Total Maximum Daily Load of Polychlorinated Biphenyls in Lake Roland of Jones Falls Watershed in Baltimore County and Baltimore City, Maryland

FINAL

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Submitted to:

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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
CI	Confidence Interval
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
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
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PCB	Polychlorinated Biphenyl

POC	Particulate Organic Carbon
Ppb	Parts per billion
Ppt	Parts per trillion
RUSLE2	Revised Universal Soil Loss Equation Version II
SediBAF	Sediment Bioaccumulation Factor
SIC	Standard Industrial Classification
TMDL	Total Maximum Daily Load
tBAF	Total Bioaccumulation Factor
tPCB	Total PCB
TSD	Technical Support Document
TSS	Total Suspended Solids
UMCES	University of Maryland Center for Environmental Science
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VA	Virginia
VCP	Voluntary Cleanup Program
WLA	Wasteload Allocation
WQA	Water Quality Analysis
WQBEL	Water Quality Based Effluent Limit
WQLS	Water Quality Limited Segment
WQS	Water Quality Standard
WWTP	Waste Water Treatment Plant
µg	Microgram

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for Polychlorinated Biphenyls (PCBs) in the Lake Roland impoundment of the Jones Falls watershed (basin number 02130904) (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID:MD-02130904). 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 designated use of Lake Roland is Use I - *Water Contact Recreation, and Protection of Non-tidal Warmwater Aquatic Life,* which applies to waters that are suitable for: a) water contact sports; b) play and leisure activities where individuals may come in direct contact with the surface water; c) fishing; d) the growth and propagation of fish, other aquatic life, and wildlife; e) agricultural water supply; and f) industrial water supply (COMAR 2013b). The Maryland Department of the Environment (MDE) has identified the waters of the Lake Roland impoundment (Integrated Report Assessment Unit ID: MD-02130904-Lake_Roland) on the State's 2012 Integrated Report as impaired by chlordane (1996) and PCBs in fish tissue (2002) (MDE 2012). The TMDL established herein by MDE will address the total PCB (tPCB) listing for the Lake Roland impoundment, for which a data solicitation was conducted, and all readily available data from the past twelve years have been considered. A chlordane TMDL was approved by the EPA in 2001. The Lake Roland impoundment was delisted for chlordane in the State's 2012 Integrated Report as data collected in 2007 established that fish tissue concentrations for chlordane were below the fish consumption listing threshold.

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

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

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 Lake Roland impoundment;
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 for the District of Columbia, requires TMDLs to be protective of all the designated uses applicable to a particular waterbody (US District Court for the District of Columbia 2011). Within the Lake Roland impoundment, these designated uses, as described previously, include "water contact recreation," "fishing," and "the protection of aquatic life." The TMDL presented herein was developed specifically to be protective of the "fishing" designated use, which is protective of human health related to the consumption of fish, since the impoundment was identified as impaired for "PCBs in fish tissue" on the Integrated Report.

The water column and sediment TMDL endpoint tPCB concentrations applied within this analysis are derived from Maryland's Integrated Report fish tissue listing threshold tPCB concentration and site specific tBAFs. In the Lake Roland, the tPCB concentrations are lower than: 1) EPA's human health criterion tPCB water column concentration relative to fish consumption, and 2) Maryland's freshwater chronic criterion tPCB water column concentration. This indicates that the TMDL is not only protective of the "fishing" designated use but also the "aquatic life" designated use, specifically the protection of "non-tidal warmwater aquatic life" (*i.e.*, water column TMDL endpoint tPCB concentration < freshwater chronic criterion). 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 Lake Roland watershed. Nonpoint sources include direct atmospheric deposition to the impoundment, identified contaminated sites, runoff from non-regulated watershed areas, and resuspension and diffusion from bottom sediment. Point sources include a single municipal wastewater treatment plant (WWTP) and National Pollutant Discharge Elimination System (NPDES) regulated stormwater runoff within the watershed. Model estimated tPCB loads from these point and nonpoint sources represent the baseline conditions for the impoundment.

Although the transport of PCBs to the impoundment from bottom sediments via resuspension and diffusion is currently estimated to be a major source of PCBs (net transport of 207.6 grams/year (g/year)), 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. In addition, the water quality model developed for this TMDL simulates conditions within the water column and sediment as a single system therefore exchanges between the sediment and water column are considered an internal loading. Only external sources to the system are assigned a baseline load or allocation within a TMDL. Therefore this load will not be presented as a baseline load or allocation.

The objective of the TMDL established herein is to reduce current tPCB loads to the Lake Roland impoundment 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.

A summary of the baseline conditions and TMDL for the Lake Roland impoundment is presented in Table ES-1. Additionally, the baseline loads and TMDL allocations only consider current sources of PCBs to the impoundment that are deemed to be directly controllable loads, and therefore do not include resuspension and diffusion from bottom sediments. When implemented, load reductions required under this TMDL will ensure that tPCB concentrations in the water column and sediment are at levels supportive of the “fishing” designated use in the Lake Roland impoundment.

The water quality model developed for simulating ambient sediment and water column tPCB concentrations within the Lake Roland impoundment 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 TMDL. 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 or VCP programs and their baseline loads constitute a relatively small percentage of the total baseline load to the impoundment (0.33%). In addition, the WWTP baseline load was considered to be *de minimis* as it also only accounts for a relatively small percentage of the total baseline load (0.02%), therefore no appreciable environmental benefit would be gained by reducing this load. 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 TMDL modeling scenario was used to develop the load reductions, WLAs, and LAs for the non-regulated watershed runoff, NPDES regulated stormwater, and atmospheric deposition source categories. The resultant TMDL scenario requires approximately a 29% reduction for all watershed sources (*i.e.,* non-regulated watershed runoff and NPDES regulated stormwater) and a 60.9% reduction for atmospheric deposition, 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 Lake Roland impoundment. Thus, the TMDL for the Lake Roland impoundment implicitly accounts for seasonal variations as well as critical conditions.

Once EPA has approved this TMDL, MDE will begin an iterative process of implementation that will first identify specific sources, or areas of PCB contamination, within the impoundment's watershed, and second, target remedial action for those sources with the largest impact on water quality, while giving consideration to the relative cost and ease of implementation. The implementation efforts will be periodically evaluated, and if necessary, improved, in order to further progress toward achieving the water quality goals. Given that a number of contaminated sites have already undergone some degree of remediation and their baseline loads constitute a relatively small percentage of the Total Baseline Loads (*i.e.,* 0.33%), 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 may 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 Lake Roland impoundment.

Table ES-1: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and Maximum Daily Loads (MDLs) in the Lake Roland Impoundment

Source	Baseline Load (g/year)	Percent of Total Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Direct Atmospheric Deposition	6.4	10.58	2.5	60.94	0.02
Non-regulated Watershed Runoff	28.9	47.77	20.5	29.07	0.15
Contaminated Sites	0.2	0.33	0.2	0.00	0.00
Nonpoint Sources/LAs	***35.5***	***58.7***	***23.2***	***34.6***	***0.17***
WWTP[1]	0.014	0.02	0.014	0.00	0.00
NPDES Regulated Stormwater[2]					
Baltimore County	24.9	41.16	17.6	29.32	0.13
Baltimore City	0.098	0.16	0.069	29.59	0.0005
Point Sources/WLAs	***25.0***	***41.3***	***17.7***	***29.2***	***0.13***
MOS (5%)	**-**	**-**	***2.1***	**-**	***0.02***
Total	**60.5**	**100**	**43.0**	**29**	**0.32**

Notes: [1] WWTP Baseline Load was considered to be *de minimis*
[2] Load per jurisdiction applies to all NPDES stormwater dischargers within the jurisdiction's portion of the watershed draining to Lake Roland. These dischargers are identified in Appendix I.

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 Lake Roland impoundment of the Jones Falls watershed (basin number 02130904) (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID:MD-02130904. 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 protection of aquatic life (COMAR 2013a). The specific designated use of Lake Roland is Use I – *Water Contact Recreation, and Protection of Non-tidal Warmwater Aquatic Life,* which applies to waters that are suitable for: a) water contact sports; b) play and leisure activities where individuals may come in direct contact with the surface water; c) fishing; d) the growth and propagation of fish, other aquatic life, and wildlife; e) agricultural water supply; and f) industrial water supply (COMAR 2013b). The Maryland Department of the Environment (MDE) has identified the waters of the Lake Roland impoundment (Integrated Report Assessment Unit ID: MD-02130904-Lake_Roland) on the State's 2012 Integrated Report as impaired by chlordane (1996) and PCBs in fish tissue (2002) (MDE 2012). The TMDL established herein by MDE will address the total PCB (tPCB) listing for the Lake Roland impoundment, for which a data solicitation was conducted, and all readily available data from the past twelve years have been considered. A chlordane TMDL was approved by the EPA in 2001. The Lake Roland impoundment was delisted for chlordane in the State's 2012 Integrated Report as data collected in 2007 established that fish tissue concentrations for chlordane were below the fish consumption listing threshold.

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.

Lake Roland was originally identified as impaired by PCBs in fish tissue on Maryland's 2002 Integrated Report based on fish tissue tPCB data from MDE's monitoring program that exceeded the tPCB fish tissue listing threshold of 39 ng/g, or ppb – (wet weight) (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 Lake Roland: Carp, Black Crappie, Small & Largemouth Bass, and Sunfish (incl. Bluegill) (MDE 2011c).

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

Lake Roland is an impoundment located in the Jones Falls, a tributary to the Patapsco River Mesohaline Chesapeake Bay Segment. The watershed draining to the impoundment covers approximately 96.8 square kilometers (km^2) (23,910 acres) and spans portions of Baltimore County and Baltimore City. The total population in the embayment's watershed is approximately 106,414 (US Census Bureau 2010). The location of the Lake Roland impoundment is shown 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 the Lake Roland impoundment watershed is predominantly urban and forest. Urban land use occupies approximately 46.7%, while 42.5% is forested, 9.4% is agricultural, and 1.4% is water/wetlands. The land use distribution is displayed and summarized in Figures 2 and 3 as well as Table 1.

