Total Maximum Daily Load of Mercury for Cash Lake Watershed, Prince George's County, Maryland

PUBLIC REVIEW DRAFT

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List of Abbreviations

BIBI	Benthic Index of Biotic Integrity
^oC	Degrees Celcius
CAA	Clean Air Act
CAIR	Clean Air Interstate Rule
CWA	Clean Water Act
DNR	Maryland Department of Natural Resources
EGU	Electrical Generating Unit
Eh	Oxidation Potential
EPA	U.S. Environmental Protection Agency
FIBI	Fish Index of Biotic Integrity
g	Gram
g/yr	Grams per year
g/day	Grams per day
g/km^2-yr	Grams per square kilometer per year
g/cm^3	Grams per centimeters cubed
gpd	gallons per day
HAA	Healthy Air Act
Hg	Mercury
kg	Kilogram
km^2	Square kilometer
L	Liter
LA	Load Allocation
µg/kg	Micrograms per kilogram
µg/L	Micrograms per liter
µm	Micrometer
M^3	cubic meters
mL	Milliliter
mm	Millimeter
MDL	Maximum Daily Load
MD 8-Digit	Maryland 8-digit watershed
MDE	Maryland Department of the Environment
MGD	Millions of Gallons per Day
MeHg	Methylmercury
Mol/L	Mols/Liter
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
N/A	Not Applicable
ng/L	Nanograms per liter
NEI	National Emissions Inventory
NADP-MDN	National Atmospheric Deposition Program – Mercury Deposition Network
NPDES	National Pollutant Discharge Elimination System
pH	Inverse logarithm of the hydrogen ion concentration
ppb	Parts per billion
PPRP	Power Plant Research Program
PWRC	Patuxent Wildlife Research Center
RfD	Reference Dose
SCS	Soil Conservation Service
TMDL	Total Maximum Daily Load
UMCES	University of Maryland Center for Environmental Science
USDA	United States Department of Agriculture
WLA	Waste Load Allocation
WQLS	Water Quality Limited Segments
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for mercury (Hg) in Cash Lake located in the Maryland 8-digit (MD 8-digit) Patuxent River Upper Watershed (basin number 02131104) (2008 *Integrated Report of Surface Water Quality in Maryland Assessment Unit ID*: MD-021311040938-Cash Lake). 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. For each WQLS, the State is required to either establish a TMDL of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2010b).

The Maryland Department of the Environment (MDE) has identified the waters of the MD 8-digit Patuxent River Upper watershed on the State's 2008 Integrated Report as impaired by sediments (1996), nutrients – nitrogen and phosphorus (1996), bacteria (2002 and 2008), methylmercury (MeHg) in fish tissue (Cash Lake - 2002), and impacts to biological communities (2006) (MDE 2008). The designated use of the MD-8 digit watershed Patuxent River Upper mainstem and its tributaries, including Cash Lake, is Use I (Water Contact Recreation and Protection of Aquatic Life) (COMAR 2010a,b,c).

A Water Quality Analysis (WQA) of eutrophication to address the nutrients (nitrogen and phosphorus) listing was approved by the EPA in 2007, and the watershed was delisted for bacteria in 2002 (relisted in 2008 – mainstem only from Old Queen Anne's Bridge Road to the river's confluence with the Little Patuxent River). A sediment TMDL for the MD 8-digit watershed and a bacteria TMDL for the river mainstem from Old Queen Anne's Bridge Road to the river's confluence with the Little Patuxent River are scheduled to be submitted to the EPA in 2010. In the 2012 Integrated Report, the listing for impacts to biological communities will include the results of a stressor identification analysis.

The TMDL established herein by MDE will address the 2002 methylmercury in fish tissue listing for Cash Lake, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. The objective of the TMDL is to ensure that the "fishing" designated use in the ponds is supported to allow for the consumption of fish that is protective of human health (COMAR 2010d). Currently, MDE's public fish consumption advisory to eat limited amounts of fish from Cash Lake, due to elevated mercury concentrations found in fish tissue, is not supportive of this use.

The methodology used to calculate this TMDL consists of two general steps. First, trophic-level four fish (sport fish) are sampled to assess the amount of mercury in their muscle (filet) tissue. Then, this fish tissue concentration is compared with the TMDL endpoint of 235 micrograms per kilogram (µg/kg) (MDE fish consumption advisory threshold) to determine the degree of impairment. The second step is to determine the maximum allowable mercury loading to the impoundment, assuming that the entirety of the fish tissue mercury is resultant from atmospheric deposition loadings.

As part of this analysis, the only nonpoint source of mercury to Cash Lake has been identified as atmospheric deposition, either directly to the surface of the impoundment or to the watershed area draining to the impoundment. No individual industrial point source discharges have been identified. Previously, there were two municipal wastewater treatment plants (WWTPs) located within the Cash Lake watershed at the Patuxent Wildlife Research Center (PWRC). The permit for the first PWRC WWTP (National Pollutant Discharge Elimination System (NPDES) Permit #: MD0025623) was officially terminated as of April 28, 2008. Effluent is now sent to a neighboring WWTP through a Washington Suburban Sanitary Commission (WSSC) sewer line, outside the watershed. The second WWTP (NPDES Permit #: MD0065358) is a small “package” WWTP at the PWRC Visitors’ Center and is still active. The design flow for this facility is 6,700 gallons per day (gpd), but actual flow is reported to be much less. Mercury loads from the facility are believed to be insignificant. Appendix G describes this issue in greater detail. NPDES regulated stormwater discharges have been identified within the watershed, including a Phase II federal municipal separate storm sewer system (MS4) and industrial facilities permitted for stormwater discharges (see Appendix F). The mercury loadings from these areas will be treated as point sources in this analysis; however, it is assumed that the origin of any urban stormwater mercury loadings is from atmospheric deposition (i.e., there are few, if any, known sources of mercury to stormwater that do not ultimately derive from atmospheric deposition) and would be addressed by emissions-based techniques, such as those that will be required via the regional Clean Air Interstate Rule (CAIR), which will be replaced by the Clean Air Transport Rule (once the latter is finalized), and Maryland’s Healthy Air Act (HAA) (see Assurance of Implementation Section for further details) (COMAR 2010f,h).

EPA’s regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2010b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. Thus, since fish tissue concentrations at the time of sampling are the result of the long-term accumulation of mercury in fish over their lifespan, and the allowable concentrations of mercury are based on human fish consumption over a long time period, which averages out critical events, seasonality and critical conditions are inherently addressed.

All TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources generated within the assessment unit, accounting for natural background, tributary, and upstream segment loads. Furthermore, all TMDLs must include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2010a,b). It is proposed that the following components of this analysis already account for such uncertainty, and therefore the MOS is implicitly included: 1) the use of trophic-level four fish, which typically have higher fish tissue mercury concentrations than other lower trophic-level fish; 2) the use of a TMDL endpoint of 235 µg/kg (MDE’s fish consumption advisory threshold), as compared to EPA’s recommended criteria (protective of human health via fish consumption) of 300 µg/kg (COMAR 2010e); 3) the use of total mercury rather than methylmercury (methylmercury, the form that represents a human health risk, comprises 90 to 95% of total mercury found in fish tissue); and 4) the assumption within the baseline loading calculations (see Section 4.3 and Appendix A) that the entirety of the atmospheric deposition mercury loading to Cash Lake's watershed actually reaches the impoundment. The TMDL includes a LA and a MOS. There is no WLA, as no individual municipal or industrial point sources were identified within the watershed. Furthermore, even though NPDES regulated stormwater discharges have been identified, the mercury loadings from these areas will not be included in the WLA, since any mercury in stormwater would arrive in the form of atmospheric deposition, which is a nonpoint source. The TMDL methodology considers all sources, but atmospheric deposition to the surface of the impoundment and to the watershed draining to the impoundment is the only source identified.

The Cash Lake Total Mercury Baseline Load is an average annual load of 147.60 grams per year (g/yr). The Cash Lake Average Annual Mercury TMDL is 88.83 g/yr, which translates to a Maximum Daily Load (MDL) of 0.2434 grams per day (g/day) (see Table ES-1). This is the total amount of mercury that can be assimilated by Cash Lake without significantly increasing the risk to human health, due to the consumption of fish, from mercury concentrations in fish tissue. It represents a 39.82% reduction from baseline conditions (see Table ES-1). The LA is apportioned between loadings from atmospheric deposition to the actual water surface of the lake as well as the watershed area draining to the lake. The water surface loading is 3.04 g/yr and 0.0083 g/day, and the remainder of the LA is apportioned to the lake's watershed area. The MOS is implicit.

Table ES-1: Cash Lake Mercury Baseline Load, TMDL, and Total Reduction Percentage

Baseline Load (g/yr)	TMDL (g/yr)	Total Reduction (%)
147.60	88.83	39.82

Due to this TMDL, immediate public health benefits will be derived from the enhanced public awareness that will be generated via the TMDL process. The TMDL will increase public awareness of the need for upgrading controls on the atmospheric emissions of mercury. Maryland has already passed legislation requiring such controls, such as the HAA, the implementation of which (full implementation supposed to occur by 2013) is anticipated to result in water quality improvements. Thus, TMDL implementation, via a reduction in the atmospheric deposition of mercury, is expected to be accomplished over time through existing and proposed regulatory controls, such as the CAIR/Clean Air Transport Rule and Maryland's HAA, which will curb current sources of atmospheric mercury emissions (See Appendix A) (COMAR 2010f,h). These controls are expected to be implemented in phases.

1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for mercury (Hg) in Cash Lake located in the Maryland 8-digit (MD 8-digit) Patuxent River Upper Watershed (basin number 02131104) (2008 *Integrated Report of Surface Water Quality in Maryland Assessment Unit ID*: MD-021311040938-Cash Lake). Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to develop a TMDL for each impaired water quality limited segment (WQLS) on the State's Integrated Report, taking into account seasonal variations, critical conditions, and a protective margin of safety (MOS) to account for uncertainty (CFR 2010b). A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to determine the pollutant load reductions needed to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, protection of aquatic life, shellfish propagation and harvest, and fishing, including the protection of human health associated with the consumption of fish. 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.

The Maryland Department of the Environment (MDE) has identified the waters of the MD 8-digit Patuxent River Upper watershed on the State's 2008 Integrated Report as impaired by sediments (1996), nutrients – nitrogen and phosphorus (1996), bacteria (2002 and 2008), methylmercury (MeHg) in fish tissue (Cash Lake - 2002), and impacts to biological communities (2006) (MDE 2008). The designated use of the MD 8-digit watershed Patuxent River Upper mainstem and its tributaries, including Cash Lake, is Use I (Water Contact Recreation and Protection of Aquatic Life) (COMAR 2010a,b,c).

A Water Quality Analysis (WQA) of eutrophication to address the nutrients (nitrogen and phosphorus) listing was approved by the EPA in 2007, and the watershed was delisted for bacteria in 2002 (relisted in 2008 – mainstem only from Old Queen Anne's Bridge Road to the river's confluence with the Little Patuxent River). A sediment TMDL for the MD 8-digit watershed and a bacteria TMDL for the river mainstem from Old Queen Anne's Bridge Road to the river's confluence with the Little Patuxent River are scheduled to be submitted to the EPA in 2010. In the 2012 Integrated Report, the listing for impacts to biological communities will include the results of a stressor identification analysis.

The TMDL established herein by MDE will address the 2002 methylmercury in fish tissue listing for Cash Lake, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. The federal CWA and Maryland's State regulations require the State to maintain water quality that supports fish and aquatic life, and fishing as a recreational activity (COMAR 2010a,d). The EPA interprets the "fishable" use under section 101(a) of the CWA to include, at a minimum, the protection of aquatic communities and human health related to the consumption of fish and shellfish. Thus, “fishable” implies that not only can fish and shellfish survive in a water body, but when harvested, can also be safely eaten by humans and terrestrial wildlife (US EPA 2000a). Based on the recommended EPA criterion, a fish tissue concentration of 300 micrograms per kilogram (µg/kg) is considered the highest possible concentration (i.e., threshold concentration) that still supports this “fishable” use (US EPA 2001). This water quality criterion describes the maximum advisable concentration of mercury in freshwater and estuarine fish and shellfish tissue to protect consumers of fish and shellfish among the general population. The EPA expects the recommended criterion to be used as guidance by States and authorized Tribes in establishing or updating water quality standards for waters of the United States. Water bodies with fish tissue concentrations above this level are thus considered to be impaired. Therefore, the objective of the TMDL is to ensure that the “fishing” designated use in Cash Lake is supported to allow for the consumption of fish that is protective of human health (COMAR 2010d).

