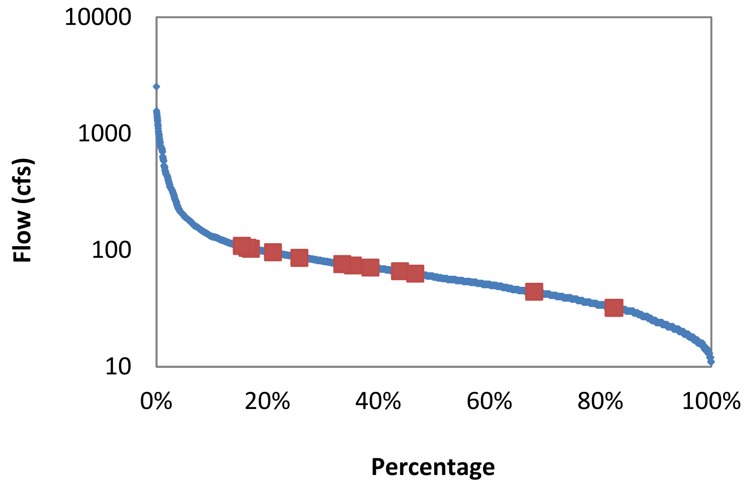



**Figure C-1: The Locations of Watershed PCB Measurement Stations and the USGS Station, and the Delineation of Subwatersheds**




**Note**: The red points represent the location of flows of the watershed station samples

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

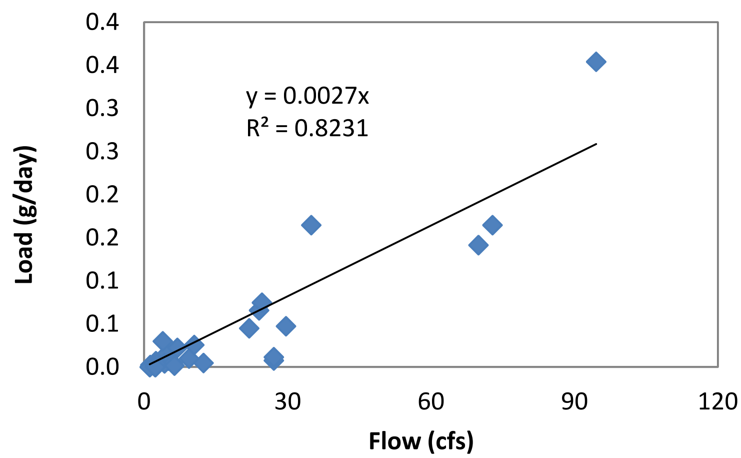



**Figure C-3: Regression between tPCB Loads and the Associated Flows**

## *Appendix D: Multi-Segment Tidally-Averaged One-Dimensional Transport Model*

A tidally averaged multi-segment one-dimensional transport model was used to simulate the total polychlorinated biphenyl (tPCB) dynamic interactions between the water column and bottom sediments within the Elk River, the C&D Canal, the Chesapeake Bay, and the Delaware part of the C&D Canal. The model is based on one-dimensional tidally averaged model (Thomann and Mueller 1987) and adopts the basic assumptions and methodology of the Water Quality Analysis Simulation Program (WASP) (Di Toro *et al*. 1983, Chapra 1997). It is assumed that the pollutant is well mixed in each segment and there is no decay of PCBs. The average observed tPCB concentrations in each segment were used as the model input representing baseline conditions. If the segment did not have any PCB observation, the linear interpolation of the most adjacent up- and down-stream segments' tPCB concentrations was used. The model assumes that at the Chesapeake Bay and Lower Elk River boundary, the water column tPCB concentration on average decreases with a rate of 6.5% per year, which is in consistent with the previous PCB TMDLs (MDE 2009a, 2009b). For the other open boundary (Delaware part of the C&D Canal), the model adopts the water column tPCB concentration decreasing rate in the C&D Canal of 4% per year (derived from DRBC 2011). All other inputs (*i.e.*, freshwater inputs, dispersion coefficients, sediment and water column exchange rates, atmosphere exchange rates, and burial rates) were kept constant.

The river was divided into 20 segments (Figure D-1) and the watershed into 20 subwatersheds as well (Figure C-1). In each segment, PCBs can enter the water column via loadings from adjacent watersheds and atmosphere ($W_n$), loadings from upstream through flow ($Q_{n+1}Cw_{n+1}$), loadings from upstream through dispersion ($D_{n+1}(Cw_{n+1}-Cw_n)CA_{n+1}/L_{n+1}$), resuspension from the sediment ($Vr_nSA_nCs_n$), and diffusion between sediment-water column interface ($VdSA_n(Fds_nCs_n - Fdw_nCw_n)$). For a main-stem segment (e.g., Segments 3) connecting to a branch, the exchange of PCBs with the branch segment is calculated in a similar way as it exchanges with the upstream segment. PCBs leave the water column via loadings to downstream segments through flow and dispersion ($Q_nCw_n$ and $D_n(Cw_n-Cw_{n-1})CA_n/L_n$), volatilization ($VvSA_nFdw_nCw_n$), and settling ($VsetSA_nFpw_nCw_n$).

In the sediment, the PCBs enter the system via settling ($VsetSA_nFpw_nCw_n$), and leave the system via diffusion ($VdSA_n(Fds_nCs_n - Fdw_nCw_n)$), resuspension ($Vr_nSA_nCs_n$) and burial to a deeper layer ($VbSA_nCs_n$).

Specifically, the mass balance for the tPCBs in the water column of segment *n* can be written as:

$$\frac{dVw_nCw_n}{dt} = W_n + Q_{n+1}Cw_{n+1} + D_{n+1}(Cw_{n+1} - Cw_n)CA_{n+1}/L_{n+1} + Vr_nSA_nCs_n + VdSA_n(Fds_nCs_n - Fdw_nCw_n) - Q_nCw_n - D_n(Cw_n - Cw_{n-1})CA_n/L_n - VvSA_nFdw_nCw_n - VsetSA_nFpw_nCw_n \quad \text{(D-1)}$$

and that in the sediment of segment *n* can be written as:

$$\frac{dVs_nCs_n}{dt} = VsetSA_nFpw_nCw_n - VdSA_n(Fds_nCs_n - Fdw_nCw_n) - Vr_nSA_nCs_n - VbSA_nCs_n \quad \text{(D-2)}$$

Where:
$n$ = the nth river segment;
$Vw_n$ and $Vs_n$ = volume of the water and sediment ($m^3$);
$Cw_n$ and $Cs_n$ = tPCB concentration in water and sediment (ng/L);
$t$ = time (day);
$W_n$ = tPCB loading from adjacent watershed (including tributaries) and atmosphere (ug/day);
$Q_n$ = quantity of water that flows from segment $n$ to $n$-$1$ ($m^3$/day);
$Q_{nb}$ = quantity of water that flows from adjacent branch to segment $n$ ($m^3$/day);
$D_n$ = dispersion coefficients (tidal averaged diffusivity) at the upstream side of segment $n$ ($m^2$/day);
$CA_n$ = cross sectional area between segment $n$ and $n$-$1$ ($m^2$);
$L_n$ = distance between center of segment $n$ to $n$-$1$ (m);
$SA_n$ = surface area of segment $n$ ($m^2$);
$Vr_n$ = rate of resuspension (m/day);
$Vd$ = diffusive mixing velocity (m/day), which is same for all the segments;
$Vv$ = volatilization coefficient (m/day), which is same for all the segments;
$Vset$ = rate of settling (m/day);
$Vb$ = burial rate (m/day), which is same for all the segments;
$Fdw_n$ = fraction of truly dissolved and dissolved organic carbon (DOC) associated PCBs in the water column;
$Fds_n$ = fraction of truly dissolved and DOC associated PCBs in the sediment;
$Fpw_n$ = fraction of particular associated PCBs in the water column.