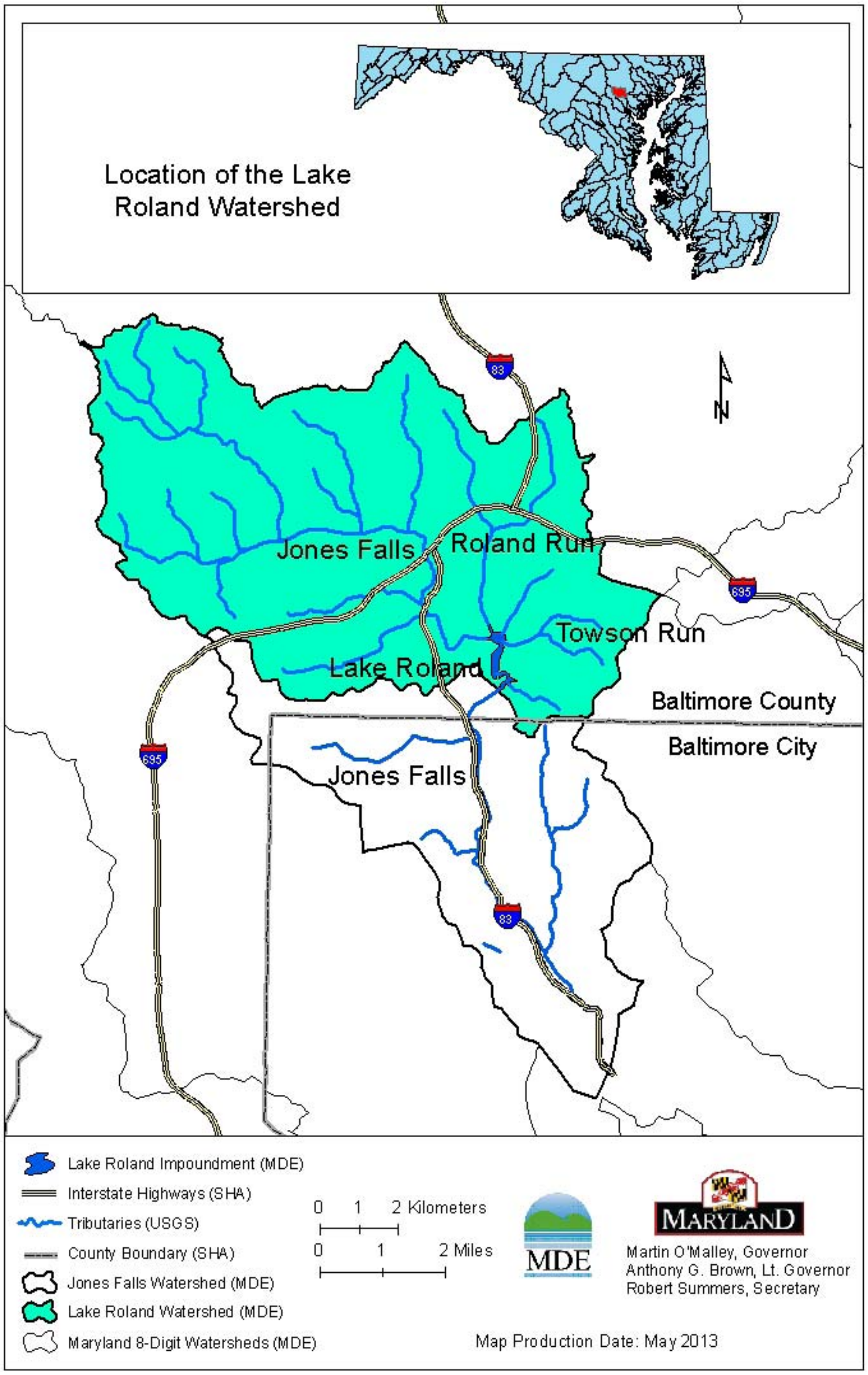


Figure 1: Location Map of the Lake Roland and Jones Falls Watersheds

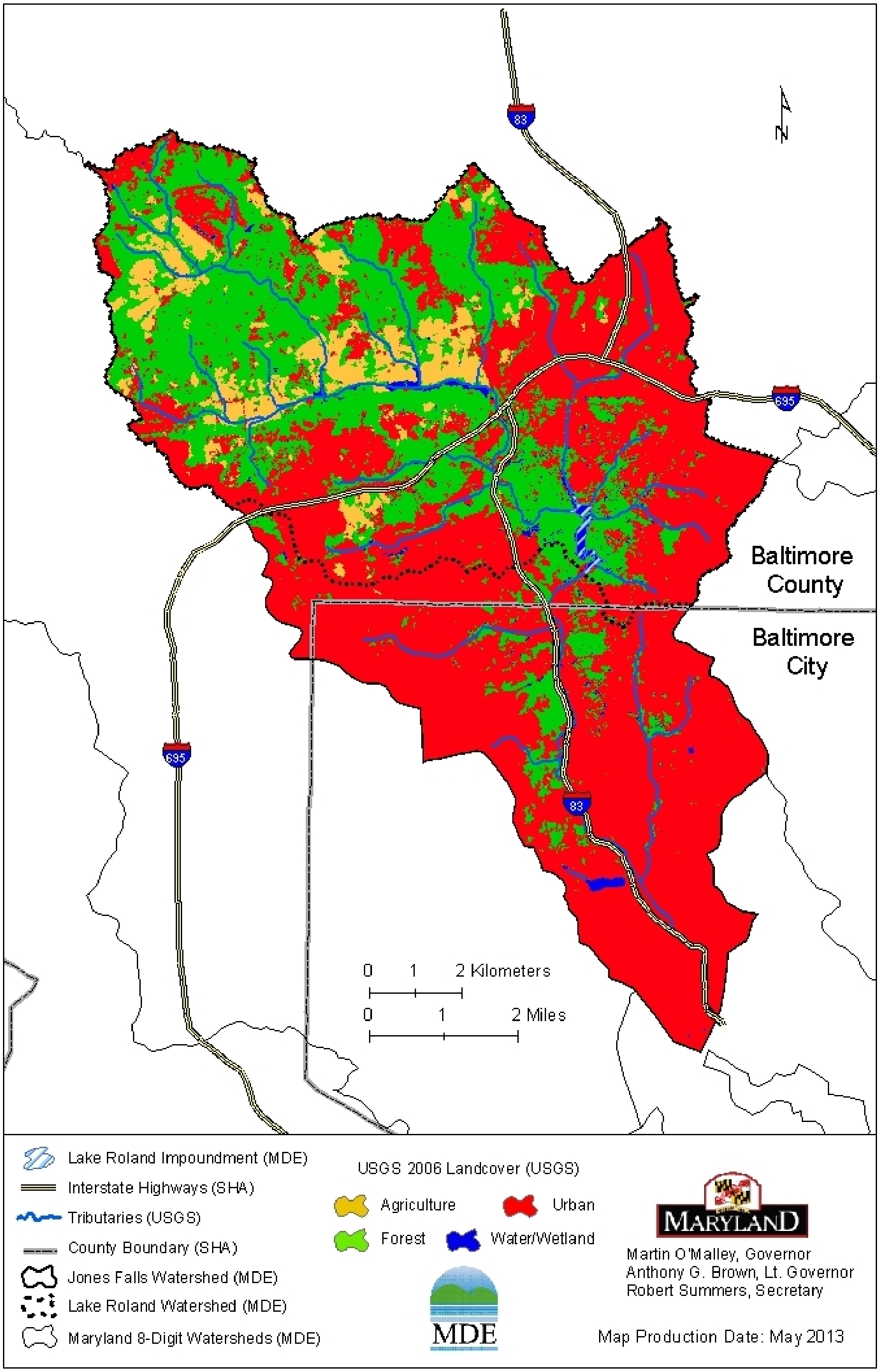


Figure 2: Land Use of the Lake Roland and Jones Falls Watersheds

Table 1: Land Use Distributions in the Lake Roland Watershed

Land Use	Area (km^2)	Percent of Total (%)
Water/Wetland	1.33	1.4
Urban	45.16	46.7
Forest	41.13	42.5
Agriculture	9.14	9.4
Total	**96.8**	**100**

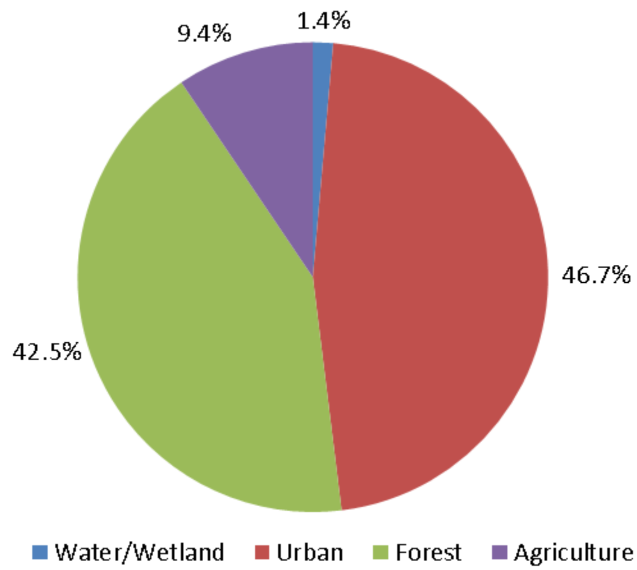


Figure 3: Land Use Distribution in the Lake Roland Drainage Area

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 designated use of the Lake Roland impoundment is Use I - *Water Contact Recreation, and Protection of Non-tidal Warmwater Aquatic Life* (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 embayment's watershed requiring the implementation of Maryland's anti-degradation policy (COMAR 2011c; MDE 2010). The State of Maryland adopted three separate water column tPCB criteria: criterion for protection of human health associated with the consumption of PCB contaminated fish, as well as fresh and salt water chronic tPCB criteria for protection of aquatic life. The Maryland human health tPCB criterion is set at 0.64 nanograms/liter (ng/L), or parts per trillion (ppt) (COMAR 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 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. A cancer slope factor is used to estimate the risk of cancer associated with exposure to a carcinogenic substance (i.e. PCBs). 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). MDE collected fish tissue samples for PCB analysis in the Lake Roland impoundment and its watershed in 2000, 2003, and 2007. The tPCB concentrations for 8 out of 15 fish tissue composite samples (several species of fish including carp, black crappie, largemouth bass, bluegill were collected) exceed the listing threshold, demonstrating that a PCB impairment exists within the Lake Roland impoundment. The PCB fish tissue concentration data are presented in Appendix J. Water column tPCB criteria and the 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* (ng/L)
Fresh Water Chronic Aquatic Life Criterion	14
Salt water Chronic Aquatic Life Criterion	30
Human Health Criterion	0.64
Fish Tissue Listing Threshold	39

* Threshold concentration units are in ng/g

In 2010, monitoring surveys were conducted by MDE to measure water column tPCB concentrations at stations within the Lake Roland impoundment and throughout the watershed.

Sediment samples were collected in 2010 as well to characterize tPCB sediment concentrations in the Lake Roland impoundment**.**

PCB analytical services were provided by the University of Maryland Center for Environmental Science (UMCES). Specific PCB congeners were identified and quantified by high resolution gas chromatography with GC-MS detection (Ayris et al. 1997, Holwell et al. 2007, Konietckka and Namiesnik 2008, Mydlová-Memersheimerová et al 2009). This method is based on EPA method 8082 which was developed in 1996. Since that time the extraction protocols have been enhanced to fall in line with those of EPA method 1668a. UMCES uses a slightly modified version of the PCB congener specific method described in Ashley and Baker (1999), in which the identities and concentrations of each congener in a mixed Aroclor standard (25:18:18 mixture of Aroclors 1232, 1248, and 1262) are determined based on their chromatographic retention times relative to the internal standards (PCB 30 and PCB 204 and ten C13 labeled standards). Based on this method, upwards of 100 chromatographic peaks can be quantified. Some of the peaks contain one PCB congener, while many are comprised of two or more co-eluting congeners.

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 the fish tissue, water column, and sediment samples that were applied in developing this TMDL. Figure 4 shows a map of the sampling locations in the watershed and Figure 5 shows a map of the sampling locations in the impoundment. Appendix J contains figures of the sampling locations and tables containing all of the tPCB water quality data.

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

tPCB Data	Units	Sampling Years	Sample Size	tPCB Concentration		
				Mean	Maximum	Minimum
Fish Tissue	ng/g	2000, 2003, 2007	15	52.5	146.2	10.4
Water Column	ng/L	2010	24	1.98	5.41	0.16
Sediment	ng/g	2010	4	84.3	109.5	72.0

The water column mean tPCB concentration within the Lake Roland impoundment exceeds the human health criterion of 0.64 ng/L; however, none of the water column samples exceed the fresh water aquatic life tPCB criterion of 14 ng/L.

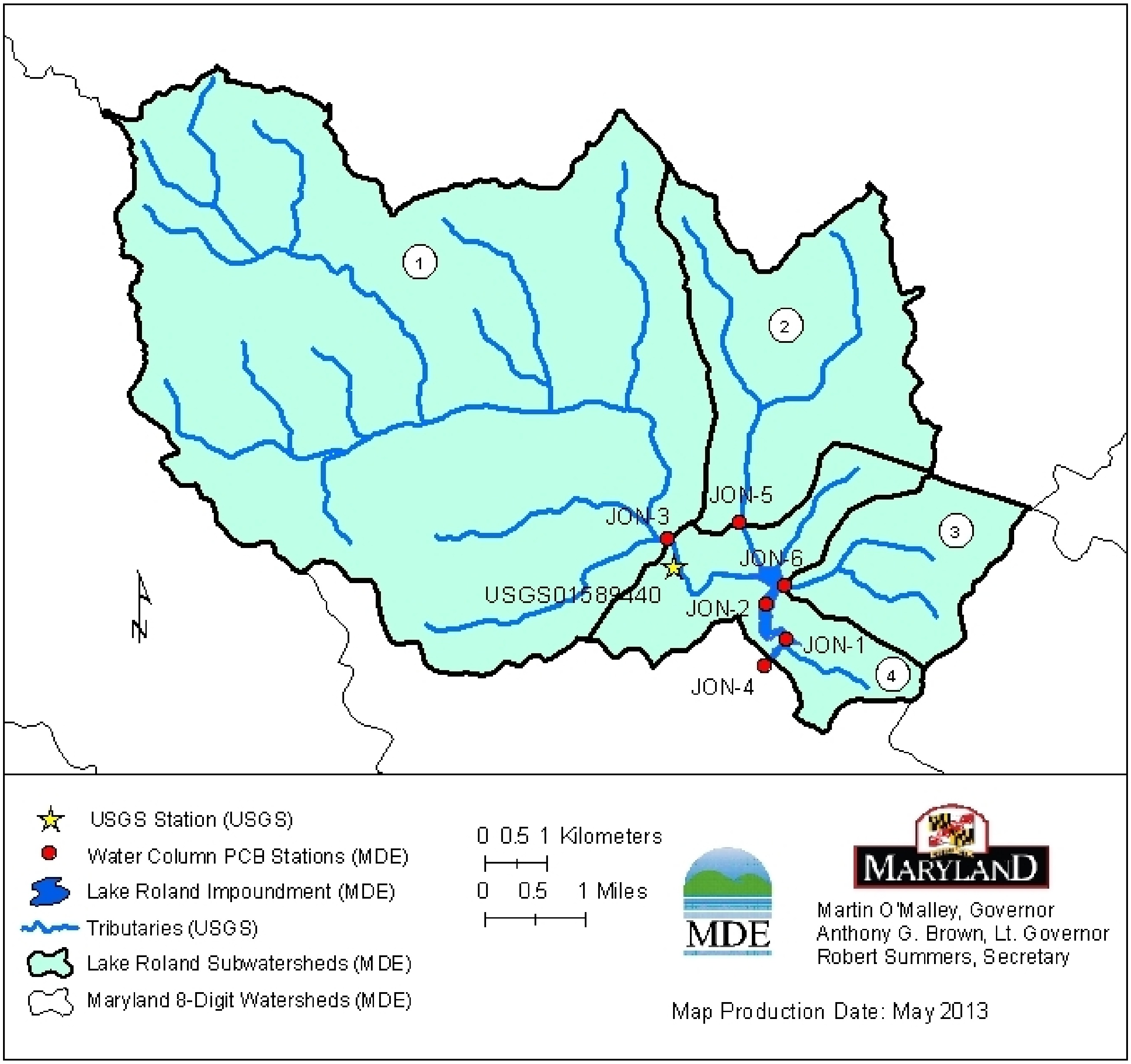


Figure 4: The Locations of Watershed PCB Measurement Stations and the USGS Station, and the Delineation of Subwatersheds

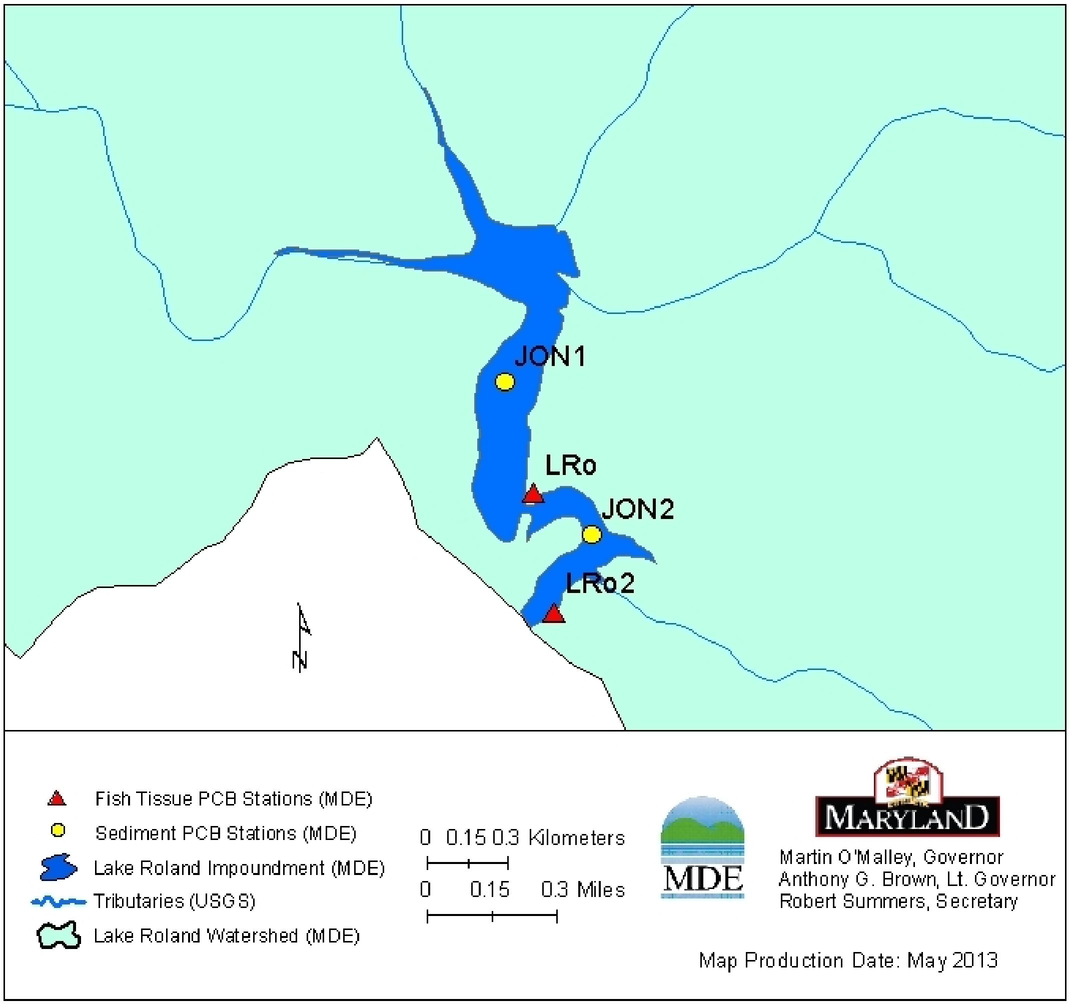


Figure 5: PCB Fish Tissue and Sediment Monitoring Stations in the Lake Roland Impoundment

3.0 WATER COLUMN AND SEDIMENT TMDL ENDPOINTS

As described in Section 2.2, MDE evaluates whether a waterbody meets PCB related WQSs based on two criteria: 1) for PCBs in fish tissue, the use of the tPCB Integrated Report fish tissue listing threshold (39 ng/g, or ppb), or 2) for PCBs in the water column, the human health tPCB water column criterion (0.64 ng/L, or ppt) and the fresh and saltwater chronic tPCB criteria for protection of aquatic life (14 ng/L and 30 ng/L, or ppt, respectively). Since the Lake Roland impoundment was identified as impaired for PCBs in fish tissue, the overall objective of the tPCB TMDL established in this document is to ensure that the "fishing" designated use, which is protective of human health related to the consumption of fish, in the impoundment is supported; however, this TMDL will also ensure the protection of all other applicable designated uses within the impoundment.