MDE measures fish tissue concentrations of total mercury. Methylmercury, which is the form that represents a human health risk, comprises 90 to 95% of total mercury found in fish tissue. Thus, as a conservative assumption, total mercury as measured by MDE in fish tissue is considered to consist entirely of its methylated form. Therefore, for the purpose of this TMDL, the terms “total mercury”, “methylmercury”, and “mercury” are used interchangeably to refer to the impairing substance, except when a distinction is made for computational purposes.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Cash Lake is an impoundment located within the 12,841 acre Patuxent Wildlife Refuge Research Center in the MD 8-digit Patuxent River Upper watershed, northeast of Washington D.C. in Prince George's County, Maryland (see Figure 1). The total population in the MD 8-digit Patuxent River Upper watershed is approximately 165,898 (US Census Bureau 2000). The watershed draining to Cash Lake covers 1,490 acres. The impoundment, which is owned by the United States Department of the Interior, discharges to a tributary of the Patuxent River Upper. An earthen dam along an unnamed tributary of the Patuxent River Upper was constructed in 1938 for the purposes of recreation and fish and wildlife management. 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 Cash Lake watershed requiring the implementation of Maryland's antidegradation policy (COMAR 2010g).

Cash Lake lies in the Coastal Plain geologic province of Maryland. Broad upland areas with low slopes, gentle drainage, and deep sedimentary soil complexes that support broad meandering streams characterize the Coastal Plain geologic province (DNR 2010; MGS 2010; MDE 2000). The soils immediately surrounding the lake lie in the Christiana-Sunnyside-Beltsville association (USDA 1967). These soils are typically level to steep, well–drained sandy and clay soils.

Soil type for the Cash Lake watershed is also categorized by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) into four hydrologic soil groups: Group A soils have high infiltration rates and are typically deep well-drained to excessively drained sands or gravels; Group B soils have moderate infiltration rates and consist of moderately deep to deep and moderately well to well drained soils, with moderately fine to moderately coarse textures; Group C soils have slow infiltration rates and a layer that impedes downward water movement and consist of moderately fine to fine textured soils; Group D soils have very slow infiltration rates and consist of clay soils with a permanently high water table that are shallow and often over nearly impervious material. The Cash Lake watershed is comprised of primarily Group C type soils (77%) with smaller amounts of and Group D (11%), Group B (9%), and Group A soils (3%) (USDA 2006).

Cash Lake has a surface area of approximately 52.7 acres (0.2133 square kilometers (km^2)). Inflow to the lake is primarily via Redington Lake, which covers approximately 36 acres (0.146 km^2). Redington Lake was created in 1943. The land use distribution in the combined watershed for the two lakes is 77% forested/herbaceous, 11% urban, 6% water, 4% pasture, and 2% mixed agriculture (see Figure 2) (MDP 2002). Table 1 lists the physical characteristics for Cash Lake.

Table 1: Physical Characteristics for Cash Lake

Location:	Prince George's County, Maryland
Latitude (At dam):	39° 01' 54"
Longitude (At dam):	76° 47' 18"
Surface Area:	0.2133 km^2
Average Depth:	0.94 meters (m)
Average Volume:	201,058 cubic meters (m^3)
Drainage Area to Lake:	6.0287 km^2
Average Annual Flow[1]:	0.045 cubic meters per second (m^3/s)

Note: [1] Source: (Obrecht 2010).

Cash Lake was temporarily drained starting in autumn of 1998 in order for work to be done on the dam parallel to Route 197. This construction was completed in the spring of 2000. The lake was refilled from runoff and discharge from Redington Lake during the winter of 2000-2001. After restocking the lake and surveying the fish population, Patuxent Wildlife Refuge Research Center biologists determined that the lake was able to support a sport-fishing season for the first time in four years (U.S. Fish and Wildlife Service 2003).

Largemouth Bass fishing at Cash Lake is permitted only on a catch-and-release basis. However, for the purpose of maintaining consistency with other mercury TMDLs and to ensure protection of public health, the TMDL is being developed using Largemouth Bass fish tissue mercury concentrations, which is considered to be representative of trophic-level four fish (sport fish) in the lake. Redington Lake is not open to public fishing, with the exception of one supervised youth fishing day in early June of each year. This is catch-and-release only. For this reason, fish tissue mercury levels in Redington Lake are not monitored. However, any controls or measures implemented as a consequence of this TMDL would equally benefit the fish in Redington Lake, given the immediate proximity of the lakes.