The values of the parameters for the Elk River and the C&D Canal are as follows:

$n$ = 20. It was delineated in consideration of the locations of the water quality monitoring stations and the bathymetry.
$Vw_n$ = mean water depth of segment $n$ × surface area of segment $n$. The mean water depth was obtained from the bathymetry data.
$Vs_n$ = active sediment layer thickness × surface area of segment $n$.
$Cw_n$ = measured tPCB water column concentration of segment $n$. If the measurement was not available, the linear interpolation of the most adjacent segments' concentrations was used.
$Cs_n$ = Measured tPCB concentration on a dry sediment base × Sediment density × (1-porosity) ÷ Fraction of particulate associated PCBs in the sediment, and the porosity (water content on a volume base) of 0.8 is selected based on reference (Thomann and Mueller 1987);
$W_n$ = tPCB loading from the adjacent watershed of segment $n$ and atmosphere. As showed in Figure C-1, the watershed was divided into 20 subwatersheds. The subwatershed baseline tPCB loading using the regression method described in Appendix C. The direct atmospheric deposition load to the surface of each segment

was calculated by multiplying the surface area and the deposition rate of 1.6 μg/m²/year.
$Q_n$ = total flow across the outlet of Segment *n*-1. It was calculated from the 3-D hydrodynamic model simulation results described below, using the 10-year daily mean flows at the USGS station 01495000.
$D_n$ = dispersion coefficient of each segment. It was calculated from the 3-D hydrodynamic model simulation results described below.
$CA_n$ = depth × length of the cross section.
$L_n$ = distance between segments directly measured using ArcView GIS.
$SA_n$ = surface area calculated from ArcView GIS.
$Vd = 69.35 \times$ Porosity $\times$ (Molecular weight of PCBs)$^{-2/3} \div 365 = 69.35 \times 0.85 \times (305.6)^{-2/3} \div 365 = 0.00356$ (m/day, Thomann and Mueller 1987).
$Vv$ = 0.246 m/day, which was derived from empirical method of Chapra (1997).
$Vset$ = 1 (m/d), a default value of settling rate used in literature (DRBC 2003).
$Vb = 3.935\times10^{-6}$ (m/day, average of the measured sedimentation rates through $^{210}$Pb technology for Corsica River, Northeast River, Bohemia river, and Sassafras River).
$V_r$ can be calculated via mass balance of the sediment in the active sediment layer at steady state.

In this study, because the targeted waterbody is located in the junction of Chesapeake Bay and Delaware Bay and partially includes the C&D Canal that connects the two large estuaries, it has two open boundaries, one in the Chesapeake Bay and the other one in Delaware Bay. Hence, the total flow across the segments in the C&D Canal is largely controlled by the higher mean sea level (MSL) at the west end in Chesapeake Bay compared to the MSL at the east end in Delaware Bay (Ward et al., 2009) other than the freshwater input from the watershed. To calculate the total flow and dispersion coefficients, a 3-D hydrodynamic model based on the widely used Finite-Volume Coastal Ocean Model (FVCOM, Chen et al., 2003) was used. Figure D-2 shows the FVCOM model configuration (model grid and NOAA tidal stations) and the corresponding 1-D PCBs model segments. The 3-D hydrodynamic model was driven by 10-year mean freshwater discharge calculated based on the USGS gage 01495000 and National Oceanic and Atmospheric Administration (NOAA) predicted tides at the two open boundaries. Specifically, for the west open boundary located in Chesapeake Bay, the averaged tides at Betterton, MD and Town Point Wharf, MD were applied; for the east open boundary, the tides at Reedy Point, DE were applied. To calculate the dispersion coefficients, a passive tracer simulation was conducted by specifying a constant tracer concentration of 2 mg/L at the west open boundary. Ten uniform sigma layers were applied at the vertical direction. The simulation was conducted for 10 years. At the end of simulation, the model results (water level, velocity, and tracer concentrations for each FVCOM model grid) were averaged over the 10-year period to calculate the total flow across the interfaces of the 20 PCBs model segments and the mean tracer concentration of each segment. The dispersion coefficients can then be calculated using the same method documented in previous study reports except in the method that salinity was replaced with tracer. Figure D-3 shows an example plot of the model predicted tide against NOAA data at Chesapeake City, NJ. It can be seen the model prediction compares with the data very well. In addition, the model predicted net flow rate (~120 $m^3/s$) through the C&D Canal is also consistent with other studies (Ward *et al*. 2009).

Some physical parameters of each segment can be found in Table D-1. For $Fdw_n$, $Fds_n$, and $Fpw_n$ see Appendix E for derivation.

**Table D-1: Physical Parameters of the Model for Each Segment**

| *n* | *SA* ($m^2$) | *Vw* ($m^3$) | *CA* | *L* | *Fdw* | *Fds* | *Fpw* |
|---|---|---|---|---|---|---|---|
| 1 | 5225649 | 21486994 | 9576 | 1969 | 0.6009 | 0.0017 | 0.3991 |
| 2 | 7284521 | 28759490 | 8405 | 3150 | 0.6156 | 0.0017 | 0.3844 |
| 3 | 5294837 | 18596494 | 7092 | 3034 | 0.5275 | 0.0017 | 0.4725 |
| 4 | 4966287 | 14840311 | 5225 | 3114 | 0.3647 | 0.0017 | 0.6353 |
| 5 | 1421457 | 4580089 | 3105 | 2169 | 0.4908 | 0.0017 | 0.5092 |
| 6 | 2658283 | 6424405 | 3253 | 1340 | 0.4782 | 0.0017 | 0.5218 |
| 7 | 1017438 | 4675624 | 1837 | 2711 | 0.6310 | 0.0017 | 0.3690 |
| 8 | 598468 | 3184135 | 1403 | 2110 | 0.6220 | 0.0017 | 0.3780 |
| 9 | 502674 | 2782355 | 1503 | 2076 | 0.6143 | 0.0017 | 0.3857 |
| 10 | 395829 | 2784183 | 1604 | 1793 | 0.6217 | 0.0017 | 0.3783 |
| 11 | 865274 | 6789121 | 1717 | 2771 | 0.6293 | 0.0017 | 0.3707 |
| 12 | 12005158 | 17310880 | 1693 | 3880 | 0.5386 | 0.0017 | 0.4614 |
| 13 | 1432283 | 2569923 | 2358 | 4503 | 0.4782 | 0.0017 | 0.5218 |
| 14 | 2739690 | 3293214 | 1977 | 1346 | 0.4696 | 0.0017 | 0.5304 |
| 15 | 1085314 | 1954496 | 1730 | 1737 | 0.6521 | 0.0017 | 0.3479 |
| 16 | 1325253 | 1156480 | 2398 | 1468 | 0.4708 | 0.0017 | 0.5292 |
| 17 | 1896496 | 1599672 | 879 | 1095 | 0.4000 | 0.0017 | 0.6000 |
| 18 | 913772 | 949430 | 597 | 1424 | 0.5409 | 0.0017 | 0.4591 |
| 19 | 151768 | 99992 | 525 | 1152 | 0.9378 | 0.0017 | 0.0622 |
| 20 | 116512 | 80151 | 32 | 2213 | 0.6327 | 0.0017 | 0.3673 |