The tPCB fish tissue listing threshold was translated into an associated tPCB water column concentration to provide a TMDL endpoint as the water quality model only simulates tPCB water column and sediment concentration and does not incorporate a food web model to predict tPCB fish tissue concentrations (see Equation 3.1 and Calculation 3.1). This was accomplished using the Adjusted Total Bioaccumulation Factor (Adj-tBAF) of 59,461 L/kg for Lake Roland, the derivation of which follows the method applied within the Potomac River tPCB TMDLs (Haywood and Buchanan, 2007). A total Bioaccumulation Factor (tBAF) is calculated per fish species, and subsequently the tBAFs are normalized by the median species lipid content and median dissolved tPCB water column concentration in their home range to produce the Adj-tBAF per species (see Appendix B for further details regarding the calculation of the Adj-tBAF). The most environmentally conservative of the Adj-tBAFs is then selected to calculate the TMDL endpoint water column concentration. This final water column tPCB concentration was subsequently compared to the water column tPCB criteria concentrations, as described in Section 2.2, to ensure that all applicable criteria within the impoundment would be attained (Calculation 3.1).

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

Substituting 39 ng/g into the equation results in:

tPCB Water Column Concentration =
(39 ng/g ÷ (59,461 L/kg × 1,000 g/kg)) = 0.66 ng/L,
which is > 0.64 ng/L (human health tPCB water column criterion)) (Calculation 3.1)

Based on this analysis, the human health water column tPCB criterion of 0.64 ng/L was selected as the TMDL endpoint for the Lake Roland impoundment, which is more stringent than the value of 0.66 ng/L derived from the tPCB fish tissue listing threshold, and the salt and fresh water aquatic life tPCB chronic criteria of 30 ng/L and 14 ng/L, respectively.

Similarly, in order to establish a TMDL endpoint for the sediment in the Lake Roland impoundment a tPCB sediment concentration was derived from the tPCB fish tissue listing threshold as the water quality model only simulates tPCB sediment concentrations and not tPCB fish tissue concentrations (see Equation 3.2 and Calculation 3.2). This was done using the Adjusted Sediment Bioaccumulation Factor (Adj-SediBAF) of 1.02 (unit-less) for the Lake Roland impoundment, the derivation of which follows the method applied within the Potomac River tPCB TMDLs (Haywood and Buchanan 2007). Similar to the calculation of the water column Adj-tBAF, a sediment Bioaccumulation Factor (SediBAF) is calculated per fish species, and subsequently the SediBAFs are normalized by the median species lipid content and median organic carbon tPCB sediment concentration in their home range to produce the Adj-SediBAF per species (see Appendix B for further details regarding the calculation of the Adj-SediBAF). The most environmentally conservative of the Adj-SediBAFs is then selected to calculate the sediment TMDL endpoint tPCB concentration.

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

Substituting 39 ng/g into the equation results in:

tPCB Sediment Concentration = (39 ng/g ÷ 1.02) = 38.1 ng/g (Calculation 3.2)

Based on this analysis, the tPCB concentration of 38.1 ng/g for the Lake Roland impoundment is set as the sediment TMDL endpoint.

The CWA, as recently interpreted by the United States District Court for the District of Columbia, requires TMDLs to be protective of all the designated uses applicable to a particular waterbody (US District Court for the District of Columbia 2011). In addition to the "fishing" designated use, the TMDL presented herein is also supportive of the other applicable designated uses within the impoundment, as described in the Introduction to this report and Section 2.2. These include "water contact recreation" and "the protection of aquatic life". Specifically, the TMDL is protective of the "aquatic life" designated use, as the water column TMDL endpoint tPCB concentration is more stringent than the freshwater chronic aquatic life criterion. Lastly, the designated use for "water contact recreation" is not associated with any potential human health risk due to PCB exposure. Dermal contact and accidental 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 aquatic organism (e.g. fish, shellfish, etc…) consumption, as drinking water consumption does not pose any additional risk for cancer development at environmentally relevant levels. The only human health risk associated with PCB exposure is through the consumption of aquatic organisms, which is addressed by the water column and sediment endpoints applied within this TMDL developed to be supportive of the "fishing" designated use for the Lake Roland impoundment.

4.0 SOURCE ASSESSMENT

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

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

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

A simplified conceptual model of PCB fate and transport in the Lake Roland impoundment is diagramed in Figure 6. 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 Lake Roland impoundment.

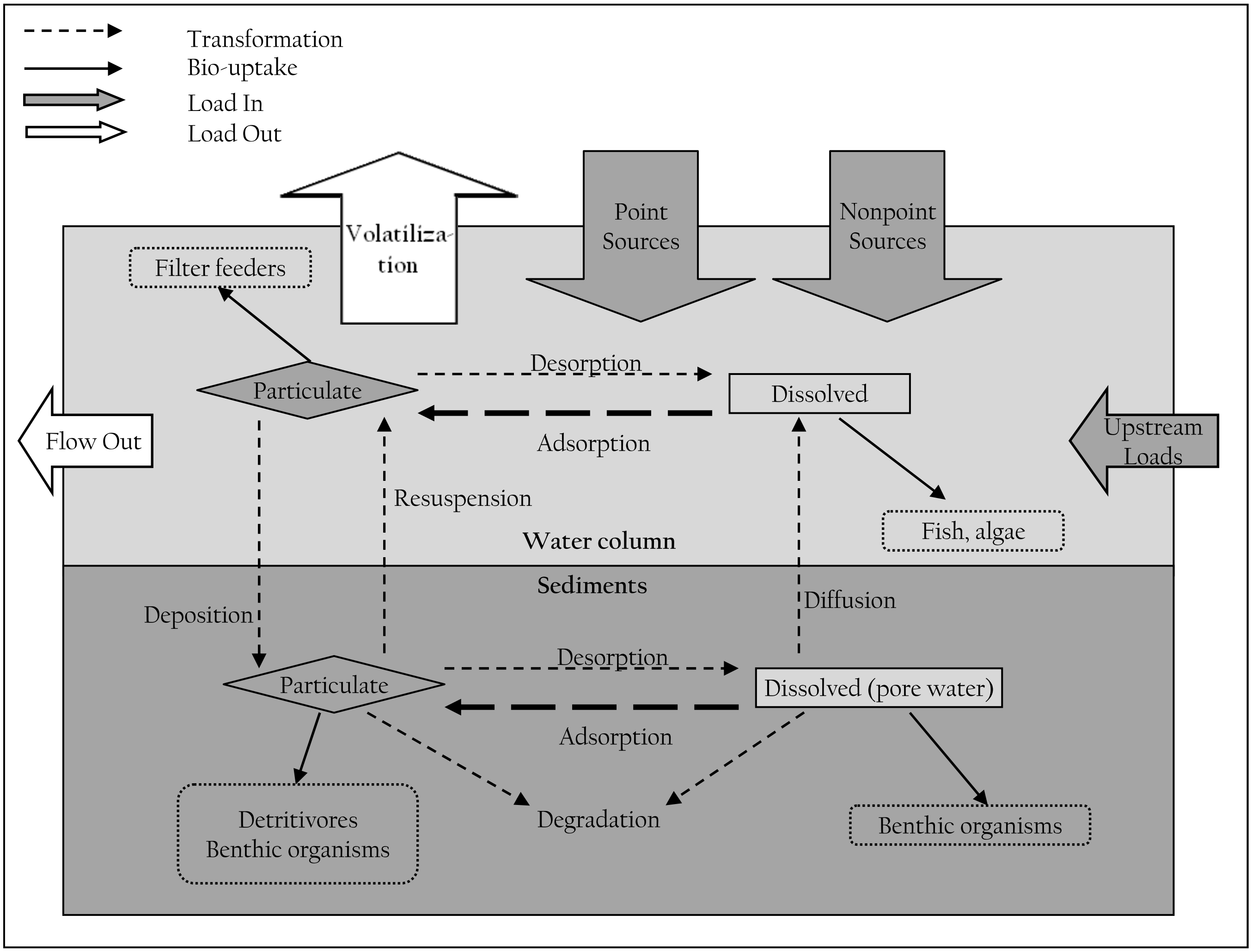


Figure 6: Conceptual Model of the Key Transport and Transformation Processes of PCBs in Surface Water and Bottom Sediments of the Lake Roland Impoundment and Entry Points to the Food Chain

4.1 Nonpoint Sources

For the purpose of this TMDL, under current conditions, the following nonpoint sources have been identified: re-suspension and diffusion from bottom sediments, direct atmospheric deposition to the impoundment, runoff from non-regulated watershed areas, and contaminated sites.

<u>**Resuspension and Diffusion from Bottom Sediments**</u>

Because PCBs tend to bind to the organic carbon fraction of suspended sediment in the water column, which settles to the impoundment floor, a large portion of the tPCB loads delivered from various point and non-point sources to the impoundment will deposit in the bottom sediments. This accumulation of PCBs can subsequently become a significant source of PCBs to the water column in the impoundment via the disturbance and resuspension of sediments. Dissolved tPCB concentrations in sediment pore water will also diffuse to the water column. The numerical model, applying observed tPCB concentrations in the water column and sediment, predicts a net tPCB transport of 207.6 g/year from the bottom sediment of the Lake Roland impoundment to the water column under baseline conditions. Although re-suspension and diffusion from bottom sediments serves as a source of PCBs to the water column, it is still not considered to be a directly controllable source (reducible) since the load contribution is resultant from other point and nonpoint source inputs (both historic and current) within the watershed. In addition, the water quality model developed for this TMDL simulates conditions within the water column and sediment as a single system therefore exchanges between the sediment and water column are considered an internal loading. Only external sources to the system are assigned a baseline load or allocation within a TMDL. Therefore this load will not be presented as a baseline load or allocation.

Atmospheric Deposition

PCBs enter the atmosphere through volatilization. There is no recent study of the atmospheric deposition of PCBs to the surface of the Lake Roland impoundment. CBP's Atmospheric Deposition Study (US EPA 1999) estimated a net deposition of 16.3 micrograms/square meter/year ($\mu g/m^2$/year) of tPCBs for urban areas and a net deposition of 1.6 $\mu g/m^2$/year of tPCBs for regional (non urban) areas. In the Delaware River estuary, an extensive atmospheric deposition monitoring program conducted by the Delaware River Basin Commission (DRBC) found PCB deposition rates ranging from 1.3 (non urban) to 17.5 (urban) $\mu g/m^2$/year of tPCBs (DRBC 2003). The 16.3 $\mu g/m^2$/year tPCB depositional rate for urban areas resultant from CBP's 1999 study is applied to the Lake Roland impoundment and its watershed, following the method assigned for the Baltimore Harbor tPCB TMDL (MDE 2011a). The direct atmospheric deposition load to the surface of the impoundment of 6.4 g/year was calculated by multiplying the surface area of the Lake Roland impoundment (0.39 km^2) and the deposition rate of 16.3 $\mu g/m^2$/year.

Similarly, the atmospheric deposition load to the watershed can be calculated by multiplying 16.3 $\mu g/m^2$/year by the watershed area (excluding the impoundment) of 96.3 km^2, which results in a load of 1570.3 g/year. However, according to Totten *et al.* (2006), only a portion of the atmospherically deposited tPCB load to the terrestrial part of the watershed is expected to be delivered to the impoundment. Applying the PCB pass-through efficiency estimated by Totten *et al.* (2006) for the Delaware River watershed of approximately 1%, the atmospheric deposition load to the Lake Roland impoundment from the watershed is approximately 15.7 g/year. This load is accounted for within the loading from the watershed and inherently modeled as part of the non-regulated watershed runoff/National Pollutant Discharge Elimination System (NPDES) Regulated Stormwater loads described below and in Section 4.2.

Non-regulated Watershed Runoff

The non-regulated watershed runoff tPCB load corresponds to the non-urbanized areas (*i.e.*, primarily forest and wetland areas) of the watershed. MDE collected water column samples for PCB analysis at 3 non-tidal monitoring stations in the tributaries of Lake Roland impoundment on January, April, July and October of 2010 (See Appendix C). Additionally, 12-year monthly flow averages from the closest USGS gage (USGS 01589440) were obtained and the mean flow was calculated. The Lake Roland watershed was divided into four sub-watersheds according to the locations of the monitoring stations and land use (Appendix C). The flows of the sub-watersheds and the whole watershed were calculated by dividing the USGS mean flow by the USGS drainage area, and multiplying the respective watershed areas. The watershed baseline loading of each sub-watershed was calculated by multiplying the average flow and mean tPCB concentration of the sub-watershed. For the sub-watershed without any tPCB measurement, the mean tPCB concentration of the other 3 sub-watersheds was used. The total watershed tPCB baseline load for the Lake Roland impoundment is 54.1 g/year.

About 15.7 g/year of the Lake Roland impoundment watershed's baseline load is attributed to atmospheric deposition to the land surface of the watershed, and is inherently captured within the total watershed tPCB baseline load of 54.1 g/year.

As mentioned above, the non-regulated watershed runoff tPCB load only corresponds to the non-urbanized areas (*i.e.*, primarily forest and wetland areas) of the watershed. The load associated with the urbanized area of the watershed represents the NPDES Regulated Stormwater tPCB baseline load. The non-regulated watershed runoff tPCB baseline load (28.9 g/year) was estimated by multiplying the percentage of non-urban land use (53.3 %) within the watershed by the total watershed baseline load (54.1 g/year).

Contaminated Sites

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

The site was 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). Soil tPCB concentration data and site information was obtained from Land Management Administration's (LMA) contaminated site survey and investigative records. Figure 7 depicts its location. 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 of 0.54 was applied to calculate the final edge-of-stream (EOS) load. The contaminated site tPCB baseline load is estimated to be 0.2 g/year. A more detailed description of the methodology used to estimate the contaminated site tPCB baseline load is presented in Appendix H.