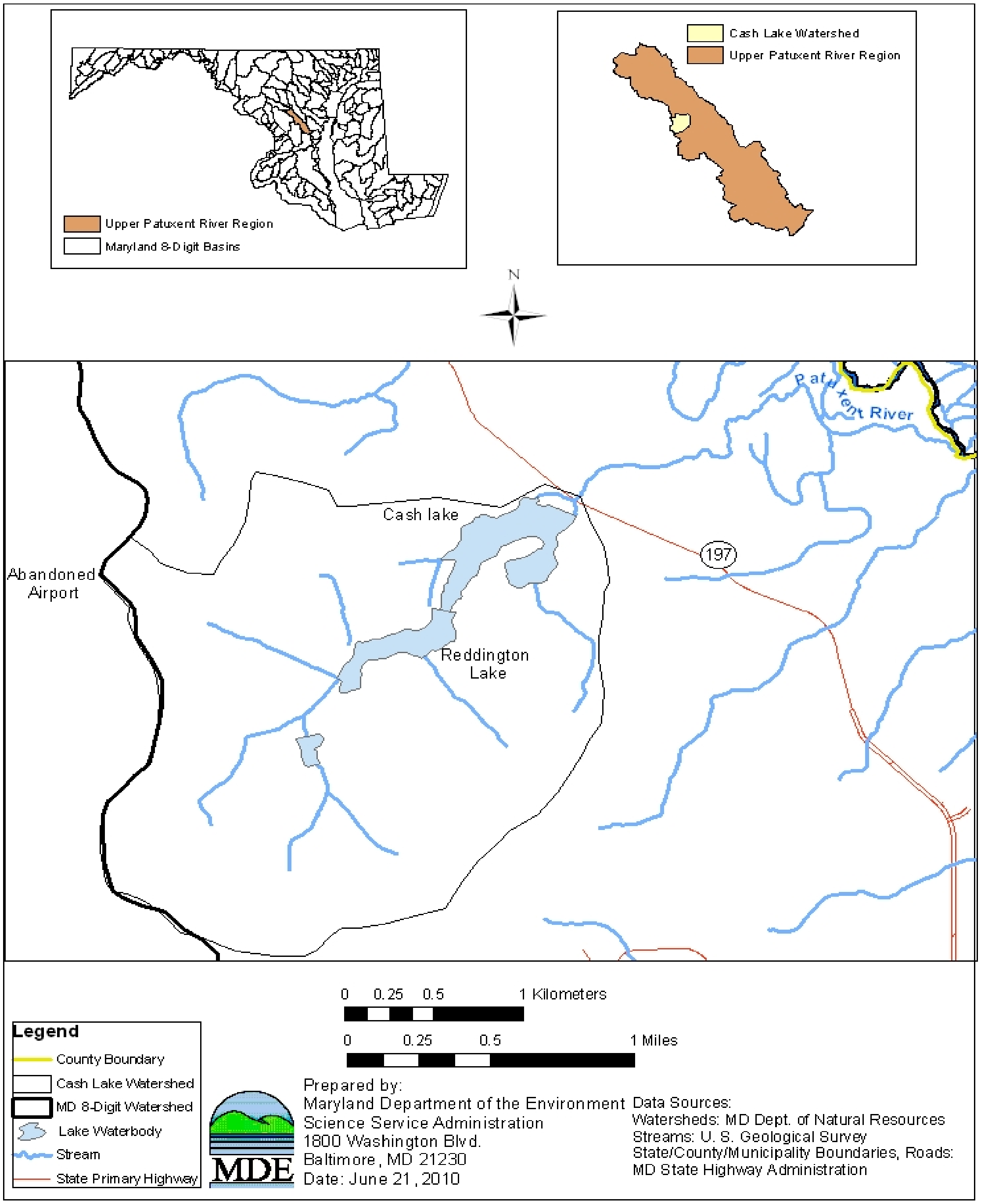

Figure 1: Location Map of Cash Lake in Prince George's County, Maryland

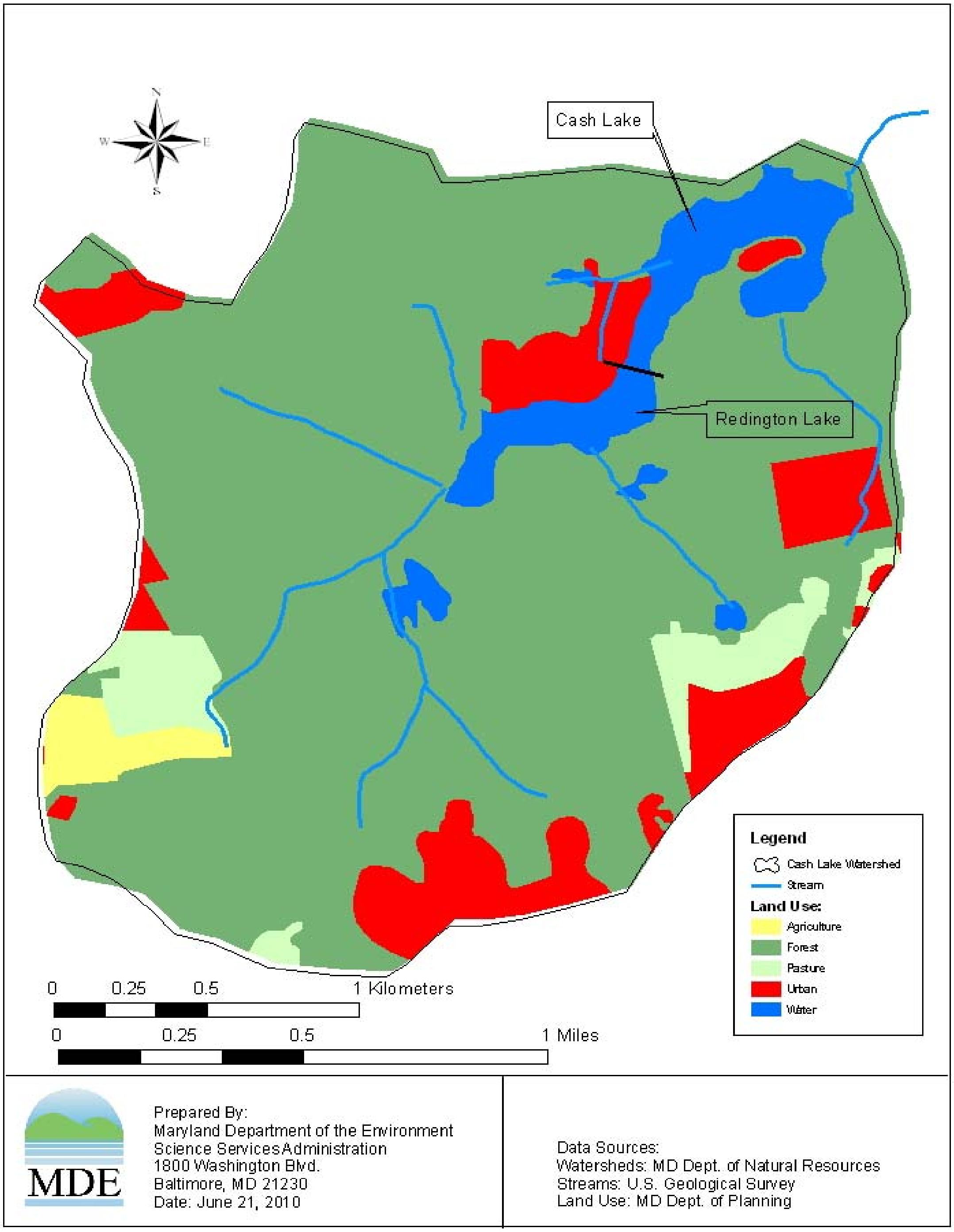

Figure 2: Predominant Land Use in the Cash Lake Watershed

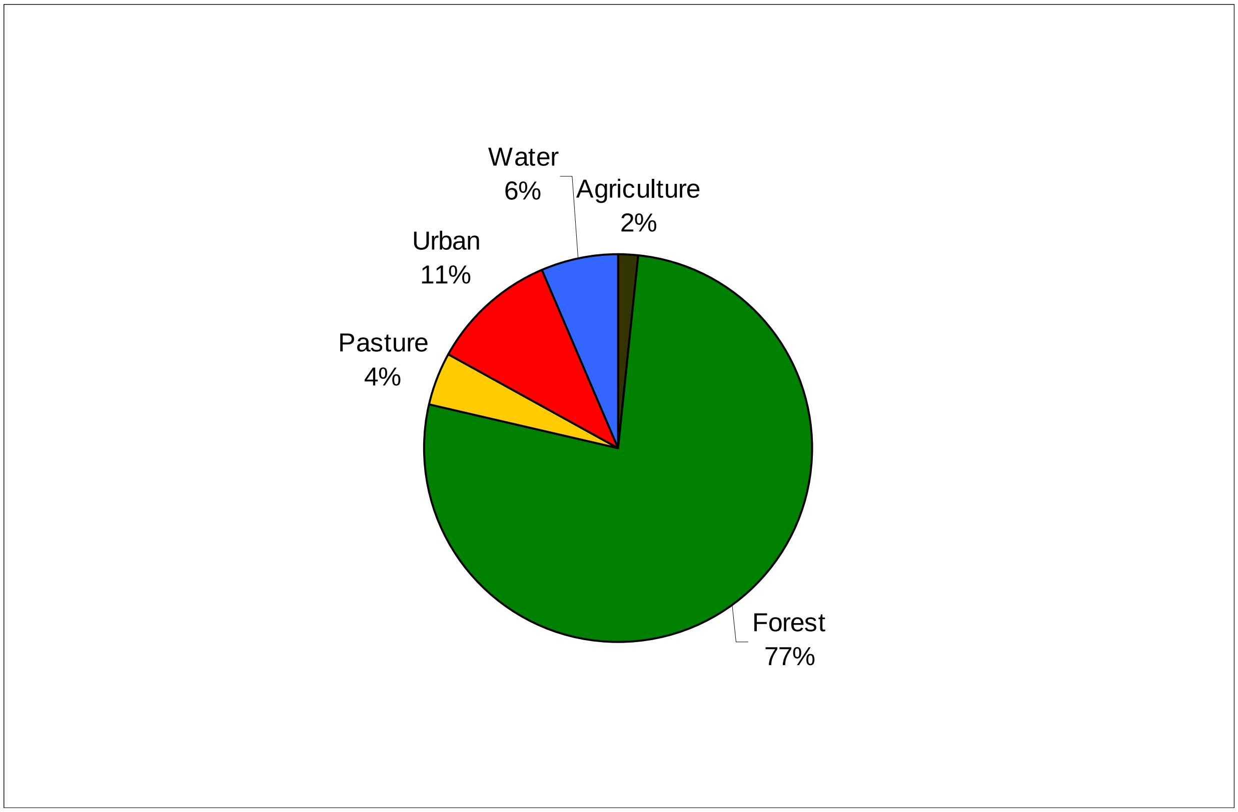

Figure 3: Land Use Distribution in the Cash Lake Watershed

2.2 Source Assessment

Cash Lake is located in a watershed in which the mercury impairment is caused entirely via atmospheric deposition. Therefore, essentially a one-to-one relationship between concentrations of mercury in fish tissue and atmospheric deposition of mercury is assumed. This assumption is explained in greater detail below.

To assess atmospheric deposition, the model CALPUFF was used. CALPUFF is an advanced, non-steady-state, time variable, Gaussian meteorological and air quality modeling system, approved by EPA for many atmospheric pollutant modeling purposes. Its use is made available to MDE via Maryland Department of Natural Resources' (DNR) Power Plant Research Program (PPRP). A detailed description of CALPUFF and a link to the model itself can be found at www.src.com/calpuff/calpuff1.htm (Sherwell et al. 2006). Appendix A summarizes the use of CALPUFF in this TMDL analysis.

The EPA considers coal-fired electric power generating plants to be the largest anthropogenic source of mercury emissions in the nation (US EPA 2005). In Maryland as a whole, the major sources of atmospheric mercury deposition are as follows: 23.3% attributed to electrical generating units (EGUs) in the state; 34.0% attributed to out-of state EGUs; 3.4% and 10.6% attributed to non-EGU sources (e.g., Portland cement plants and medical waste incinerators) in-state and out-of-state, respectively; and the remaining 28.7% to global background sources, including natural emissions (PPRP 1994). The corresponding estimates for Cash Lake and its