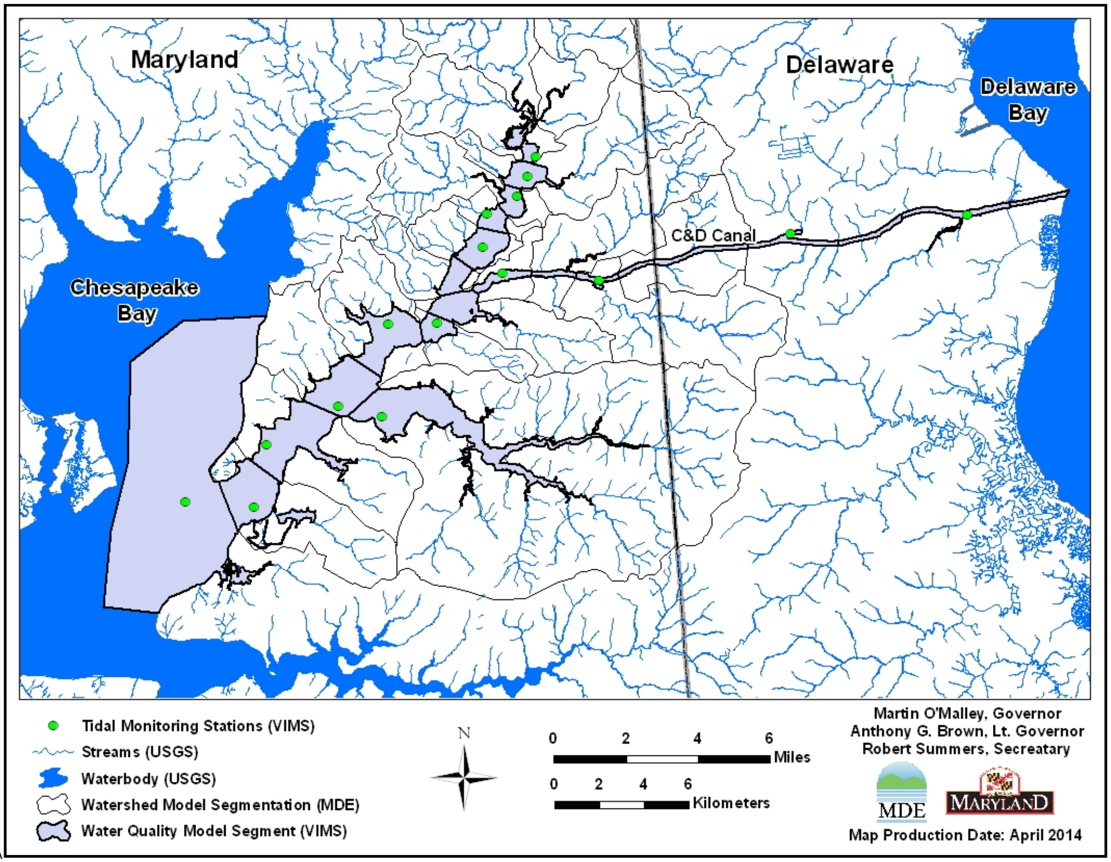



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**Figure D-1: Tidal PCB Measurement Stations and FVCOM Model Grid**

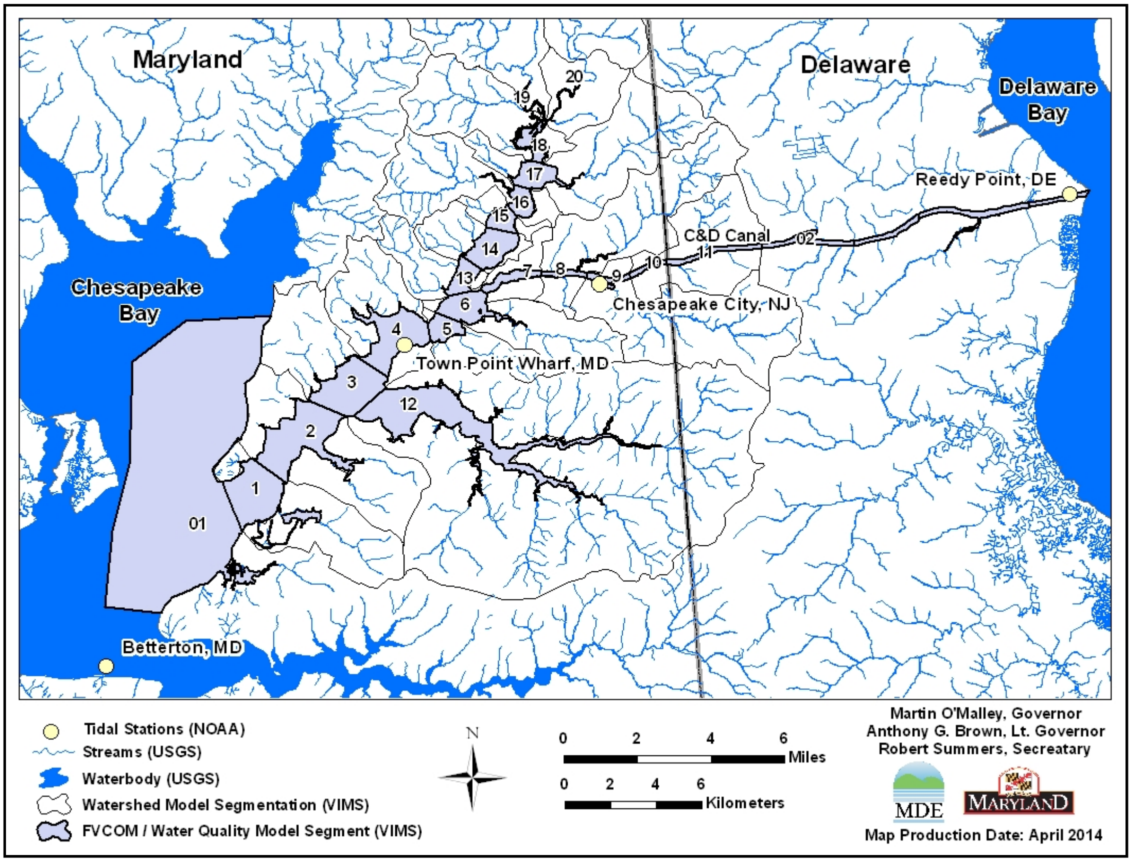


**Figure D-2: FVCOM Model Grid and Corresponding 1-D PCB Model Segments (Segments 01 and 02 Correspond to the Open Boundary Segments in the 1-D PCB Model)**

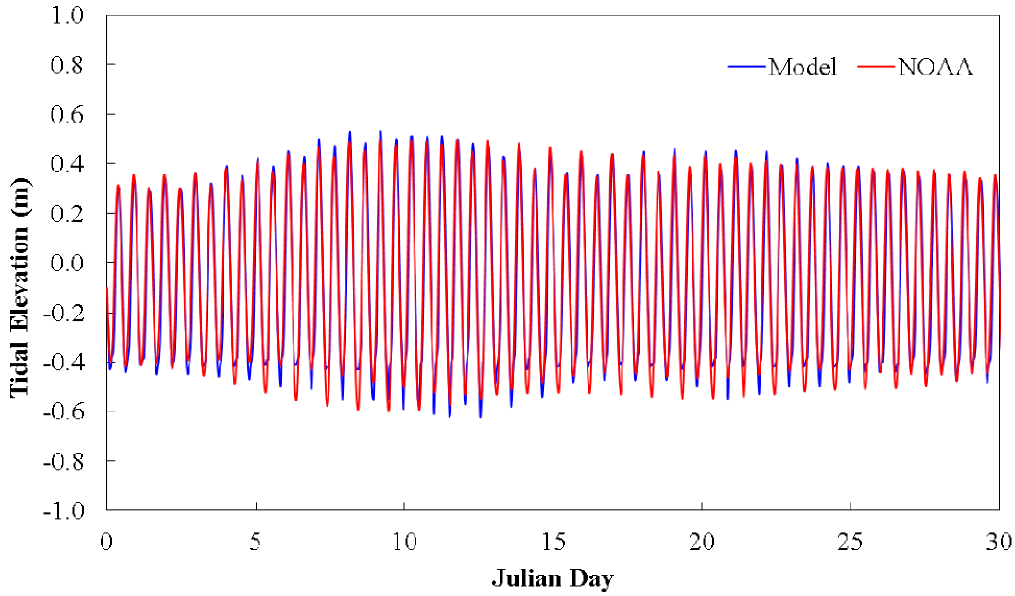


**Figure D-3: FVCOM Model Predicted Tides vs. NOAA Data at Chesapeake City, NJ Tidal Station**

### *Appendix E: Calculation of Fractions of Different PCB Forms*

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

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

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

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

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.