Table 4: Summary of Contaminated Site tPCB Baseline Loads

Site Name	Jurisdiction	Soil Remediation	Area (acres)	EOS Load (g/year)
Har Sinai Property	Baltimore County	No	17.6	0.2

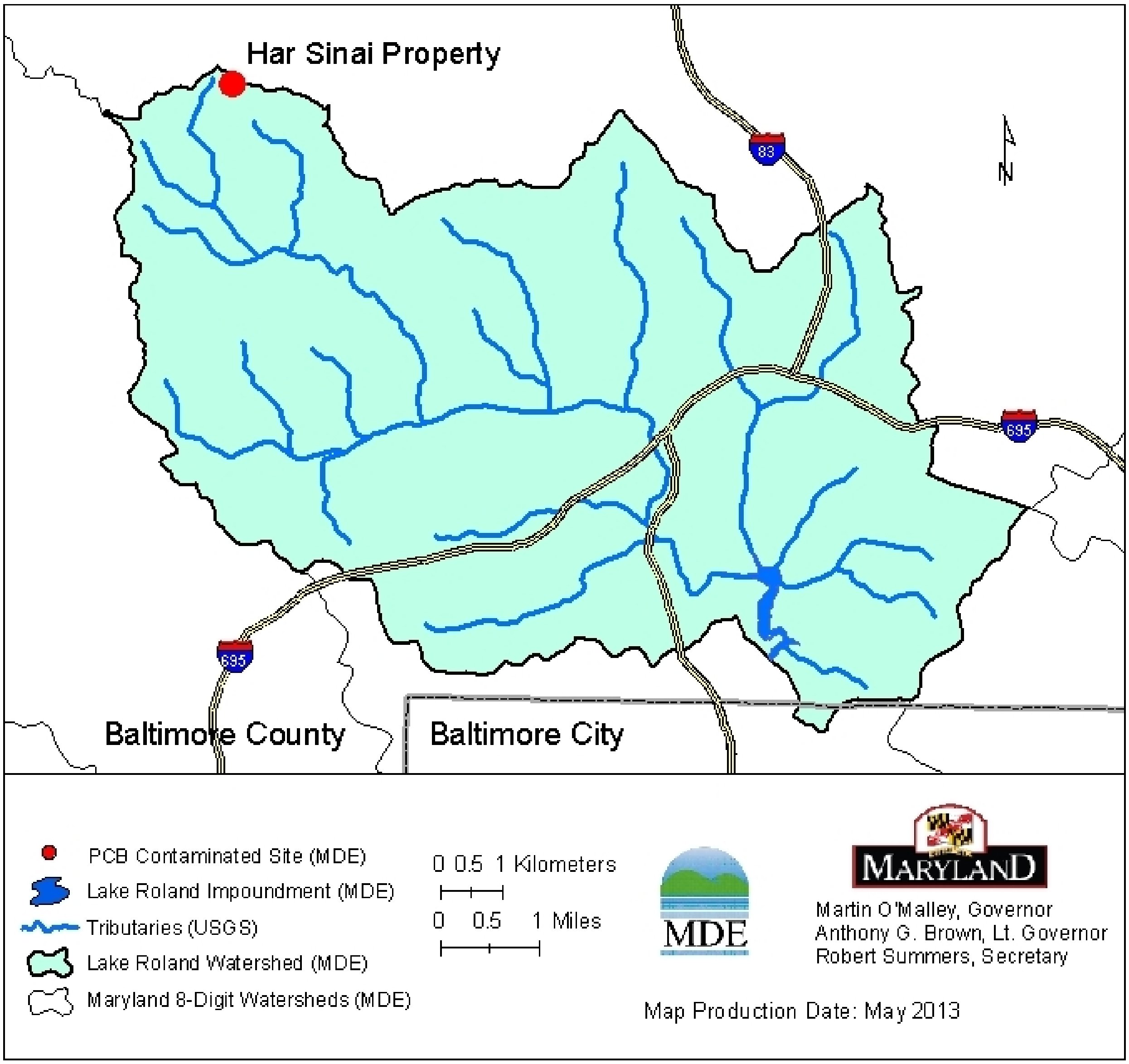


Figure 7: Location of PCB Contaminated Site in the Lake Roland Watershed

4.2 Point Sources

Point Sources in the Lake Roland impoundment's watershed include a single municipal waste water treatment plant (WWTP), three industrial process water discharges and stormwater discharges that are regulated under Phase I and Phase II of the NPDES stormwater program.

Municipal WWTP

Stevenson University WWTP (NPDES MD0066001) is the only municipal WWTP that has been identified within the Lake Roland watershed. As no tPCB effluent concentration data is available for this facility, the concentration was estimated based on the median tPCB effluent concentration from 13 WWTPs monitored by MDE in the Chesapeake Bay watershed. The baseline tPCB loading (0.014 g/year) was calculated based on the daily monitoring record (DMR) average discharge flow (0.011 million gallons per day [MGD]) and the estimated median tPCB concentration (0.91 ng/l). Figure 8 depicts the location of the municipal WWTP and Table 5 provides information on the data used in calculating the tPCB baseline load.

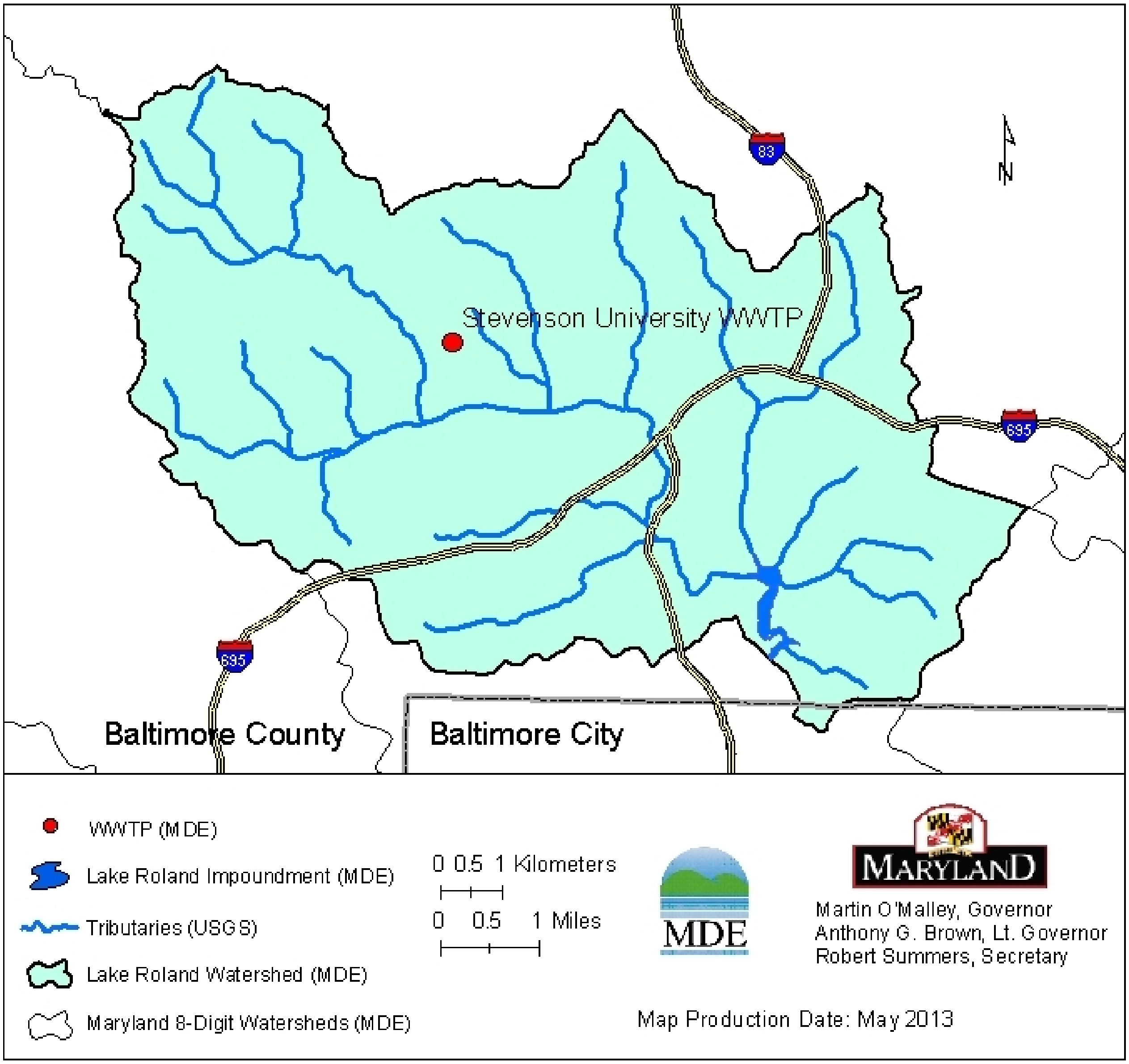


Figure 8: Location of Municipal WWTP in the Lake Roland Impoundment's Watershed

Table 5: Summary of Municipal WWTP tPCB Baseline Load

Facility Name	NPDES #	County	Average Concentration (ng/L)	Average Flow (MGD)	tPCB Baseline Load (g/year)
Stevenson University WWTP	MD0066001	Baltimore County	0.91	0.011	0.014

Industrial Process Water

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). There are three industrial process water facilities within the watershed. However, none of them has the potential to discharge PCBs.

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 Lake Roland watershed that could potentially convey tPCB loads to the impoundment is presented in Appendix I. 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 Lake Roland watershed spans a portion of Baltimore County and Baltimore City, Maryland. The NPDES stormwater permits within the watershed include: (i) the area covered under Baltimore County and Baltimore City's Phase I jurisdictional MS4 permit, (ii) the State Highway Administration's Phase I MS4 permit, (iii) state and federal general Phase II MS4's, (iv) industrial facilities permitted for stormwater discharges, and (v) construction sites (see Appendix I for a list of all NPDES regulated stormwater permits).

The NPDES Regulated Stormwater tPCB Baseline Load (25.2 g/year) was estimated by multiplying the percentage of urban land use (46.7%) within the watershed by the total watershed baseline load (54.1 g/year). Since the identified PCB contaminated site is located within the urban land use area, its EOS load of 0.2 g/year is subtracted giving a final NPDES Regulated Stormwater tPCB baseline load of 25.0 g/year. Table 6 lists the aggregate NPDES Regulated Stormwater tPCB Baseline Load, subdivided by jurisdiction (Baltimore County and Baltimore City).

Table 6: Summary of NPDES Regulated Stormwater tPCB Baseline Load

Jurisdiction	**tPCB Baseline Load (g/year)**[1]
Baltimore County	24.9
Baltimore City	0.098
Total	**25.0**

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

4.3 Source Assessment Summary

From this source assessment all point and nonpoint sources of PCBs to the Lake Roland impoundment have been identified and characterized. Nonpoint sources include direct atmospheric deposition to the impoundment, identified contaminated sites, runoff from non-regulated watershed, and resuspension and diffusion from bottom sediments. Point sources include a WWTP and NPDES regulated stormwater runoff. No industrial facility with the potential to discharge PCBs to the watershed was identified. Estimated tPCB loads from these point and nonpoint sources represent the baseline conditions for the impoundment.

A summary of the tPCB baseline loads for the Lake Roland impoundment is presented in Table 7. As explained in Section 4.1, since resuspension and diffusion from bottom sediments is not considered to be directly controllable (reducible) it will not be included as a baseline load or allocation within the framework of this TMDL.

Table 7: Summary of tPCB Baseline Loads in the Lake Roland Impoundment

Source	Baseline Load (g/year)	Percent of Total Baseline Load (%)
Direct Atmospheric Deposition	6.4	10.58
Non-regulated Watershed Runoff	28.9	47.77
Contaminated Sites	0.2	0.33
Nonpoint Sources	***35.5***	***58.7***
WWTP	0.014	0.02
NPDES Regulated Stormwater[1]		
Baltimore County	24.9	41.16
Baltimore City	0.098	0.16
Point Sources	***25.0***	***41.3***
Total	**60.5**	**100**

Notes: [1] Load per jurisdiction applies to all NPDES stormwater dischargers within the jurisdiction's portion of the watershed draining to the Lake Roland Impoundment. These dischargers are identified in Appendix I.

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 2013b):

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

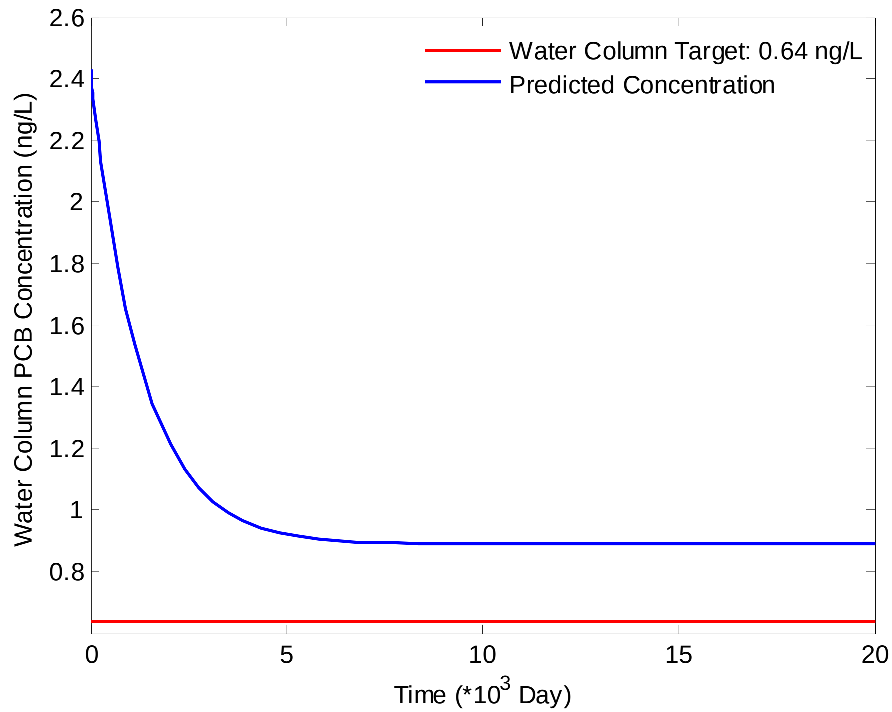
This section describes how the tPCB TMDL and the corresponding LAs and WLAs have been developed for the Lake Roland impoundment. The analysis framework for simulating PCB concentrations is described in Section 5.2. Section 5.3 addresses critical conditions and seasonality, and Section 5.4 presents the 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 numerical model was used to simulate the dynamic interactions between the water column and bottom sediments within the Lake Roland impoundment. Within the impoundment, the freshwater inputs, the exchanges with the atmosphere due to deposition and volatilization, and the exchange with the bottom sediments through diffusion, resuspension, and settling are the dominant processes affecting the transport of PCBs in the water column. The burial of PCBs to deeper inactive layers of sediment and exchanges at the sediment-water column interface (through diffusion, resuspension, and settling) are the dominant processes affecting the transport of PCBs in the bottom sediments. A detailed description of the model is presented in Appendix D.