watershed (including land area draining to Redington Lake), as calculated using the CALPUFF model, are: 33.7% attributed to in-state EGUs; 28.5% attributed to out-of-state EGUs; 4.5% attributed to in-state non-EGU sources; 8.2% attributed to out-of-state non-EGU sources, and 25.2% to global background sources. These estimates represent modeled 2007 baseline conditions (Sherwell et al. 2006). There are no individual industrial point source discharges in the Cash Lake watershed. Previously, there were two municipal wastewater treatment plants (WWTPs) located within the Cash Lake watershed at the Patuxent Wildlife Research Center (PWRC). The permit for the first PWRC WWTP (National Pollutant Discharge Elimination System (NPDES) Permit #: MD0025623) was officially terminated as of April 28, 2008. Effluent is now sent to a neighboring WWTP through a Washington Suburban Sanitary Commission (WSSC) sewer line, outside the Cash Lake watershed. The second WWTP (NPDES Permit #: MD0065358) is a small “package” WWTP at the PWRC Visitors’ Center, and is still active (see Figure 4). The design flow for this facility is 6,700 gallons per day (gpd), but actual flow is reported to be much less. Mercury loads from the facility are considered to be insignificant. Appendix G describes this issue in greater detail. NPDES regulated stormwater discharges have been identified within the watershed, including a Phase II federal municipal separate storm sewer system (MS4) and industrial facilities permitted for stormwater discharges (see Appendix F); the mercury loadings from these areas will be treated as point sources in this analysis; however, it is assumed that the origin of any urban stormwater mercury loadings is from atmospheric deposition (i.e., there are few, if any, known sources of mercury to stormwater that do not ultimately derive from atmospheric deposition).