$\varphi$ = the porosity of the sediment.

## *Appendix F: 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 Elk River and the C&D Canal area. 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 Elk River and the C&D Canal.

<u>Level of Resolution</u>

The level of resolution pertains to the amount of detail used in specifying the MDL. The draft EPA guidance on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Elk River and the C&D Canal watershed:

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

<u>Probability Level</u>

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

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

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

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

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

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

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

## V. Selected Approach

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

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

The CV was calculated using the arithmetic mean and standard deviation of the baseline ambient water column tPCB concentrations in the Elk River and the C&D Canal. The resulting CV of 0.58 was calculated using the following equation:

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

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:

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

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 0.58, and consistent units, the resulting dimensionless conversion factor from long-term average loads to a maximum daily value is 1.88. The average annual Elk River and C&D Canal PCB TMDL is reported in g/year, and the conversion from g/year to a maximum daily load in g/day is 0.0052 (e.g. 1.88/365).

## VIII. Approach for WWTPs

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

## IX. Results of Approach

This section lists the results of the selected approach to define the Elk River and the C&D Canal MDLs.

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

    Direct Atmospheric Deposition LA (g/day) = Average Annual TMDL Direct Atmospheric Deposition LA (g/year) * 0.0052

    Non-regulated Watershed Runoff LA (g/day) = Average Annual TMDL Non-regulated Watershed Runoff LA (g/year) * 0.0052

    Contaminated Site LA (g/day) = Average Annual TMDL Contaminated Site LA (g/year) * 0.0052

    NPDES Stormwater WLA (g/day) = Average Annual TMDL NPDES Regulated Stormwater WLA (g/year) * 0.0052

- Calculation Approach for WWTPs

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

**Table F-1: Summary of tPCB MDLs for the Elk River**

| Source | MDL (g/day) |
|---|---|
| Direct Atmospheric Deposition | 0.304 |
| Maryland Non-regulated Watershed Runoff | 0.302 |
| Big Elk Creek Tributary | |
| Maryland | 0.088 |
| Pennsylvania | 0.177 |
| Delaware Upstream Watershed | 0.008 |
| Pennsylvania Upstream Watershed | 0.052 |
| Contaminated Sites | 0.005 |
| ***Nonpoint Sources*** | ***0.936*** |
| WWTPs | 0.008 |
| NPDES Regulated Stormwater | 0.055 |
| ***Point Sources*** | ***0.063*** |
| ***MOS*** | ***0.052*** |
| **Total** | **1.051** |

**Table F-2: Summary of tPCB MDLs for the C&D Canal**

| Source | MDL (g/day) |
|---|---|
| Direct Atmospheric Deposition | 0.021 |
| Maryland Non-regulated Watershed Runoff | 0.053 |
| Delaware Upstream Watershed | 0.046 |
| ***Nonpoint Sources*** | ***0.120*** |
| WWTPs | 0.002 |
| NPDES Regulated Stormwater | 0.005 |
| ***Point Sources*** | ***0.007*** |
| ***MOS*** | ***0.007*** |
| **Total** | **0.134** |

## *Appendix G: 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 thirty-six contaminated sites within the Elk River watershed and one in the C&D Canal watershed, for which EOF tPCB baseline loads have been estimated. Only twelve sites in the Elk River area have been identified with PCB soil concentrations at or above method detection levels. In the C&D Canal watershed no site has been identified. Figure 5 depicts their locations. These sites (see Table G-1) were identified based on information gathered from MDE's LRP-MAP database (MDE 2013), 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, thirteen of which have been approved by the EPA since 2006. 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 the site (contained within MDE's LRP-MAP database and located within the Elk River and the C&D Canal watersheds) 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. Twelve properties (See Table G-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:

[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.

http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm. The site characteristics (e.g., 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 previous area of the site was used in the calculations). These total adjusted pervious areas were then used in conjunction with the RUSLE2 generated soil loss values to produce a total soil loss value for each site in tons/year. To be consistent with the RUSLE2 soil loss units, the median tPCB soil 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 G-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. Varies delivery factors have been applied to different sites to the EOF loads. The resultant EOS loads are listed in Table G-1.

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

| Site Name | Median tPCB (μg/kg) | Soil Loss (lbs/year) | EOF Load (g/year) | Delivery Factor | EOS Load (g/year) |
|---|---|---|---|---|---|
| Childs Property | 273 | 25 | $3.10\times10^{-3}$ | 0.50 | $1.54\times10^{-3}$ |
| Dwyer Property | 314 | 1944 | $2.76\times10^{-1}$ | 0.57 | $1.57\times10^{-1}$ |
| IP Inc. | 362 | 1338 | $2.19\times10^{-1}$ | 0.33 | $7.18\times10^{-2}$ |
| Herron Area 3 | 300 | 3679 | $5.01\times10^{-1}$ | 0.40 | $2.00\times10^{-1}$ |
| Herron Area 4 | 133 | 2344 | $1.41\times10^{-1}$ | 0.52 | $7.31\times10^{-2}$ |
| Former PECO Elkton Service Building | 206 | 43 | $4.03\times10^{-3}$ | 0.34 | $1.36\times10^{-3}$ |
| RMR/JMR Corporation | 2000 | 46 | $4.19\times10^{-2}$ | 0.33 | $1.39\times10^{-2}$ |
| Reginald Thompson Property | 297 | 693 | $9.34\times10^{-2}$ | 0.64 | $5.98\times10^{-2}$ |
| Old Elkton Dump | 3500 | 345 | $5.48\times10^{-1}$ | 0.32 | $1.74\times10^{-1}$ |
| New Jersey Fireworks and Route 7 Dum | 184 | 449 | $3.74\times10^{-2}$ | 0.62 | $2.31\times10^{-2}$ |
| Patriotic Fireworks | 91 | 5145 | $2.13\times10^{-1}$ | 0.44 | $9.33\times10^{-2}$ |
| Globe Fireworks / Bacon Hill | 38 | 104 | $1.76\times10^{-3}$ | 0.44 | $7.75\times10^{-4}$ |
| **Total** | | **16,155** | $\mathbf{2.08\times10^{0}}$ | | $\mathbf{8.70\times10^{-1}}$ |

### V. Contaminated Site Baseline Load Summary

The total Contaminated Site tPCB Baseline Load from the identified sites in the Elk River watershed is estimated to be 0.87 g/year. No sites were identified in the C&D Canal watershed.

## *Appendix H: List of NPDES Regulated Stormwater Permits*

### Table H-1: NPDES Regulated Stormwater Permit Summary for the Elk River and the C&D Canal Watersheds [1]

| MDE Permit | NPDES | Facility | City | County | Type | TMDL | Watershed |
|---|---|---|---|---|---|---|---|
| 05-SF-5501 | MDR055501 | State Highway Administration (MS4) | State-wide | All Phase II (Cecil) | WMA6 | Stormwater WLA | C&D Canal/ Elk River |
| 09-GP-0000 | MDR100000 | MDE General Permit to Construct | All | All | | Stormwater WLA | C&D Canal/ Elk River |
| 03-IM-5500 | MDR055500 | Cecil County Phase II MS4 | County-wide | Cecil | WMA6 | Stormwater WLA | C&D Canal/ Elk River |
| 03-IM-5500 | MDR055500 | Town of Elkton Phase II MS4 | City-wide | Cecil | WMA6 | Stormwater WLA | Elk River |
| 02-SW-0433 | MDR000433 | Terumo Medical Corporation | Elkton | Cecil | WMA6 | Stormwater WLA | Elk River |
| 02-SW-0611 | MDR000611 | W.L. Gore & Associates, Inc. Elk Creek | Elkton | Cecil | WMA6 | Stormwater WLA | Elk River |
| 02-SW-0924 | MDR000924 | Norton Petroleum Corporation | Elkton | Cecil | WMA6 | Stormwater WLA | Elk River |
| 02-SW-1319 | MDR001319 | SHA - Elkton Shop | Elkton | Cecil | WMA6 | Stormwater WLA | Elk River |
| 02-SW-2075 | MDR002075 | Elkton Recycling, Inc. | Elkton | Cecil | WMA6 | Stormwater WLA | Elk River |
| | | | | | | | |
| 02SW0402 | MDR000402 | Elkton WWTP | Elkton | Cecil | WMA6 | Stormwater WLA | Elk River |
| 02SW0678 | MDR000678 | Luqui-box Corporation | Elkton | Cecil | WMA6 | Stormwater WLA | Elk River |
| 02-SW-1363 | MDR001363 | Elk Neck State Park | Northeast | Cecil | WMA6 | Stormwater WLA | Elk River |