The mean observed tPCB water column and sediment concentrations in year 2010 in the Lake Roland impoundment were used to characterize initial (baseline) model conditions. Figure 9 depicts the model predicted time series of water column and sediment tPCB concentrations. All other factors (*i.e.*, freshwater inputs, bottom sediment and water column exchange rates, and burial rates) were kept constant.

From Figure 9, it can be seen that under the current condition, the water column tPCB concentration of the Lake Roland impoundment will never meet the TMDL water column endpoint. Therefore, a tPCB loading reduction scenario was conducted by gradually reducing the current watershed loading. When a total load reduction of 29% is applied, the water column TMDL endpoint is met and the Lake Roland impoundment is supportive of the “fishing” designated use. The time series of water column and sediment tPCB concentrations for a load reduction of 29% is displayed in Figure 10. As the load reduction increases beyond 29%, the length of time required to achieve the TMDL endpoint in the water column decreases. The time response for meeting the TMDL under load reduction scenarios from 29% to 100% is displayed in Appendix F. Final sediment concentrations also meet the TMDL sediment endpoint for all reduction scenarios and as the load reductions increases so do the final sediment concentrations. The final sediment concentration will be higher with greater initial load reductions as less time has passed in order for sediment concentrations to decline. In order to assess the effect of varying the baseline conditions on the time required to achieve the TMDL, the upper and lower bounds of the 95% confidence interval (CI) around the mean water column tPCB concentration were estimated and applied in the analysis assuming a tPCB load reduction of 29%. The time required to reach the TMDL endpoints increased by about 17% (3.2 years) compared to the actual baseline condition when the higher tPCB water column concentration was used as the baseline condition. Results of the CI analysis are presented in Appendix F.



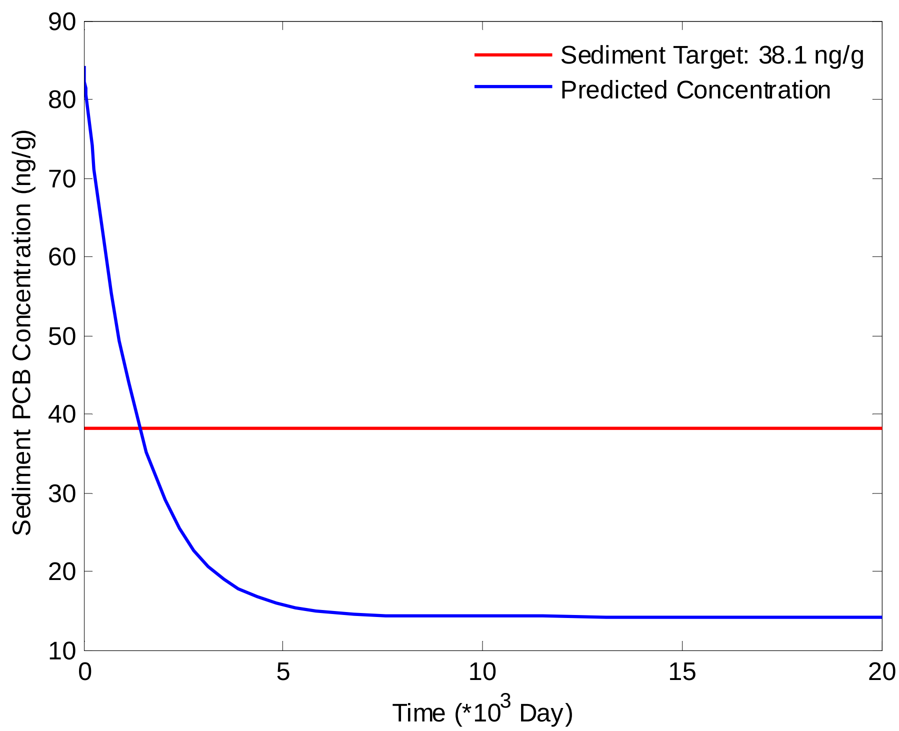


Figure 9: Change of Average Water Column and Bottom Sediment tPCB Concentrations over Time within the Lake Roland Impoundment

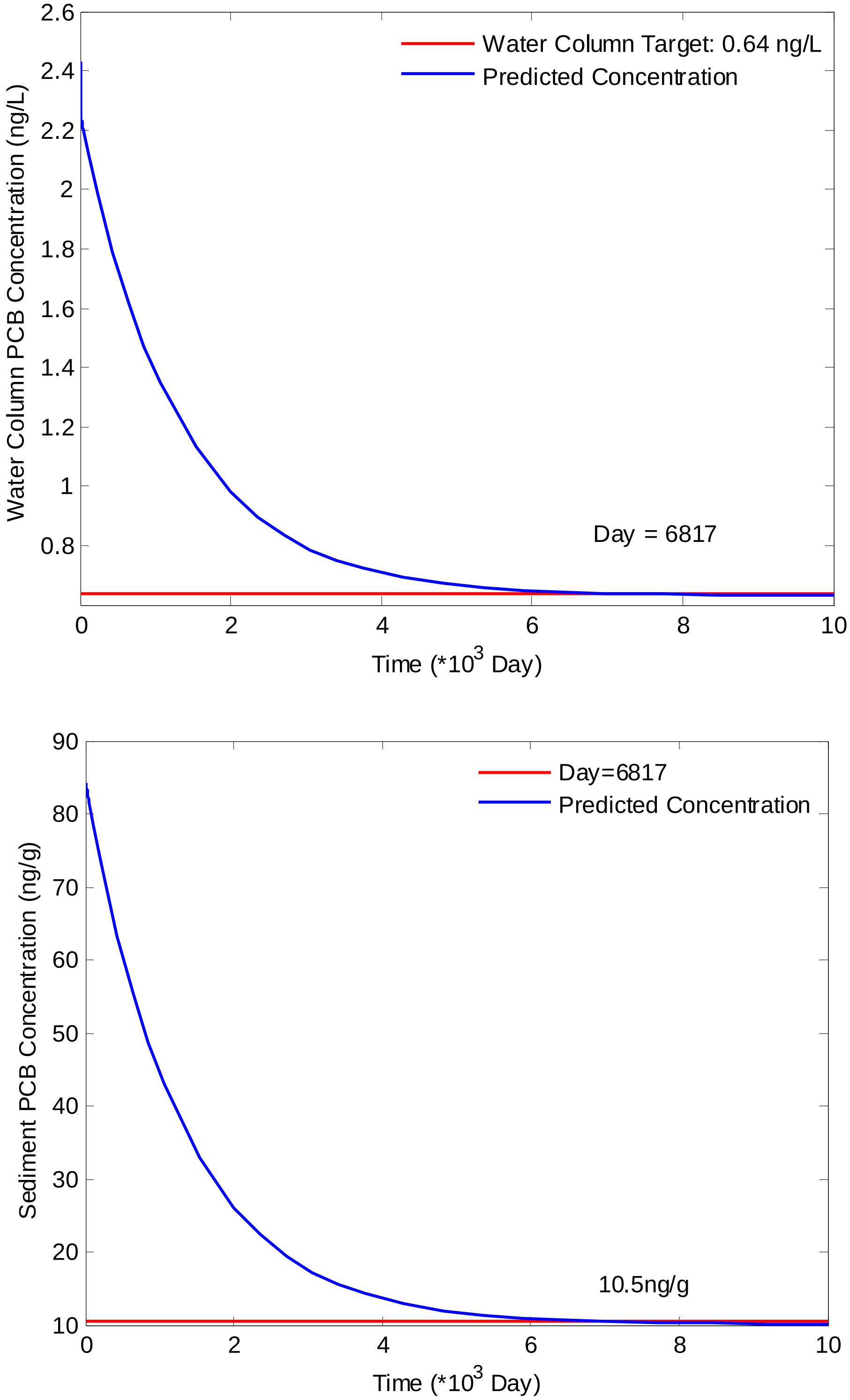


Figure 10: Change of Average Water Column and Bottom Sediment tPCB Concentrations over Time within the Lake Roland Impoundment Assuming a 29% Load Reduction

In the Baltimore Harbor tPCB TMDL (MDE 2011a), a 91.5% tPCB reduction from Jones Falls tributary is required. As Lake Roland watershed is located at the upstream part of the Jones Falls watershed, a 91.5% tPCB reduction from Lake Roland is required to meet the downstream conditions. As can be seen in Appendix F, Table F-1 and Figure F-1; 1,534 days is required to meet the water column TMDL endpoint after a 91.5% reduction. At that time the sediment concentration will be 27.1 ng/g and also meets the sediment tPCB TMDL endpoint. For this TMDL, all the calculations and tables will be displayed for a 29% reduction, as this TMDL is designed to meet the TMDL condition solely within the Lake Roland Impoundment.

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.

The TMDL is protective of human health at all times; thus, it implicitly accounts for seasonal variations as well as critical conditions. Achievement of the TMDL endpoints for sediment and water column through the implementation of load reductions will result in PCB levels in fish tissue acceptable for human consumption without posing a risk for development of cancer. Bioaccumulation of PCBs in fish is driven by long-term exposure through respiration, dermal contact, and consumption of lower order trophic level organisms. The critical condition defined by acute exposure to temporary fluctuations in PCB water column concentrations during storm events is not a significant pathway for uptake of PCBs. Monitoring of PCBs was conducted on a quarterly basis to account for seasonal variation in establishing the baseline condition for ambient water quality in the Lake Roland impoundment 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 Lake Roland Impoundment. Furthermore, the water column TMDL endpoint is also supportive of the “protection of aquatic life” designated use at all times as it is more stringent than the freshwater 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 Lake Roland Impoundment. 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 meet the "fishing" designated use in the Lake Roland impoundment: atmosphere deposition and non-regulated watershed runoff. The model results show that in order to meet the "fishing" designated use in the impoundment, the TMDL requires load reductions of 60.9% from atmospheric deposition and 29.07% from non-regulated watershed runoff. The load reduction to atmospheric deposition is consistent with the reduction required within the Baltimore Harbor tPCB TMDL. Implementation of this reduction to atmospheric sources within the Baltimore Harbor area will influence conditions within the watersheds as they fall within the same depositional region (MDE 2011a).

Given that the contaminated site baseline load constitutes a relatively small percentage of the Total Baseline Load (0.33%), 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 or VCP programs.

Loads from re-suspension and diffusion from bottom sediments were necessary for inclusion within the model to predict tPCB concentrations within the impoundment; however, they are not deemed to be directly controllable within the framework of the TMDL. In addition, the water quality model 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 baseline loads and allocations within a TMDL. Therefore, this source will not be assigned an allocation or a required reduction. This load is expected to be reduced naturally through attenuation as contaminated sediments are buried under freshly deposited sediment with reduced levels of PCBs as a result of load and wasteload reductions.

5.4.2 Wasteload Allocations

Municipal WWTPs and Industrial Process Water

Stevenson University WWTP (NPDES: MD0066001) is the only municipal WWTP that has been identified within the Lake Roland impoundment's watershed. The estimated tPCB baseline loading for the facility's outfall 001 is 0.014 g/year. The WWTP baseline load only accounts for 0.02 % of the total baseline load and was therefore considered *de minimis* as no appreciable environmental benefit would be gained by reducing this load. The elevated tPCB concentrations in wastewater are believed to be primarily due to external sources (*e.g.*, source water, atmospheric deposition, and stormwater runoff) infiltrating the waste water collection system through broken sewer lines and connections. There are currently no effluent tPCB limits established in the discharge permits for WWTPs. Inclusion of a WLA in this document does not reflect any determination to impose a tPCB effluent limit.

Relative to industrial process water facilities, these 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. No facility was identified within the Lake Roland watershed under these criteria.

NPDES Regulated Stormwater

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

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

The NPDES Regulated Stormwater Baseline Load to the Lake Roland impoundment constitutes a large portion of the total baseline load to the impoundment, and it therefore requires a 29.2 % reduction. The NPDES Regulated Stormwater WLA for the impoundment is 17.7 g/year. Table 8 lists the aggregate NPDES Regulated Stormwater WLA subdivided by jurisdiction (Baltimore County and Baltimore City).

Table 8: Summary of the NPDES Regulated Stormwater tPCB Baseline Load, WLA, and Load Reduction

Jurisdiction	tPCB Baseline Load (g/year)	tPCB WLA (g/year)	tPCB Reduction (%)[1]
Baltimore County	24.9	17.6	29.32
Baltimore City	0.098	0.069	29.59
Total	**25.0**	**17.7**	**29.2**

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

5.5 Margin of Safety

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

5.6 Maximum Daily Loads

All TMDLs must include maximum daily loads (MDLs) consistent with the average annual TMDL. For this TMDL, tPCB MDLs are developed for each source category by converting daily time-series loads into TMDL values consistent with available EPA guidance on generating daily loads for TMDLs (US EPA 2007). The approach builds upon the TMDL modeling analysis that was conducted to ensure that average annual load targets result in compliance with the TMDL endpoint tPCB concentrations and considers a daily load level of a resolution based on specific data for each source category.

5.7 TMDL Summary

Table 9 summarizes the tPCB baseline loads, TMDL allocations, load reductions, and maximum daily loads (MDLs) (see Appendix G for further details regarding MDL calculations) for Lake Roland.

Table 9: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in the Lake Roland Impoundment

Source	Baseline Load (g/year)	Percent of Total Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Direct Atmospheric Deposition	6.4	10.58	2.5	60.94	0.02
Non-regulated Watershed Runoff	28.9	47.77	20.5	29.07	0.15
Contaminated Sites	0.2	0.33	0.2	0.00	0.00
Nonpoint Sources/LAs	***35.5***	***58.7***	***23.2***	***34.6***	***0.17***
WWTP[1]	0.014	0.02	0.014	0.00	0.00
NPDES Regulated Stormwater[2]					
Baltimore County	24.9	41.16	17.6	29.32	0.13
Baltimore City	0.098	0.16	0.069	29.59	0.0005
Point Sources/WLAs	***25.0***	***41.3***	***17.7***	***29.2***	***0.13***
MOS (5%)	-	-	***2.1***	-	***0.02***
Total	**60.5**	**100**	**43.0**	**29**	**0.32**

Notes: [1] WWTP Baseline Load was considered to be *de minimis*
[2] Load per jurisdiction applies to all NPDES stormwater dischargers within the jurisdiction's portion of the watershed draining to Lake Roland. These dischargers are identified in Appendix I.

6.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurance that the tPCB TMDL for the Lake Roland impoundment will be achieved and maintained. As discussed in the previous sections, assuming a future decrease in watershed loads, resuspension and diffusion from bottom sediments could be a significant source of PCBs to the impoundment in the future. However, this source is not considered directly controllable within the framework of this TMDL.