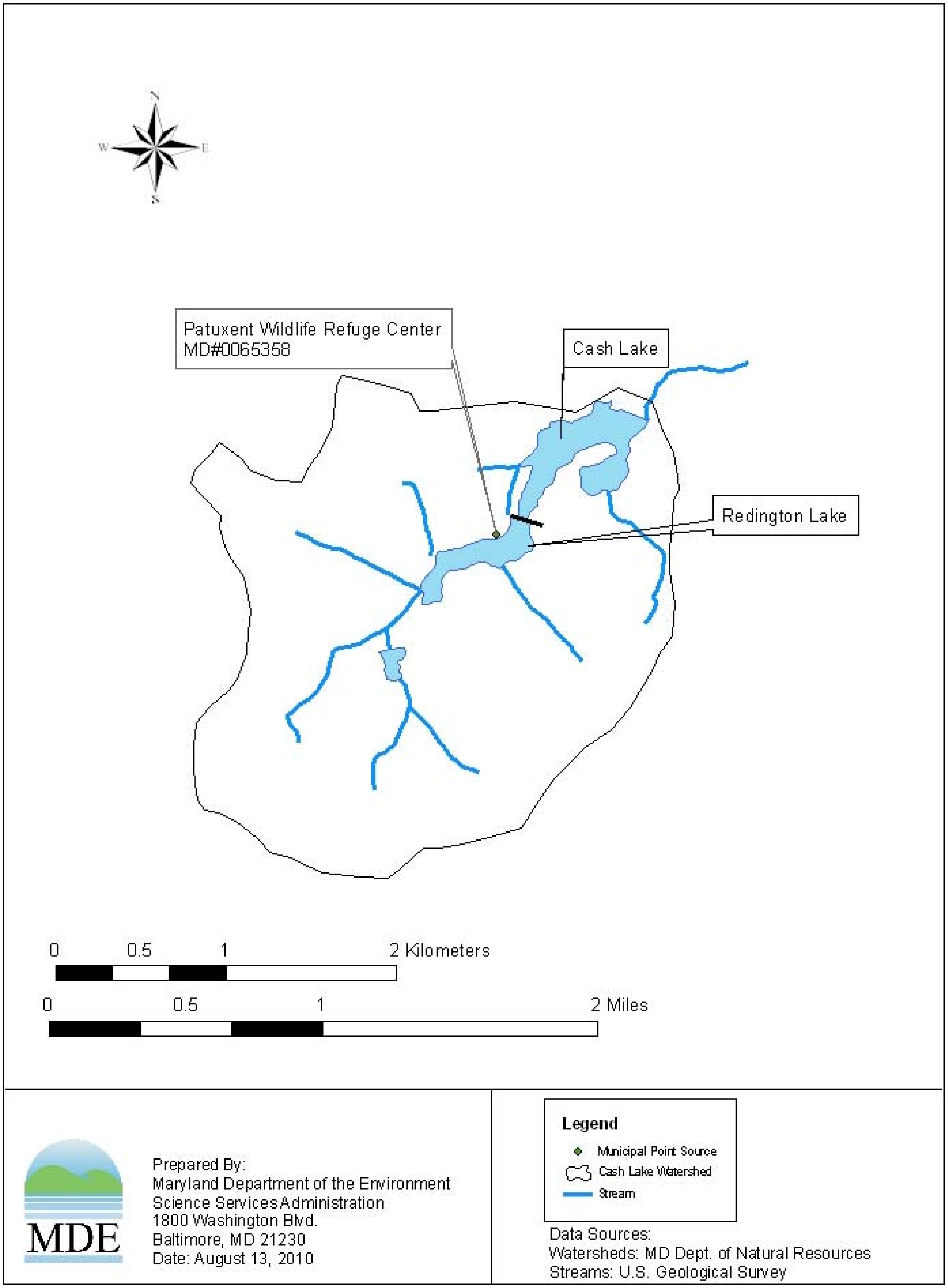

Figure 4: Municipal Point Source in the Cash Lake Watershed

2.3 Water Quality Characterization

To characterize the water quality of Cash Lake, two parameters were assessed: 1) mercury concentrations in fish tissue and 2) mercury concentrations in the water column.

2.3.1 General Discussion

In 2001, MDE announced a statewide fish consumption advisory for all lakes throughout Maryland, based on fish tissue mercury data from a subset of lakes across the State. The advisory was established statewide as a precautionary measure because the primary source of mercury is understood to be atmospheric deposition, which is widely dispersed (MDE 2001). Based on additional fish tissue data collected presently in 2010, Maryland has verified that Cash Lake is impaired due to elevated levels of mercury in fish tissue.

Two composite samples of trophic-level four fish (Largemouth Bass) were collected from Cash Lake and analyzed for total mercury tissue concentrations. Water column samples were also taken and analyzed for mercury concentrations. Samples were collected by MDE’s Field Office staff. Fish tissue samples were analyzed at the University of Maryland Center for Environmental Science’s (UMCES) Appalachian Laboratory, and water column samples were analyzed at UMCES’s Chesapeake Biological Laboratory.

In fish tissue, mercury is not usually found in concentrations high enough to cause fish to exhibit signs of toxicity, but the mercury in sport fish (trophic-level four) can present a potential health risk to humans. The health risk to humans represented by the mercury content in consumed fish tissue is due to methylmercury. Typically, almost all of the mercury found in fish tissue (90 to 95%) is in the form of methylmercury. Mercury chemistry in the environment is complex and not totally understood. It exhibits the properties of a metal, specifically persistence in the environment. It is not chemically broken down beyond the elemental mercury form of Hg^0 or the ionic forms of Hg^+ and Hg^{+2}. It also has properties similar to a hydrophobic organic chemical, due to its ability to methylate via a bacterial process. Methylation of mercury can occur in water, sediment, and soil matrices under anaerobic conditions and, to a lesser extent, under aerobic conditions. In water, methylation occurs mainly at the water-sediment interface and at the oxic-anoxic boundary within the water column. Methylmercury is readily taken up by organisms and will bioaccumulate as it has a strong affinity for muscle tissue. It is effectively transferred through the food web, with tissue concentrations magnifying at each trophic level. This process can result in high levels of mercury in organisms high on the food chain, despite nearly immeasurable quantities of mercury/methylmercury concentrations in the water column. Appendix B discusses mercury chemistry, including methylation, in greater detail.

For public health purposes, MDE has the responsibility to monitor and evaluate the contaminant levels in Maryland’s fish, shellfish and crabs, to determine if contaminant levels are within the limits established as safe for human consumption. In fulfillment of this public health responsibility, MDE issued a statewide fish consumption advisory for mercury in fish in 2001. This advisory provides guidelines (Table 2) on fish consumption (allowable meals per month) for recreational anglers and their families (not including commercially harvested fish) and includes fish species in publicly accessible lakes and impoundments (MDE 2001).

Table 2: MDE Fish Consumption Guidelines

Mercury in Fish Tissue Residue Range (μg/kg)[1]	**Recommended Fish Consumption** (meals per month: (based on an 8 ounce meal size)
117 – 235	7 - 4
236 - 322	3
322 – 409	2
410 – 939	1
> 939	< 1

Note: [1]Mercury can either be total mercury or methylmercury.