**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 I: Total PCB Concentrations and Locations of the Sediment and Fish PCB Monitoring Stations*

Tables I-1 through I-6 list the tPCB concentrations in the sediment, water column and fish tissue samples collected in the Elk River and the C&D Canal area. Sediment and fish tissue samples were collected at tidal monitoring stations while water column samples were collected at tidal and non-tidal monitoring stations. Figures I-1, I-2, and I-3 display the locations of the non-tidal, tidal and fish tissue monitoring stations, respectively.

**Table I-1: Sediment tPCB Concentrations (ng/g) in the Elk River**

| Station | Date | Concentration (ng/g) |
|---|---|---|
| BOR4 | 10/1/2003 | 38.64 |
| CBTox1 | 6/25/2003 | 42.51 |
| ELR1 | 7/16/2003 | 10.09 |
| ELR12 | 7/17/2003 | 47.14 |
| ELR2 | 10/1/2003 | 5.42 |
| ELR3 | 7/16/2003 | 27.32 |
| ELR4 | 7/16/2003 | 38.22 |
| ELR5 | 7/16/2003 | 49.62 |
| ELR6 | 7/16/2003 | 25.33 |
| ELR7 | 7/16/2003 | 27.15 |
| ELR8 | 7/16/2003 | 23.92 |
| NSS7 | 5/1/1993 | 51.97 |

**Table I-2: Sediment tPCB Concentrations (ng/g) in the C&D Canal**

| Station | Date | Concentration (ng/g) |
|---|---|---|
| CD1 | 6/25/2003 | 0.6 |
| CD1 | 10/1/2003 | 192.92 |
| CD2 | 6/25/2003 | 1.85 |
| CD2 | 10/1/2003 | 143.21 |
| CD3 | 6/25/2003 | 0.58 |
| CD3 | 10/1/2003 | 25.83 |
| CD4 | 6/25/2003 | 2.14 |
| CD4 | 10/1/2003 | 17.13 |
| BCE8 | 5/20/2010 | 60.63 |
| BCE8 | 10/20/2010 | 53.74 |

**Table I-3: Water Column tPCB Concentrations (ng/L) in the Elk River**

| Date | Station | Station Type | Conc. (ng/L) | Date | Station | Station Type | Conc. (ng/L) |
|---|---|---|---|---|---|---|---|
| 3/8/1993 | cb1 | Tidal | 4.59 | 9/16/2003 | BOR4 | Tidal | 4.02 |
| 4/12/1993 | cb1 | Tidal | 5.19 | 9/16/2003 | ELR6 | Tidal | 7.82 |
| 6/1/1993 | cb1 | Tidal | 2.74 | 10/1/2003 | BOR4 | Tidal | 4.4 |
| 9/20/1993 | cb1 | Tidal | 4.19 | 10/1/2003 | ELR2 | Tidal | 4.62 |
| 2/24/2003 | CBTOX1 | Tidal | 0.44 | 3/11/2003 | ELR13 | Non-Tidal | 1.93 |
| 3/12/2003 | ELR5 | Tidal | 3.98 | 3/12/2003 | ELR10 | Non-Tidal | 1.75 |
| 3/12/2003 | ELR6 | Tidal | 2.98 | 3/12/2003 | ELR11 | Non-Tidal | 1.53 |
| 3/12/2003 | ELR7 | Tidal | 3.4 | 3/12/2003 | ELR9 | Non-Tidal | 0.43 |
| 3/12/2003 | ELR8 | Tidal | 2 | 4/15/2003 | ELR13 | Non-Tidal | 1.24 |
| 3/13/2003 | BOR4 | Tidal | 0.87 | 4/16/2003 | ELR10 | Non-Tidal | 4.78 |
| 3/13/2003 | ELR12 | Tidal | 2.14 | 4/16/2003 | ELR11 | Non-Tidal | 0.83 |
| 3/12/2003 | ELR1 | Tidal | 3.51 | 4/16/2003 | ELR9 | Non-Tidal | 1.31 |
| 3/13/2003 | ELR2 | Tidal | 1.83 | 7/16/2003 | ELR10 | Non-Tidal | 3.18 |
| 3/13/2003 | ELR3 | Tidal | 1.92 | 1/21/2010 | BCE-1 | Non-Tidal | 0.65 |
| 3/13/2003 | ELR4 | Tidal | 2.75 | 1/21/2010 | BCE-2 | Non-Tidal | 1.12 |
| 4/1/2003 | CBTOX1 | Tidal | 1.45 | 1/21/2010 | BCE-3 | Non-Tidal | 0.76 |
| 4/16/2003 | ELR1 | Tidal | 0.64 | 1/21/2010 | BCE-7 | Non-Tidal | 0.56 |
| 4/16/2003 | ELR5 | Tidal | 2.11 | 5/20/2010 | BCE-1 | Non-Tidal | 0.92 |
| 4/16/2003 | ELR6 | Tidal | 6.2 | 5/20/2010 | BCE-2 | Non-Tidal | 0.82 |
| 4/16/2003 | ELR7 | Tidal | 6.44 | 5/20/2010 | BCE-3 | Non-Tidal | 0.68 |
| 4/16/2003 | ELR8 | Tidal | 3.43 | 5/20/2010 | BCE-7 | Non-Tidal | 0.11 |
| 4/17/2003 | BOR4 | Tidal | 3.95 | 7/29/2010 | BCE-2 | Non-Tidal | 0.84 |
| 4/17/2003 | ELR12 | Tidal | 0.45 | 7/29/2010 | BCE-3 | Non-Tidal | ND |
| 4/17/2003 | ELR2 | Tidal | 3.48 | 7/29/2010 | BCE-7 | Non-Tidal | ND |
| 4/17/2003 | ELR3 | Tidal | 3.84 | 7/29/2010 | BCE-1 | Non-Tidal | 0.11 |
| 4/17/2003 | ELR4 | Tidal | 2.61 | 10/26/2010 | BCE-1 | Non-Tidal | 0.17 |
| 6/25/2003 | CBTOX1 | Tidal | 4.01 | 10/26/2010 | BCE-2 | Non-Tidal | 0.93 |
| 7/16/2003 | ELR2 | Tidal | 5.71 | 10/26/2010 | BCE-3 | Non-Tidal | ND |
| 7/16/2003 | ELR6 | Tidal | 6.81 | 10/26/2010 | BCE-7 | Non-Tidal | ND |
| 7/17/2003 | BOR4 | Tidal | 5.44 | | | | |