The TMDL presented in this report calls for substantial reductions in tPCB loads from diffuse sources present throughout the Lake Roland impoundment's watershed. Given that PCBs are no longer manufactured, and their use has been substantially restricted, it is reasonable to expect that with time PCB concentrations in the aquatic environment will decline. The tPCB levels in Lake Roland 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 sediments were dredged within the Lake Roland impoundment, 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 temporally during dredging operations. In addition, the resuspension of contaminated sediments causes additional exposure of PCBs to aquatic organisms. In the case of Lake Roland, 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 19 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 Lake Roland.

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

The success of the implementation process will depend in large part on the feasibility of locating and evaluating opportunities to control on-land PCB sources, such as unidentified contaminated sites, leaky equipment, and contaminated soil or sediment. A collaborative approach involving MDE and the identified NPDES permit holders as well as those responsible for nonpoint PCB runoff throughout the watersheds will be used to work toward attaining the WLAs and LAs presented in this report. The reductions will be implemented in an adaptive and iterative process that will: 1) identify specific sources, or areas of PCB contamination, within the 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.

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). For example, MDE's Phase I MS4 permits require restoration targets for impervious surfaces (*i.e.*, restore 10% or 20% of a jurisdiction's total impervious cover with no stormwater management/BMPs), and these restoration efforts have known total suspended solids (TSS) reduction efficiencies. Since PCBs are known to adsorb to sediments and their concentrations correlate with TSS concentrations, the significant restoration requirements in the MS4 permits, which will lead to a reduction in sediment loads entering Lake Roland, 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 Lake Roland watershed including Municipal Phase I MS4, the SHA Phase I MS4, industrial facilities, State and Federal Phase II MS4s, and any construction activities on area greater than 1 acre (see Appendix I of this document to view the current list of known NPDES stormwater dischargers).

An example of another jurisdiction currently developing a PCB TMDL implementation plan is Montgomery County. The current Montgomery County Phase I MS4 permit already requires that the jurisdiction develop an implementation plan to meet its assigned NPDES Regulated Stormwater WLAs. Similar requirements will be placed in the Baltimore County, Baltimore City, and Maryland SHA Phase I MS4 permits when they are renewed.

Subtitle 14 of Title 26 within COMAR establishes the administrative procedures and standards for identifying, investigating, and remediating sites that have a release of, or imminent threat to release, hazardous substances to the environment. Specifically, Section 14.02.04 of the Title 26 requires MDE to establish criteria for ranking these sites relative to their need for investigation and remediation (COMAR 2013e). 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 2013b), 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 loads constitutes a relatively small percentage of the Total Baseline Load (0.33%), it is not intended to be targeted during the initial stages of implementation and thus at this point were not subjected to any reductions. However, if in the future it becomes clear that the TMDL goals cannot be achieved without load reductions from these sites, additional reduction measures might need to be considered.

Given the persistent nature of PCBs, the difficulty in removing them from the environment and the significant reductions necessary in order to achieve water quality goals in Lake Roland, 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.

7.0 REFERENCES

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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, Konietckka and Namiesnik 2008, Mydlová-Memersheimerová et al 2009). This method is based on EPA method 8082 which was developed in 1996. Since that time the extraction protocols have been enhanced to fall in line with those of EPA method 1668a. UMCES uses a slightly modified version of the PCB congener specific method described in Ashley and Baker (1999), in which the identities and concentrations of each congener in a mixed Aroclor standard (25:18:18 mixture of Aroclors 1232, 1248, and 1262) are determined based on their chromatographic retention times relative to the internal standards (PCB 30 and PCB 204 and ten C13 labeled standards). Based on this method, upwards of 100 chromatographic peaks can be quantified. Some of the peaks contain one PCB congener, while many are comprised of two or more co-eluting congeners. PCB congeners identified under this method are displayed in Table A-1. The PCB analysis presented in this document is based on tPCB concentrations that are calculated as the sum of the detected PCB congeners/congener groups representing the most common congeners that were historically used in the Aroclor commercial mixtures.

Table A-1: List of Analyzed PCB Congeners

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

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

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

I. Data Description

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

Table B-1: Species Trophic Levels and Home Ranges

Common Name	Scientific Name	Trophic Level	Home Range (miles)
Black Crappie	*Pomoxis nigromaculatus*	Predator	2
Bluegill Sunfish	*Lepomis macrochirus*	Planktivore	2
Carp	*Cyprinus carpio*	Benthivore-generalist	2
Largemouth Bass	*Micropterus salmoides*	Predator	2

* These species were not included in the Adj-tBAF and Adj-SediBAF calculation as no sediment or water column PCB data were available within their home ranges.

II. Total BAFs

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

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

Where: $[tPCB]_{fish}$ = tPCB concentration in wet fish tissue (ng/kg)
$[tPCB]_{water}$ = 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):

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

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

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

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

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

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

Table B-2: Kow Values of Homologs Used in the Baseline BAF Calculation

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

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

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

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. The lowest tPCB water column concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the "fishing" designated use (Table B-3). In the Lake Roland impoundment, the lowest concentration (0.66 ng/L) is associated with carp. Therefore, this value is selected as the water column endpoint of Lake Roland.

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

Species Name	Number of Fish	tBAF (L/kg)	Baseline BAF (L/kg)	Adj-tBAF (L/kg)	Water Column TMDL Endpoint tPCB Concentration (ng/L)
Black Crappie	3	32,706	4231,821	35,327	1.10
Bluegill Sunfish	1	12,068	1918,902	13,006	3.00
Carp	4	70,651	7869,617	59,461	0.66
Largemouth Bass	3	19,166	3047,487	20,655	1.89

V. Biota-Sediment Accumulation Factors and Adjusted Sediment BAFs

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

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

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

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

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

The tPCB fish tissue listing threshold of 39 ng/g can then be divided by the median Adj-SedBAF for each species to translate an associated tPCB sediment threshold concentration. The lowest tPCB sediment concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the "fishing" designated use (Table B-4). In the Lake Roland impoundment, the lowest concentration (38.1 ng/g) is associated with carp and will be selected as the sediment TMDL endpoint.

Table B-4: BSAF, Adj-SedBAF, and Sediment TMDL Endpoint tPCB Concentrations

Species Name	BSAF	Adj-SedBAF	Sediment TMDL Endpoint tPCB Concentration (ng/g)
Black Crappie	0.29	0.59	66.6
Bluegill Sunfish	0.12	0.23	167.6
Carp	0.51	1.02	38.1
Largemouth Bass	0.18	0.37	105.5

Appendix C: Method Used to Estimate Watershed tPCB Load

In January, April, July, and October 2010, MDE collected water column PCB measurements at the three stations in the Lake Roland watershed (JON-3, JON-5, and JON-6, see Figure C-1). In order to assess whether or not these samples covered all flow ranges so that they could be used to calculate watershed loads, the closest USGS station (USGS 01589440) was identified (see Figure C-1), and its daily average flow rates from July 3, 2007 to July 2, 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 are mainly located in the medium to high flow region. It was therefore not justifiable to use the regression method applied in the Back River tPCB TMDL (MDE 2011b) to Lake Roland.

To calculate the watershed tPCB loads, the entire Lake Roland watershed was divided into four subwatersheds according to the locations of the monitoring stations and landuse (Figure C-1). The flows of these subwatersheds were calculated by dividing the USGS mean flow by the USGS drainage area, and multiplying the respective subwatershed area. The watershed tPCB baseline loading of each subwatershed was calculated by multiplying the flow and mean tPCB water column concentration of the subwatershed. As Subwatershed 4 does not have any PCB measurement, the mean tPCB concentration of the other three subwatersheds was used. The tPCB loads for the entire Lake Roland impoundment's watershed was calculated as the sum of the individual subwatershed loads. As demonstrated in the relationship between the measured tPCB concentrations and flows (Figure C-3), the higher flow regime is often associated with high tPCB concentrations and therefore high tPCB watershed loadings. As the sampling dates fall within the medium to high flow regimes of the watershed, it is concluded that the loading calculation method is a conservative approach.

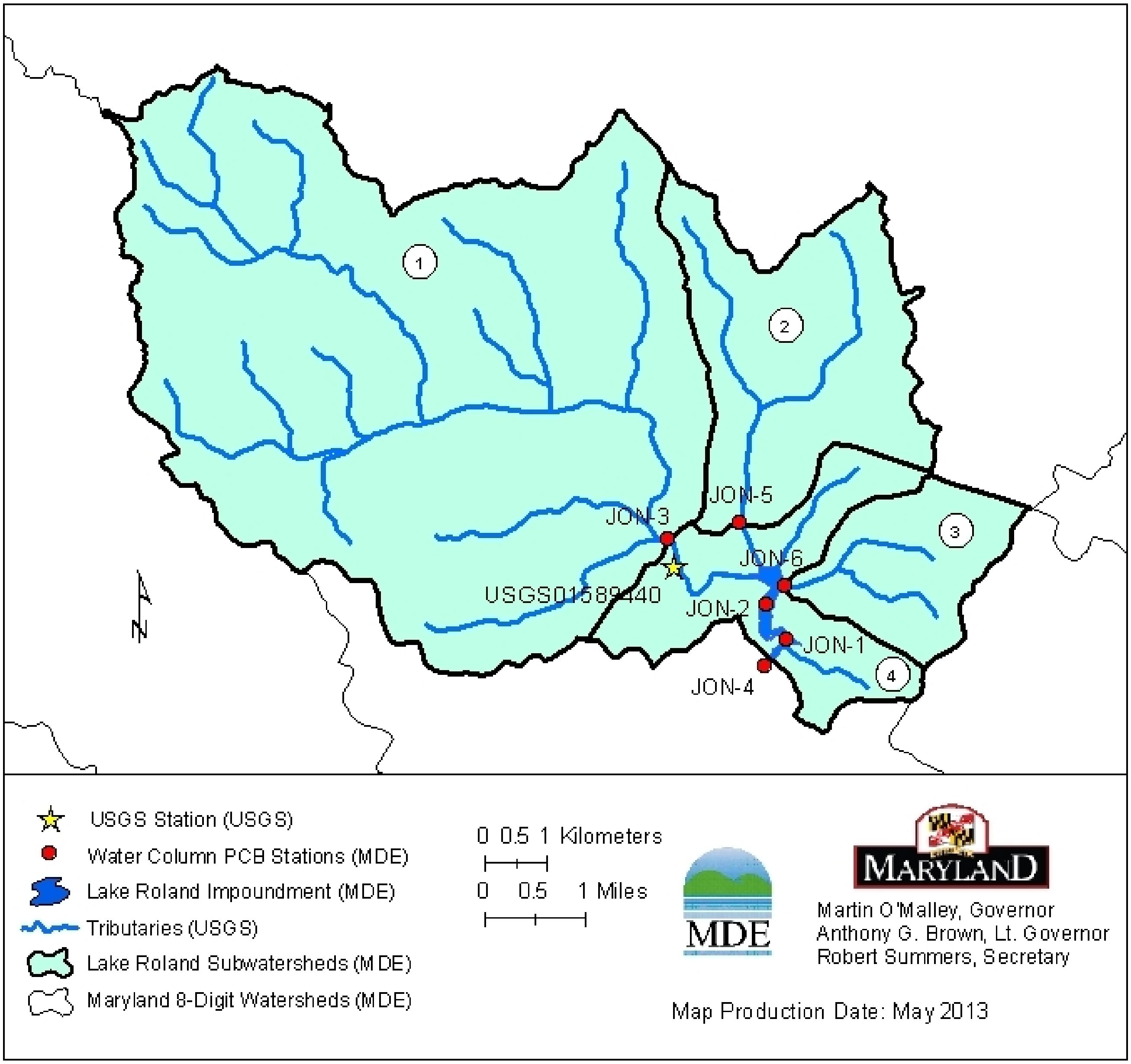
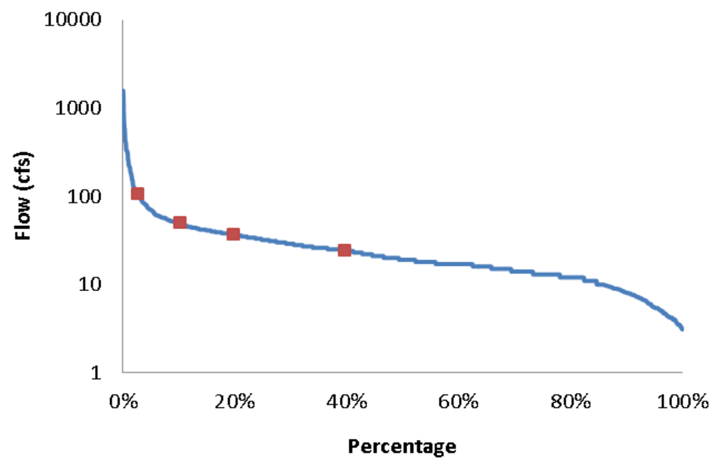


Figure C-1: The Locations of Watershed PCB Measurement Stations and the USGS Station, and the Delineation of Subwatersheds



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

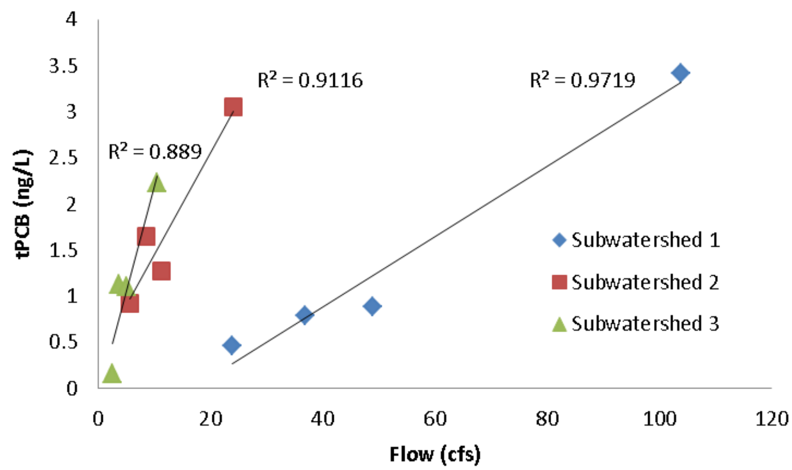


Figure C-3: Regression between PCB Concentrations and the Associated Flows of the Three Subwatersheds

Appendix D: Numerical Model Description

A description of the numerical model applied in the development of the Lake Roland impoundment TMDL is presented in this Appendix. The model assumes that a single volume can represent a waterbody, and that the pollutant is well mixed in the waterbody, as shown in Figure D-1. Assuming no decay, PCBs can enter the water column via loads from watershed sources and the atmosphere (L_f), resuspension from the bottom sediments ($V_r AC_2$), and the diffusion between the sediment-water column interface ($V_d A(F_{do2}C_2 - F_{do1}C)$). PCBs leave the water column via volatilization ($V_v AF_{do1}C_1$), flows to the downstream of Lake Roland ($Q_b C_1$), and sedimentation ($V_s AF_{p1}C_1$). In the sediment, PCBs enter the system via settling ($V_s AF_{p1}C_1$), and leave the system via diffusion ($V_d A(F_{do2}C_2 - F_{do1}C)$), resuspension ($V_r AC_2$), and burial to a deeper layer ($V_b AC_2$). Specifically, the mass balance for the PCBs in the water column and sediment can be written as:

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

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

Where:
L_f = PCB load from upstream (point and nonpoint sources) and direct atmosphere deposition;
V_v = volatilization coefficient (m/d);
A = area of the impoundment (m^2);
Q_b = quantity of water that leaves the impoundment through the downstream boundary (m^3/d);
C_1 = tPCB concentrations in the water column of the impoundment (ng/L);
C_2 = tPCB concentrations in the sediment of the impoundment (ng/L);
V_1 = volume of the water column in the impoundment (m^3);
V_2 = volume of the active sediment layer of the impoundment (m^3);
V_d = diffusive mixing velocity;
F_{p1} = fraction of particular-associated PCBs in the water column;
F_{do1}= fraction of truly dissolved and DOC-associated PCBs in the water column;
F_{do2}= fraction of truly dissolved and DOC-associated PCBs in the sediment;
V_r = rates of resuspension (m/d);
V_s = rates of settling (m/d);
V_b = rates of burial (m/d).