The fish consumption guidelines were developed in part to be protective for neurobehavioral effects during human fetal development and early childhood. An 8-ounce meal size is assumed for the general population. Assumed meal sizes for women of childbearing age and children (0-6 years) are 6 ounces and 3 ounces, respectively. The guidelines were developed assuming a desired level of protection to the general fish-eating public corresponding to a consumption level of four fish meals per month. Levels of mercury in fish tissue above 300 μg/kg are an indication of impairment, as recommended by EPA and subsequently adopted by MDE as a state water quality standard, and therefore a TMDL goal of 235 μg/kg mercury in fish tissue ensures safe consumption at a four meal-per-month level. These guidelines were developed based on methylmercury; however, analysis in this document is conducted using total mercury, which therefore represents a conservative assumption. Details of Maryland's fish consumption advisory methodology appear in Appendix C. Appendix D describes MDE's methodology of listing impairments based on contaminants in fish tissue.

2.3.2 Mercury in Fish Tissue Data

Samples of fish were taken from Cash Lake. Trophic-level four fish (Largemouth Bass) were targeted in the collection because they represent the top of the food chain (highest bioaccumulation potential) and provide a conservative estimate of the mercury dose associated with fish consumption from this impoundment. Length and weight of the fish were measured. The individual fish were filleted and combined into two composite samples of five individuals each before being analyzed for total mercury concentrations. Appendix E lists composite sample data for mercury residue in fish tissue from Cash Lake.

As stated previously, levels of mercury (methyl or total) in fish tissue above the EPA criterion of 300 μg/kg are an indication of impairment of the fishable use of the waterbody. To determine if a waterbody is impaired, the contaminant concentration from a composite sample of fish fillets of any single common species of recreational fish is compared to the established threshold. Maryland collects composite samples of trophic-level four fish (e.g., Largemouth Bass) of legally harvestable size. If the threshold is exceeded, the water body's designated use (*i.e*., fishable) is not met and the waterbody is considered impaired. Table 3 below summarizes the fish tissue data.

Table 3: Summary of Fish Tissue Mercury Concentrations in Cash Lake

Trophic-Level	Composite Sample Count	Total Mercury Mean Concentration (µg/kg)
4	2	390.50

2.3.3 Water Column Mercury Concentrations

Water column samples were taken from Cash Lake and analyzed for total mercury concentrations using EPA Method 1631 (US EPA 2002b). Samples were analyzed for both whole water and as dissolved (filtered). Samples were collected near the dam overflow at the lower end of the lake and at the inflow (near where Redington Lake discharges into Cash Lake), and the geometric mean was computed.

The geometric mean value of unfiltered total mercury in the water column for Cash Lake is 3.80 nanograms per liter (ng/L). The geometric mean value of filtered (dissolved) total mercury in the water column for Cash Lake is 2.26 ng/L. Appendix E also contains the water column data.

Table 4: Summary of Water Column Data Analysis in Cash Lake

Geometric Mean of Total Hg (ng/L)	3.80
Geometric Mean of Dissolved Total Hg (ng/L)	2.26

2.4 Water Quality Impairment

The Maryland water quality standards Surface Water Use Designation of the MD 8-digit watershed Patuxent River Upper mainstem and its tributaries, including Cash Lake, is Use I (Water Contact Recreation and Protection of Aquatic Life) (COMAR 2010a,b,c). The water quality impairment of Cash Lake addressed by this TMDL is due to elevated levels mercury in fish tissue. Maryland's water quality standards, under the federal CWA, require that water quality support public health and welfare for a waterbody's designated uses. In Cash Lake, concentrations in the water are well below the threshold for concern with regard to drinking water. However, an existing public health fish consumption advisory for Cash Lake recommends significant limits on the consumption of fish caught from the impoundment. This is a violation of the State's narrative water quality standards, because the "fishable" designated use is not being fully supported (COMAR 2010d). This nonattainment of the lake's designated use results in the listing of Cash Lake on Maryland's 2008 Integrated Report as impaired for mercury residue in fish tissue.

3.0 TARGETED WATER QUALITY GOAL

The objective of the TMDL established herein is to reduce mercury loads to Cash Lake to levels that support the Use I designation (Water Contact Recreation and Protection of Aquatic Life) (COMAR 2010a,b,c). Specifically, a reduction in mercury loads is expected to result in mercury concentrations in fish tissue that are protective of human health.

- MDE considers the term "suitable for…fishing" or "fishable" (COMAR 2010d) as the ability for the general population to eat at least four meals per month of any single common recreational fish species from a given waterbody. This threshold concentration for fish tissue reflective of the consumption of four meals per month is 235 μg/kg for mercury.

The fish tissue threshold is designed to ensure that the general population can safely consume at least four meals per month. This is consistent with water quality standards, which must protect the overall population and do not have to be protective of more sensitive subpopulations. The risk assessment used by MDE to determine this concentration threshold incorporates the same risk level, reference dose (RfD) and body weight, and is consistent with the guidance adopted by the U.S. EPA for the protection of human health from methylmercury, as described in *Water Quality Criteria for the Protection of Human Health: Methylmercury* (US EPA 2001).

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATIONS

4.1 Overview

This section describes how the mercury TMDL and loading allocations were developed for Cash Lake. The second subsection describes the analysis framework for developing the TMDL calculation. The third subsection describes the steps in the TMDL calculation, and the fourth subsection describes the TMDL allocations. The fifth subsection addresses seasonal variations and critical conditions, and the sixth subsection explains the rationale for the MOS. Finally, in the seventh subsection, the pieces of the equation are combined in a summary accounting of the TMDL.

4.2 Analysis Framework

In the calculation of previously established mercury TMDLs (i.e., Mercury TMDLs submitted to the EPA by MDE in 2002), Maryland used a computational framework based on a refinement of the methodology described in the *Total Maximum Daily Load for Total Mercury in Fish Tissue Residue in Big Haynes Reservoir,* which was developed and proposed by the EPA, Region IV for the State of Georgia (US EPA 2002a). Maryland refined that methodology by using a fish tissue threshold for mercury that is consistent with its fish consumption advisory methodology, which was more stringent than the EPA guidelines applied in Georgia. In 2002, Maryland estimated atmospheric deposition of mercury using the National Atmospheric Deposition Program – Mercury Deposition Network (NADP-MDN). Five sites in this network were used: Wye (MD), Lewes (DE), and Valley Forge, Arendtsville, and Holbrook (Pennsylvania). Loads were estimated using extrapolations of measurements at these sites, along with mass balance calculations. Details of the 2002 methodology are described in full in any mercury TMDL developed by Maryland and approved by EPA up through 2004; these are available at www.mde.state.md.us/tmdl.