**Table I-4: Water Column tPCB Concentrations (ng/L) in the C&D Canal**

| Date | Station | Station Type | Conc. (ng/L) | Date | Station | Station Type | Conc. (ng/L) |
|---|---|---|---|---|---|---|---|
| 3/12/2003 | CD1 | Tidal | 9.58 | 1/21/2010 | BCE-8 | Tidal | 2.91 |
| 3/12/2003 | CD2 | Tidal | 1.78 | 5/20/2010 | BCE-8 | Tidal | 1.9 |
| 3/12/2003 | CD3 | Tidal | 1.32 | 7/29/2010 | BCE-8 | Tidal | 3.24 |
| 3/12/2003 | CD4 | Tidal | 0.76 | 10/26/2010 | BCE-8 | Tidal | 3.85 |
| 4/16/2003 | CD1 | Tidal | 1.54 | 1/21/2010 | BCE-4 | Non-Tidal | 0.61 |
| 4/16/2003 | CD2 | Tidal | 1.5 | 1/21/2010 | BCE-5 | Non-Tidal | 0.41 |
| 4/16/2003 | CD3 | Tidal | 1.97 | 1/21/2010 | BCE-6 | Non-Tidal | 1.16 |
| 4/16/2003 | CD4 | Tidal | 7.28 | 5/20/2010 | BCE-4 | Non-Tidal | 0.16 |
| 6/25/2003 | CD1 | Tidal | 5.29 | 5/20/2010 | BCE-5 | Non-Tidal | 1 |
| 6/25/2003 | CD2 | Tidal | 4.54 | 5/20/2010 | BCE-6 | Non-Tidal | 0.29 |
| 6/25/2003 | CD3 | Tidal | 6.47 | 7/29/2010 | BCE-4 | Non-Tidal | 1.31 |
| 6/25/2003 | CD4 | Tidal | 4.85 | 7/29/2010 | BCE-5 | Non-Tidal | 3.14 |
| 10/1/2003 | CD1 | Tidal | 9.37 | 7/29/2010 | BCE-6 | Non-Tidal | 0.34 |
| 10/1/2003 | CD2 | Tidal | 5.25 | 10/26/2010 | BCE-4 | Non-Tidal | 0.96 |
| 10/1/2003 | CD3 | Tidal | 6.86 | 10/26/2010 | BCE-5 | Non-Tidal | ND |
| 10/1/2003 | CD4 | Tidal | 4.52 | 10/26/2010 | BCE-6 | Non-Tidal | 0.03 |

**Table I-5: Fish Tissue tPCB Concentrations (ng/g) in the Elk River**

| Station | Date | Fish Species | Fish/ Composite (#) | Mean Length (cm) | Mean weight (g) | Conc. (ng/g) |
|---|---|---|---|---|---|---|
| BoRL | 9/11/2000 | Channel Catfish | 2.0 | 53.6 | 1610.0 | 345 |
| BoRL | 9/11/2000 | White Perch | 5.0 | 19.1 | 89.0 | 256.6 |
| BoRL | 9/11/2000 | Channel Catfish | 3.0 | 48.6 | 1179.0 | 336.2 |
| BoRL | 9/11/2000 | Channel Catfish | 3.0 | 39.4 | 579.0 | 354.8 |
| BoRL | 9/11/2000 | Channel Catfish | 4.0 | 36.5 | 437.0 | 365.2 |
| BoRL | 9/11/2000 | White Perch | 5.0 | 17.2 | 72.0 | 486.9 |
| BoRL | 10/5/2006 | White Perch | 5.0 | 19.0 | 91.8 | 189.5 |
| BoRL | 10/5/2006 | White Perch | 5.0 | 21.7 | 134.2 | 153.2 |
| BoRL | 10/5/2006 | Channel Catfish | 4.0 | 33.3 | 317.0 | 117 |
| BoRL | 10/5/2006 | Channel Catfish | 5.0 | 35.1 | 391.2 | 375.4 |
| ElkR | 10/14/2004 | Channel Catfish | 1.0 | 54.0 | 1588.0 | 527.8 |
| ElkR | 10/14/2004 | Channel Catfish | 4.0 | 41.0 | 646.5 | 303.9 |
| ElkR | 10/14/2004 | Channel Catfish | 3.0 | 39.9 | 635.0 | 280.2 |
| ElkR | 10/14/2004 | Channel Catfish | 3.0 | 38.2 | 552.0 | 258.3 |
| ElkR | 10/14/2004 | Striped Bass | 1.0 | 45.5 | 1009.0 | 157.9 |
| ElkR | 10/3/2006 | Channel Catfish | 2.0 | 44.5 | 856.6 | 160.2 |
| ElkR | 10/3/2006 | White Perch | 5.0 | 20.1 | 104.6 | 122.1 |
| ElkR | 10/3/2006 | White Perch | 5.0 | 17.4 | 66.8 | 76.1 |
| ElkRa | 10/14/2004 | Brown Bullhead | 4.0 | 23.3 | 177.0 | 70.7 |
| ElkRa | 10/14/2004 | Yellow Perch | 5.0 | 19.4 | 88.0 | 208.8 |
| ElkRb | 10/14/2004 | White Perch | 5.0 | 17.3 | 73.4 | 557.8 |
| ELRBR | 11/1/1999 | Channel Catfish | 6.0 | 36.9 | 475.9 | 872.6 |
| ELRBR | 11/1/1999 | White Perch | 5.0 | 19.6 | 108.8 | 721.2 |
| ELRBR | 11/1/1999 | White Perch | 5.0 | 19.6 | 108.8 | 794 |
| ELRBR | 11/1/1999 | Channel Catfish | 6.0 | 36.9 | 475.9 | 826.4 |
| ELRBR | 11/1/1999 | Channel Catfish | 6.0 | 36.9 | 475.9 | 1327.2 |
| ElRU | 9/7/2000 | White Perch | 5.0 | 21.0 | 123.0 | 327.4 |
| ElRU | 9/7/2000 | Channel Catfish | 2.0 | 36.5 | 430.0 | 286.5 |
| ElRU | 9/7/2000 | White Perch | 5.0 | 19.4 | 94.0 | 230.4 |