The values of the parameters for Lake Roland are as follows:

L_f = 165,827 ug/day
V_v = 89.8 m/year = 0.246 m/day [derived using the method of Chapra (1997), assuming a wind speed of 1 m/s and a temperature of 10□]
A = 394,391 (m^2).
Q_b = Volume of water leaving the impoundment = 104,205 (m^3)

C_1 = 2.77 (ng/L, average of Stations JON-1 and JON2's January, April, and July measurement, which was selected for model building).

C_2 = Measured tPCB concentration on a dry sediment base × Sediment density × (1-porosity) ÷ Fraction of particular-associated PCBs in the sediment = 91.88×2,500×(1-0.80) ÷ 0.9983 = 46,018 (ng/L) [the porosity (water content on a volume base) of 0.80 is selected based on observations and reference (Thomann and Mueller 1987)]

V_1 = 1,233,482 (m^3).

V_2 = A × Active sediment layer thickness = 394,391×0.03=11,832 (m^3) (active sediment layer thickness value of 0.03 m is a typical value used in water quality models for lakes)

V_d = 69.35× Porosity × (Molecular weight of PCBs)$^{-2/3}$ ÷ 365 = 69.35 × 0.85× (305.6)$^{-2/3}$ ÷ 365 = 0.00336 (m/d; Thomann and Mueller 1987)

F_{p1} = 0.2817; F_{do1} = 0.7183; F_{do2}= 0.00171 (see Appendix E for derivation)

V_s= 1.0 (m/d) (a default value of settling rate normally used in literature)

V_b = 3.935×10^{-6} (m/d, average of the measured sedimentation rates of Northeast River, Corsica River, Bohemia River, and Sassafras River through ^{210}Pb technology)

V_r can be calculated via mass balance of the sediment in the active sediment layer at steady state:

$$\frac{d\rho(1-\varphi)}{dt} = V_s \times TSS - V_r \times \rho \times (1-\varphi) - V_b \times \rho \times (1-\varphi) = 0 \qquad \text{(D-3)}$$

Where: TSS is the total suspended solid concentration (g/m^3, measured)

ρ is the sediment density (g/m^3; Thomann and Mueller, 1987)

φ is the porosity.

Rearrange Equation E-1:

$$V_r = \frac{V_s \times TSS}{\rho \times (1-\varphi)} - V_b = \frac{1.0 \times 14.85}{2500000 \times (1-0.80)} - 3.935 \times 10^{-6} = 2.58 \times 10^{-5} \text{(m/d)} \qquad \text{(D-4)}$$

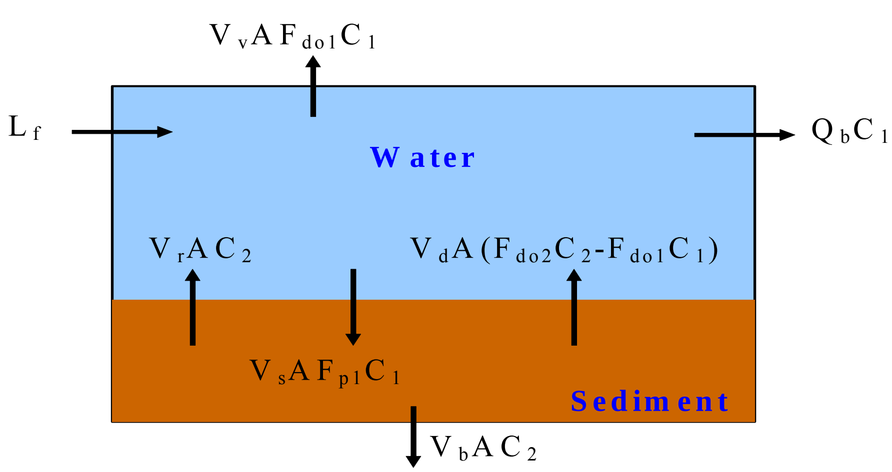


Figure D-1: Schematic Diagram of the Numerical Model and PCB Budget

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.

φ = the porosity of the sediment.

Appendix F: Calculation of 95% Confidence Intervals

The response time to reach the tPCB water column TMDL endpoint concentration for load reductions from 29% to 100% is displayed in Figure F-1 and Table F-1. The final sediment concentration is also displayed.

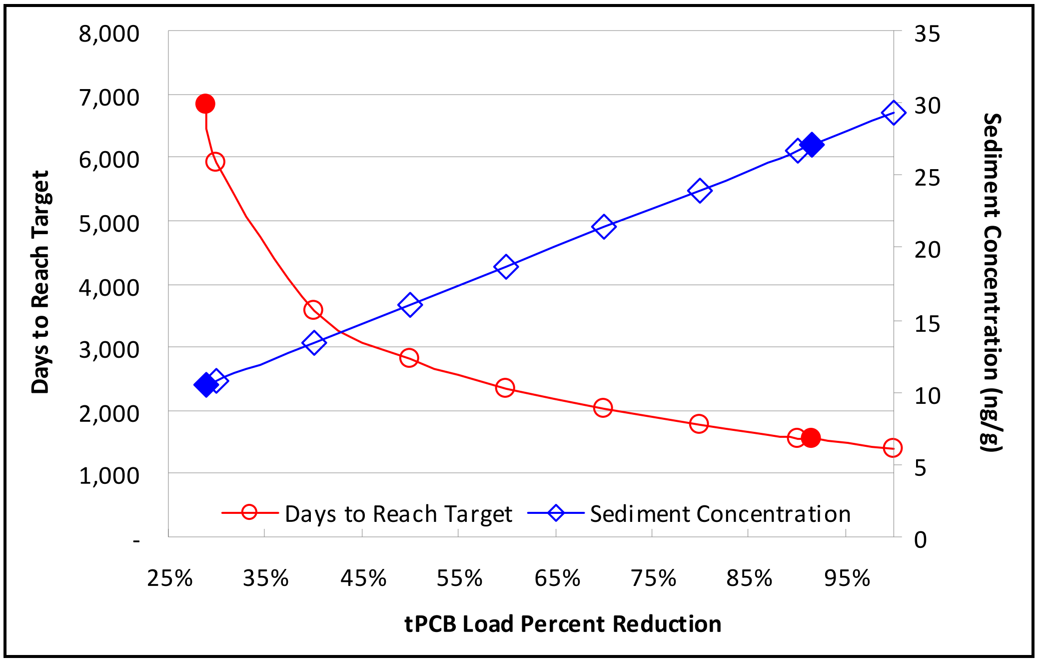


Figure F-1: Response Time (Days) to Reach the tPCB Water Column TMDL endpoint and tPCB Sediment Concentrations for Load Reductions from 29% to 100% (Solid data points represent 29% and 91.5% Reduction Scenarios)

Table F-1: Response Time (Days) to Reach the tPCB Water Column TMDL Endpoint and tPCB Sediment Concentrations for Load Reductions from 29% to 100%

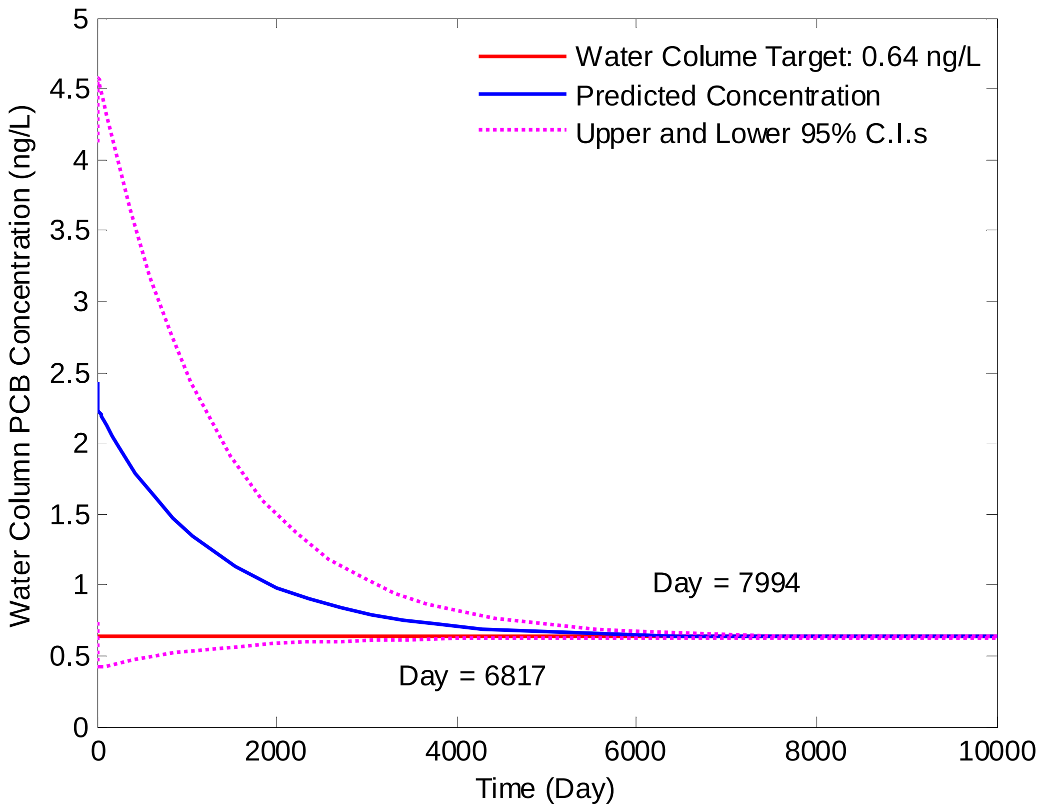
Reduction	Time Required to Meet the Target Water Column tPCB Concentration (Days)	Sediment tPCB Concentration (ng/L) When Target Water Column tPCB Concentration is Achieved
29%	6,817	10.5
30%	5,924	10.8
40%	3,588	13.4
50%	2,813	16.1
60%	2,351	18.7
70%	2,010	21.4
80%	1,757	24.0
90%	1,563	26.7
91.5%	1,534	27.1
100%	1,378	29.3

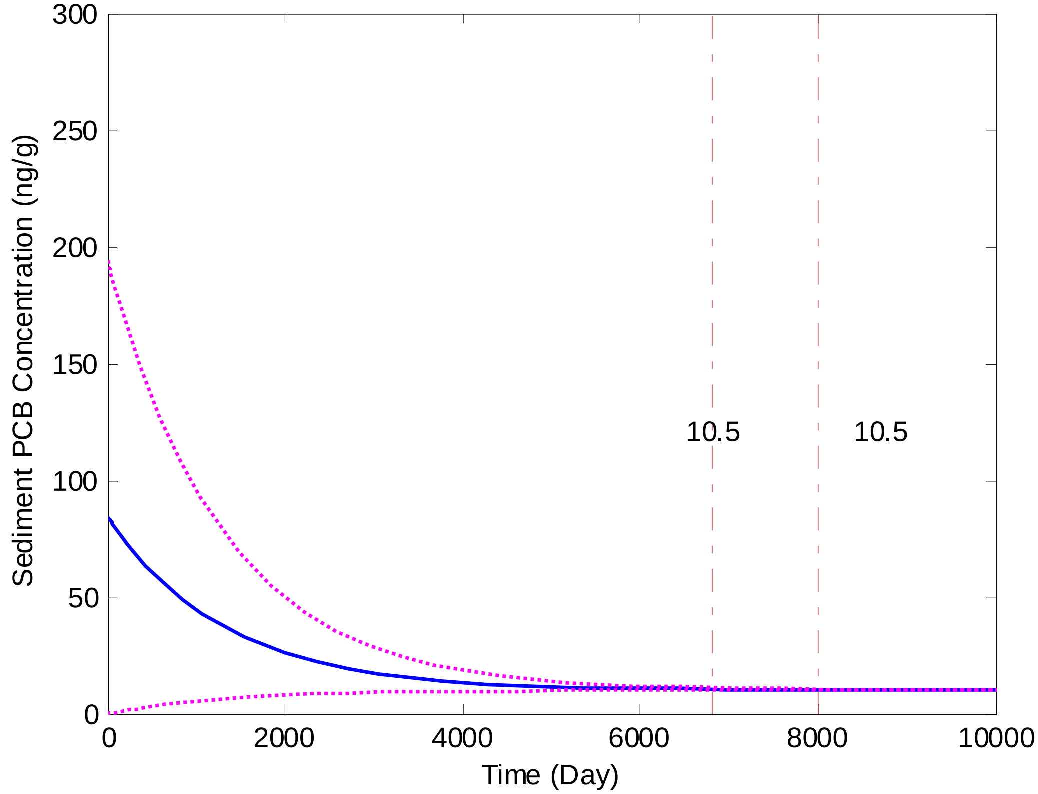
The 95% CIs for the baseline mean tPCB concentrations were calculated as follows:

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

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

The model was run with the mean as well as the upper- and lower- 95% CIs as the initial conditions in the impoundment and outside of the impoundment, assuming a 29% total tPCB load reduction. The results are presented in Figure F-2. The time required to meet the water column and sediment TMDL endpoint tPCB concentrations are listed in Table F-2. The time required to meet the TMDL endpoint tPCB concentration in the impoundment increased by approximately 20% (3.3 years) when the higher tPCB water column concentration was applied as the baseline.





Note: The dashed red lines in the sediment graph represent what the sediment concentrations will be within the impoundment when the water column TMDL endpoint concentration is achieved in the 2 different scenarios (*i.e.*, mean and upper CIs). As in the lower CI scenario, the water column concentration meets the endpoint from the very beginning, no dash line is generated.