**Table I-6: Fish Tissue tPCB Concentrations (ng/g) in the C&D Canal**

| Station | Date | Fish Species | Fish/ Composite (#) | Mean Length (cm) | Mean weight (g) | Conc. (ng/g) |
|---|---|---|---|---|---|---|
| Bdg213 | 9/5/2000 | Channel Catfish | 3 | 35.0 | 347.0 | 490.3 |
| Bdg213 | 9/5/2000 | Channel Catfish | 2 | 55.3 | 1837.0 | 811.4 |
| Bdg213 | 9/5/2000 | Channel Catfish | 2 | 50.0 | 1104.0 | 331.1 |
| Bdg213 | 9/6/2000 | White Perch | 3 | 18.7 | 89.0 | 688.8 |
| Bdg213 | 9/6/2000 | Channel Catfish | 3 | 40.3 | 572.0 | 408.9 |
| Bdg213 | 9/6/2000 | White Perch | 3 | 16.4 | 57.0 | 394.4 |
| Bdg213 | 9/27/2000 | White Perch | 3 | 19.3 | 97.0 | 459.9 |
| Bdg213 | 9/27/2000 | White Perch | 5 | 18.1 | 78.0 | 147.6 |
| Bdg213 | 9/27/2000 | Channel Catfish | 3 | 53.3 | 1724.3 | 349.1 |
| Bdg213 | 9/27/2000 | Channel Catfish | 5 | 34.3 | 327.8 | 159 |
| CDGD | 10/27/1999 | Channel Catfish | 5 | 44.1 | 893.9 | 550.4 |
| CDGD | 10/27/1999 | Channel Catfish | 5 | 44.4 | 893.9 | 1501.6 |
| CDGD | 11/1/1999 | White Perch | 10 | 20.2 | 124.3 | 565.7 |
| CDGD | 9/27/2006 | Channel Catfish | 3 | 33.8 | 333.0 | 90.9 |
| CDGD | 9/27/2006 | Channel Catfish | 3 | 53.7 | 1829.6 | 270.4 |
| CDGD | 9/27/2006 | Channel Catfish | 3 | 38.6 | 501.7 | 151.7 |
| CDGD | 10/5/2006 | White Perch | 5 | 19.8 | 111.6 | 178.4 |
| CDGD | 10/5/2006 | White Perch | 5 | 16.5 | 62.4 | 166.9 |
| SLMDDE | 9/5/2000 | Channel Catfish | 1 | 60.3 | 2562.0 | 590.1 |
| SLMDDE | 9/5/2000 | Channel Catfish | 5 | 38.7 | 501.0 | 538.9 |
| SLMDDE | 9/5/2000 | Channel Catfish | 6 | 33.3 | 296.0 | 562.4 |
| SLMDDE | 9/5/2000 | White Perch | 5 | 17.9 | 81.0 | 591.1 |
| SLMDDE | 9/6/2000 | White Perch | 3 | 18.9 | 88.0 | 383.6 |
| SLMDDE | 9/6/2000 | White Perch | 6 | 16.6 | 65.0 | 492.6 |
| SLMDDE | 9/6/2000 | Channel Catfish | 3 | 50.5 | 1338.0 | 791.7 |
| SLMDDE | 9/6/2000 | Channel Catfish | 1 | 51.0 | 1360.0 | 750.6 |
| SLMDDE | 9/6/2000 | Channel Catfish | 3 | 41.1 | 643.0 | 233 |
| SLMDDE | 9/6/2000 | Channel Catfish | 3 | 33.2 | 286.0 | 235.3 |
| SLMDDE | 9/6/2000 | White Perch | 3 | 19.3 | 97.0 | 458.1 |
| SLMDDE | 9/7/2000 | Channel Catfish | 2 | 54.5 | 1909.0 | 292.9 |
| SLMDDE | 9/26/2006 | Channel Catfish | 5 | 38.0 | 476.0 | 122.1 |
| SLMDDE | 9/26/2006 | Channel Catfish | 4 | 53.7 | 1141.0 | 529.3 |
| SLMDDE | 9/26/2006 | Channel Catfish | 5 | 34.5 | 338.4 | 186.7 |
| XKJ 1811 | 9/7/2000 | Channel Catfish | 5.0 | 54.7 | 1827.4 | 556.7 |

| Station | Date | Fish Species | Fish/ Composite (#) | Mean Length (cm) | Mean weight (g) | Conc. (ng/g) |
|---|---|---|---|---|---|---|
| XKJ 1811 | 9/7/2000 | Channel Catfish | 4.0 | 47.8 | 1071.0 | 978.1 |
| XKJ 1811 | 9/7/2000 | Channel Catfish | 4.0 | 43.2 | 779.0 | 470.3 |
| XKJ 1811 | 9/7/2000 | Channel Catfish | 4.0 | 38.7 | 532.3 | 441.8 |
| XKJ 1811 | 9/7/2000 | American Eel | 3.0 | 59.9 | 459.7 | 681 |

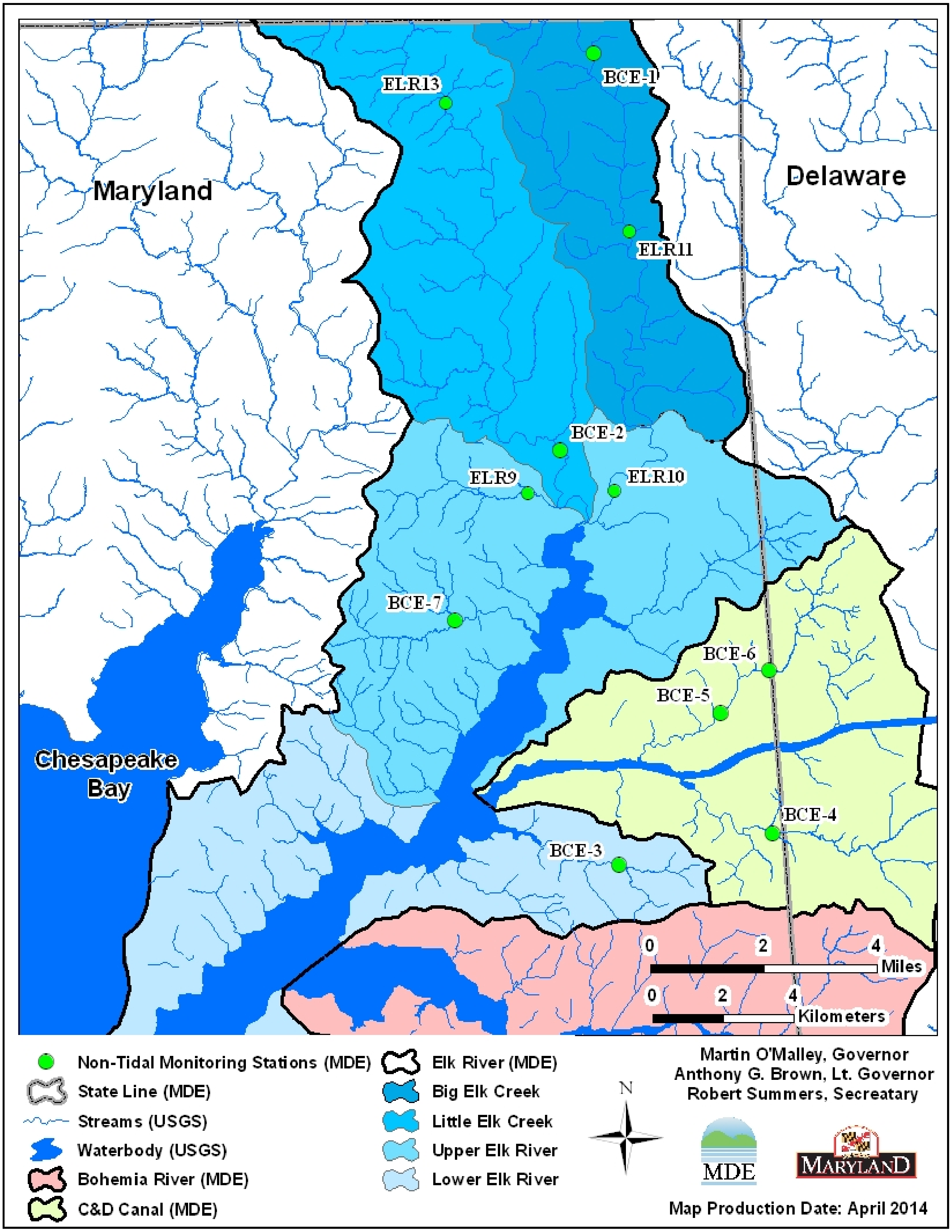


**Figure I-1: PCB Non-Tidal Monitoring Stations in the Elk River and the C&D Canal**

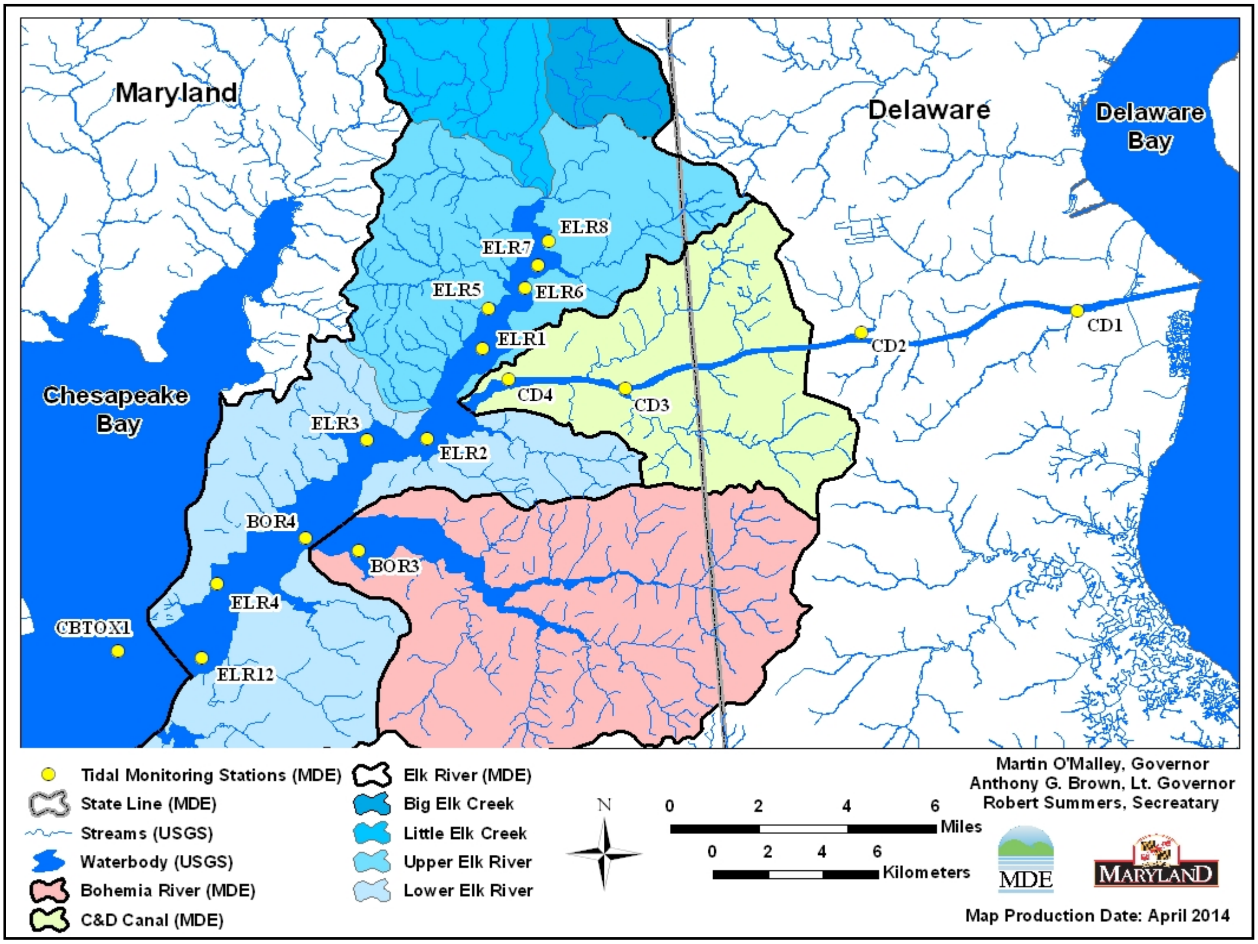


**Figure I-2: PCB Tidal Monitoring Stations in the Elk River and the C&D Canal**

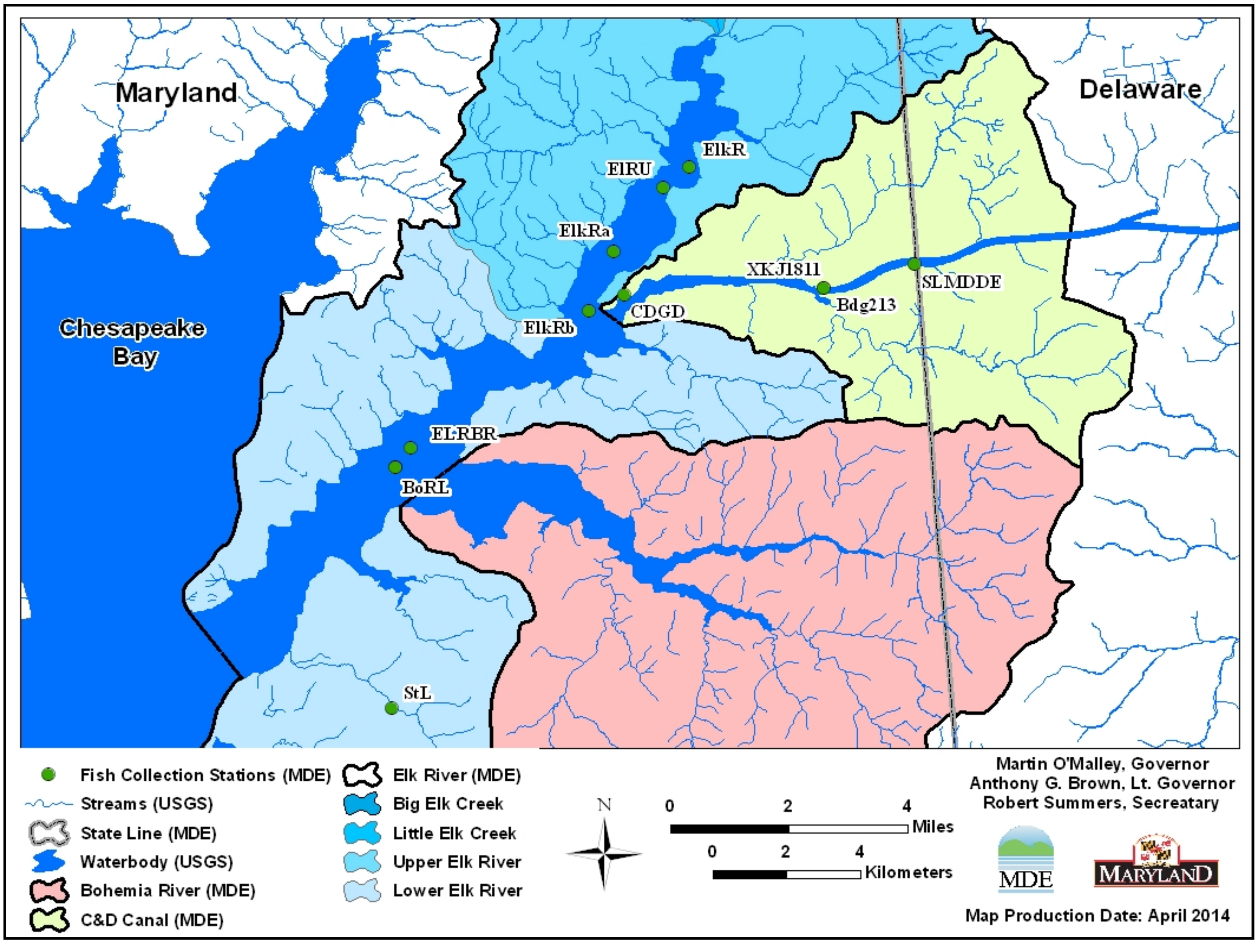


**Figure I-3: PCB Fish Tissue Monitoring Stations in the Elk River and the C&D Canal**

***Appendix J: Sensitivity Tests to Set the Baseline Load Reduction Goal***

Several scenario runs were conducted as sensitivity tests to decide the reduction goal for the baseline load to meet the TMDL endpoints for both the Elk River and the C&D Canal. Table J-1 lists these runs. It can be seen that 43% is the minimum reduction necessary for the baseline load when the Bay boundary concentration is set at the TMDL endpoint. Therefore, it is set as the reduction goal while both of the boundary concentrations were set at their respective initial condition and declined based on the 6.5% (MD) and 4 % (DE) reduction rates.

**Table J-1: Scenario Runs for the Elk River and the C&D Canal**

| Scenario (#) | Boundary Conditions (Water Column) | | Minimum Reduction |
|---|---|---|---|
| | Chesapeake Bay | C&D Canal | |
| 1 | Elk River TMDL Endpoint (0.14 ng/L) | Initial concentration (3.27 ng/l) (Declining rate of 4% per year) | 43% |
| 2 | 0.14 ng/L | 3.27 ng/l | 54% |
| 3 | 0.14 ng/L | Delaware Bay TMDL endpoint (7.9 pg/l) | 43% |
| 4 | 0.14 ng/L | 0.14 ng/L | 43% |