Figure F-2: Change of Average Water Column and Bottom Sediment tPCB Concentrations Over Time Within the Lake Roland Impoundment

Table F-2: Water Column TMDL Endpoint tPCB Achievement - Mean and 95% CI Sediment tPCB Concentrations

Initial Conditions Scenario	Time Required to Meet the TMDL Endpoint Water Column tPCB Concentration (Days)	Sediment tPCB Concentration (ng/L) When TMDL Endpoint Water Column tPCB Concentration is Achieved
Mean	6,817	10.5
Upper 95% C.I.	7,994	10.5
Lower 95% C.I.	0	NA

Appendix G: Technical Approach Used to Generate Maximum Daily Loads

I. Summary

This appendix documents the technical approach used to define MDLs of tPCBs consistent with the average annual TMDL, which is protective of the "fishing" designated use, which is protective of human health related to the consumption of fish, in the Lake Roland impoundment. 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 Lake Roland impoundment.

Level of Resolution

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

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

Probability Level

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

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

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

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

2. **The MDL reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the MDL is based upon the allowable load that is predicted to occur during some critical period examined during the analysis. The developer does not explicitly specify the probability of occurrence;

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

V. Selected Approach

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

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

The CV was calculated using the arithmetic mean and standard deviation of the baseline ambient water column tPCB concentrations in the Lake Roland impoundment. The resulting CV of 0.76 was calculated using the following equation:

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

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

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

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

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

Using a z-score associated with the 99^{th} percent probability of 2.33, a CV of 0.76, and consistent units, the resulting dimensionless conversion factor from long-term average loads to a maximum daily value is 2.62. The average annual Lake Roland impoundment tPCB TMDL is reported in g/year, and the conversion from g/year to a maximum daily load in g/day is 0.0072 (*e.g.* 2.62/365).

VIII. Approach for WWTPs

The TMDL also considers contributions from NPDES permitted WWTPs that discharge quantifiable concentrations of tPCBs to the Lake Roland impoundment. 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 99^{th} percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual Lake Roland impoundment 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 Lake Roland impoundment 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) * 0.0072

  Non-regulated Watershed Runoff LA (g/day) = Average Annual TMDL Non-regulated Watershed Runoff LA (g/year) * 0.0072

  Contaminated Site LA (g/day) = Average Annual TMDL Contaminated Site LA (g/year) * 0.0072

  NPDES Stormwater WLA (g/day) = Average Annual TMDL NPDES Regulated Stormwater WLA (g/year) * 0.0072

- Calculation Approach for WWTPs

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

Table G-1: Summary of tPCB MDLs for the Lake Roland Impoundment

Source	**MDL (g/day)**
Direct Atmospheric Deposition (to the Surface of the Impoundment)	0.02
Non-regulated Watershed Runoff	0.15
Contaminated Sites	0.001
Nonpoint Sources/LAs	***0.17***
WWTP	0.0001
NPDES Regulated Stormwater[1]	
Baltimore County	0.13
Baltimore City	0.0005
Point Sources/WLAs	***0.13***
MOS	***0.02***
Total	***0.32***

Notes: [1] Load per jurisdiction applies to all NPDES stormwater dischargers within the jurisdiction's portion of the watershed draining to the Lake Roland impoundment. These dischargers are identified in Appendix I.

Appendix H: Contaminated Site Load Calculation Methodology

The term PCB contaminated site used throughout this report refers to areas with known PCB soil contamination, as documented by state or federal hazardous waste cleanup programs (*i.e.*, state or federal Superfund programs). When compared against the human health screening criteria for soil and groundwater exposure pathways, PCBs are not necessarily a contaminant of concern at these sites, but have been screened for, reported, and detected during formal site investigations. MDE has identified one PCB contaminated site within the Lake Roland impoundment's watershed, for which EOF tPCB baseline loads have been estimated. This site (see Table I-1) was 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 has been converted to an EOS load using methods applied within Maryland's non-tidal sediment TMDLs. The modeling assumption behind the conversion to EOS load is that only a portion of the contaminated site tPCB load associated with sediment delivery is expected to reach the impaired waterbody. Thus, the EOS load is considered a more accurate representation of the tPCB load from the site. A delivery factor of 0.54 is 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 Lake Roland impoundment's watershed) with samples where tPCB concentrations were found to be at or above the method detection limits used in the soil sampling analyses conducted as part of site investigations. Har Sinai Property is the only PCB contaminated site identified. For the most part, these soil sampling analyses employed an Aroclor based analytical method. Thus, when a given sample was analyzed for multiple Aroclors and more than one mixture was detected (*e.g.*, 1232, 1248, 1262, etc.), the results were added together to represent tPCB concentrations. Next, the median value of the tPCB concentrations from this site was calculated (155 ug/kg).

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

The Revised Universal Soil Loss Equation Version II (RUSLE2)[1] was run for the site with the use of the Maryland state climate database, county soil databases, and management databases that can be downloaded from the following website: http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm. The site characteristics (*i.e.*, soil

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.

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

For sites with multiple soil types and land cover classifications, 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 H-1 in g/year.

Table H-1: Summary of Contaminated Site Soil Loss Value and EOF tPCB Load

Site Name	Site Description	Median tPCB (µg/kg)	Soli Loss (lbs/year)	EOF PCB Loads (g/year)
Har Sinai Property	No Remediation	155	5409.4	0.38

IV. Calculating EOS tPCB loads

The EOF load is expected to be delivered partially to the system with losses expected to occur over land, and a delivery factor (DF) is consequently applied to the EOF load to calculate the EOS load. The EOS and DF are calculated as below:

$$EOS = EOF \times DF$$
$$DF = 0.417762 \times A^{-0.134958} - 0.127097$$

Where A = drainage area in square miles; drainage area was assumed to be equal to the area of a circle with radius equal to the distance between the site and the applicable 1:24,000 NHD stream segment the site drains to in the watershed. The DF and EOS load for the contaminated site are 0.54 and 0.2 g/year, respectively.

V. Contaminated Site Baseline Load Summary

The Contaminated Site tPCB Baseline Load from the identified site in the Lake Roland impoundment's watershed is estimated to be 0.2 g/year.

Appendix I: List of NPDES Regulated Stormwater Permits

Table I-1: NPDES Regulated Stormwater Permit Summary for the Lake Roland Impoundment Watershed[1]

MDE Permit	NPDES	Facility	City	County	Type	TMDL
04DP3313	MD0068276	State Highway Administration (MS4)	State-wide	All Phase I (Baltimore County and City)	WMA6	Stormwater WLA
09-GP-0000	MDR100000	MDE General Permit to Construct	All	All		Stormwater WLA
05-DP-3317	MD0068306	Baltimore County MS4	County-wide	Baltimore	WMA6	Stormwater WLA
04-DP-3315	MD0068292	Baltimore City MS4	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-0105	MDR000105	Hedwin Corporation - Roland Heights	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-0255	MDR000255	Woodberry Quarry Landfill	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-0599	MDR000599	Pepsi Bottling Group, LLC.	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-0702	MDR000702	Baltimore City DPW - Northeastern Substation	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-0704	MDR000704	Baltimore City DPW - Middletown Fueling Substation	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-0707	MDR000707	Baltimore City DPW - Fallsway Substation	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-0747	MDR000747	U.S. Postal Service - Oliver Street VMF	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-0861	MDR000861	Hollins Organic Products, Inc.	Baltimore	Baltimore	WMA6	Stormwater WLA
02-SW-1056	MDR001056	Veolia Transportation - Baltimore	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-1156	MDR001156	Norfolk Railway Corporation - Flex-flo Terminal	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-1211	MDR001211	Cold Spring Landfill	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-1296	MDR001296	Cockeys Enterprises, Inc.	Stevenson	Baltimore	WMA6	Stormwater WLA
02-SW-1675	MDR001675	MTA - North Avenue Lightrail Facility	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-1676	MDR001676	MTA - Kirk Avenue Bus Division	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-1751	MDR001751	SHA - Brooklandville Shop	Brooklandville	Baltimore	WMA6	Stormwater WLA
02-SW-1810	MDR001810	Potts & Callahan, Inc. - Repair Shop	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-2140	MDR002140	Ellicott Dredges, LLC	Baltimore City	Baltimore City	WMA6	Stormwater WLA
02-SW-3029	MDR003029	Pall Filtration & Separations Group - Greenspring	Timonium	Baltimore	WMA6	Stormwater WLA

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

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

Tables J-1 through J-3 list the tPCB concentrations in the water column, sediment, and fish tissue samples collected in Lake Roland. Figure C-1 shows the locations of the water column monitoring stations, and Figure J-1 shows the locations of the sediment and fish tissue monitoring stations.

Table J-1: Sediment tPCB Concentrations (ng/g) in the Lake Roland Impoundment

Station	Date	Conc.
JON1	2010/4/26	74.25
JON1	2010/10/6	71.98
JON2	2010/4/26	109.51
JON2	2010/10/6	81.54

Table J-2: Water Column tPCB Concentrations (ng/L) in Lake Roland

Date	Station	Type	Conc.	Date	Station	Type	Conc.
2010/1/14	JON 1	Impoundment	1.54	2010/1/14	JON 4	Downstream	1.04
2010/4/21	JON 1	Impoundment	1.55	2010/4/21	JON 4	Downstream	1.65
2010/7/14	JON 1	Impoundment	5.36	2010/7/14	JON 4	Downstream	5.41
2010/10/6	JON 1	Impoundment	0.63	2010/10/6	JON 4	Downstream	2.84
2010/1/14	JON 2	Impoundment	1.27	2010/1/14	JON 5	Tributary	1.64
2010/4/21	JON 2	Impoundment	1.56	2010/4/21	JON 5	Tributary	1.27
2010/7/14	JON 2	Impoundment	5.36	2010/7/14	JON 5	Tributary	3.05
2010/10/6	JON 2	Impoundment	2.18	2010/10/6	JON 5	Tributary	0.92
2010/1/14	JON 3	Tributary	0.79	2010/1/14	JON 6	Tributary	1.13
2010/4/21	JON 3	Tributary	0.89	2010/4/21	JON 6	Tributary	1.10
2010/7/14	JON 3	Tributary	3.41	2010/7/14	JON 6	Tributary	2.23
2010/10/6	JON 3	Tributary	0.46	2010/10/6	JON 6	Tributary	0.16

Table J-3: Fish Tissue tPCB Concentrations (ng/g) in Lake Roland*

Site	Date	Conc.	Species
LRo	10/10/2000	146.18	Carp
LRo	10/10/2000	48.65	Black Crappie
LRo	10/10/2000	58.48	Black Crappie
LRo	10/10/2000	137.59	Carp
LRo	10/10/2000	48.69	Largemouth Bass
LRo	10/10/2000	39.71	Black Crappie
LRo2	10/24/2007	19.34	Bluegill
LRo2	10/24/2007	74.38	Carp
LRo2	10/24/2007	78.24	Carp
LRo2	10/24/2007	30.72	Largemouth Bass
LRo2	10/24/2007	14.72	Largemouth Bass

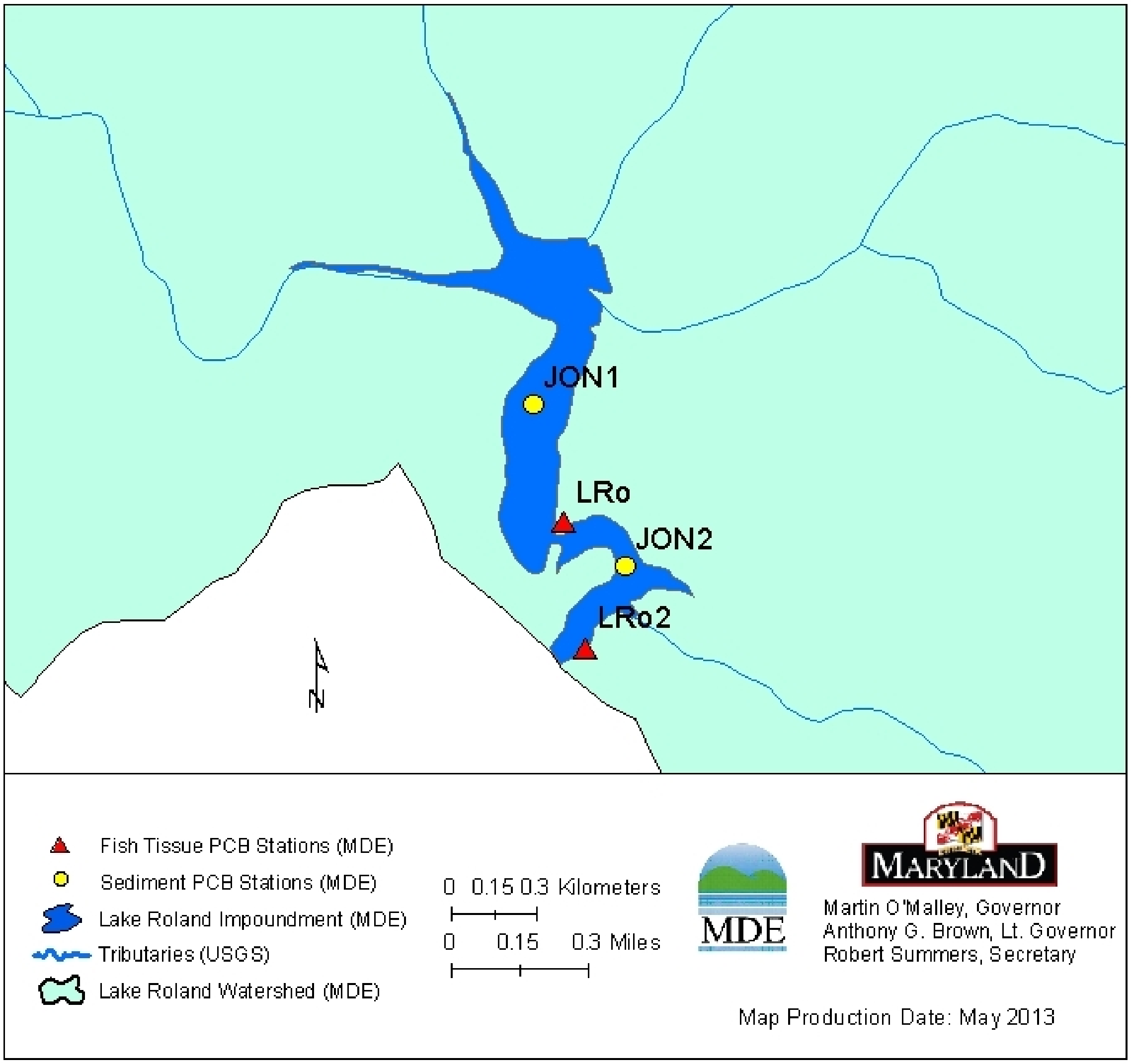


Figure J-1: PCB Fish Tissue and Sediment Monitoring Stations in the Lake Roland Impoundment