The previous approach, while suitable and representative of the best tools available at the time, can be improved and simplified by using refined air deposition modeling and an updated data inventory. Additionally, the 1996 data inventory that was previously used in modeling air deposition contained an error in one emission source in Maryland (that issue has since been corrected). In addition to incorporating an updated methodology and data, the new approach will allow potential future impairments to be addressed more expeditiously.

Maryland has recently adopted a TMDL approach based on the principle of proportionality, as was done first in the Minnesota Statewide Mercury TMDL (MPCA 2007) and subsequently in the Northeastern Regional Mercury TMDL (NEIWPCC 2007). The background and rationale are described fully in either TMDL and summarized in MDE (2010b). In addition to incorporating updated tools and data, the approach will also make it easier for Maryland to address any future mercury listings. The principle of proportionality can be outlined as follows:

- It is assumed that a specified reduction in mercury emissions will result in a proportionate reduction in deposition;
- This reduction in deposition will in turn result in a proportionate reduction in mercury load to the watershed and water body in question;
- The reduced load will ultimately result in a proportionate decrease in concentrations of mercury in fish tissue.

The TMDL analysis sets a maximum allowable depositional load, which ensures that the mercury concentration in fish tissue will remain below the fish consumption threshold protective of human health described in Section 3.0. The TMDL is expressed in terms of an average annual load to the watershed and assumes steady-state conditions both initially and under the TMDL scenario. For the purposes of this TMDL, the term "watershed" should be interpreted as comprising the drainage area and the surface of the lake itself; however, baseline and allowable loads are still provided for both the drainage area and the water surface of the impoundment for consistency with prior mercury TMDLs. Maximum Daily Loads (MDLs) are also provided for informational purposes, though long-term loads are more meaningful, since deposition is driven by emissions and meteorological conditions, fish tissue bioaccumulation occurs over long periods of time, and the overriding methodology, the principle of proportionality, assumes steady-state conditions.

The TMDL analysis framework can be summarized in the following steps:

(1) Determine baseline conditions by assessing trophic-level four fish tissue concentrations of mercury and modeled atmospheric deposition of mercury;
(2) Compute the reduction in fish tissue mercury concentration needed to reach the TMDL endpoint of 235 µg/kg;
(3) On the basis of the principle of proportionality as described above, using the reduction factor computed in step (2), calculate a required reduction in deposition needed to reach the targeted water quality goal of a mean fish tissue concentration of 235 µg/kg;
(4) Compute the allowable depositional load to the watershed.

4.3 Scenario Descriptions and Results

This section expands upon the steps outlined above in Section 4.2. The analyses allow a comparison of baseline conditions (under which water quality problems exist) with future conditions, which project the water quality response to simulated reductions in mercury loadings. The analyses are grouped according to baseline conditions and future conditions of maximum allowable loads associated with the TMDL.

The key findings in these analyses are the depositional loads estimated using the CALPUFF model, and the proportionate relationship between fish tissue concentrations (baseline and maximum allowable) and these loads.

4.3.1 Baseline Conditions

Two composite samples of Largemouth Bass were analyzed for total mercury. The mean of the two composite samples was computed to be 390.50 μg/kg. For a more detailed description of the process and rationale, see Section 2.3, and the actual individual composite fish tissue data are presented in Appendix E.

Using the CALPUFF model (simulating 2007 conditions), about 147.60 grams per year (g/yr) is estimated to be the baseline load to Cash Lake (including Redington Lake) (Sherwell et al. 2006). The baseline load is comprised of loadings from atmospheric deposition to the surface of the lake and to the lake's watershed, and it comprises both wet and dry deposition. This value of 147.60 g/yr works out to a unit area load of approximately 23.60 grams per square kilometer per year ($g/km^2/yr$).). Steady-state conditions are assumed. The calculation of the baseline mercury load using the CALPUFF model is described in Appendix A.

The baseline loads are summarized as follows:

Atmospheric Deposition to Cash Lake	=	5.04 g/yr (3.42%)
Atmospheric Deposition to Cash Lake Watershed[1]	=	142.56 g/yr (96.58%)
Point Sources	=	0.00 g/yr (0.00%)
Total Baseline Load	=	147.60 g/yr (100.00%)

4.3.2 Maximum Allowable Watershed Load

The maximum allowable load to the watershed ensures that fish tissue concentrations of mercury will not exceed 235 μg/kg for any trophic-level fish. This loading is computed as follows:

- A reduction in the fish tissue mercury concentration from 390.50 μg/kg to 235 μg/kg constitutes a reduction of 39.82 %.
- Using the principle of proportionality, the same reduction in atmospherically-deposited mercury is required to meet water quality standards. Thus, this 39.82% reduction in fish tissue mercury concentrations is applied to the modeled baseline load. The 39.82% reduction equates to a maximum allowable depositional load to the watershed that is 60.18% of the baseline load. This works out to about 88.83 g/yr for the entire area, including both the watershed and lake surface. For informational purposes, the maximum allowable depositional load to the surface of Cash Lake is approximately 3.04 g/yr.

The maximum allowable loads are summarized as follows:

[1] Includes Redington Lake surface water area. Atmospheric deposition to Redington Lake = 4.20 g/yr (2.85%).

Atmospheric Deposition to Cash Lake	=	3.04 g/yr (3.42%)
Atmospheric Deposition to Cash Lake Watershed[2]	=	85.79 g/yr (96.58%)
Point Sources	=	0.00 g/yr (0.00%)
Total Maximum Allowable Load	=	88.83 g/yr (100.00%)

4.4 Total Maximum Daily Load Allocations

Per EPA regulation, all TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint source loads generated within the assessment unit, accounting for natural background, tributary, and upstream segment loads (CFR 2010a). Also, 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" (US EPA 2002c). No individual industrial point source discharges have been identified in the Cash Lake watershed. One individual municipal WWTP has been identified - the PWRC Visitors' Center (NPDES #: MD0065358). The mercury load from this facility is considered to be insignificant, and therefore no WLA is assigned to the facility. Appendix G discusses this issue in detail. NPDES regulated stormwater discharges have been identified within the watershed, including a Phase II federal MS4 and industrial facilities permitted for stormwater discharges (see Appendix F). The mercury loadings from these areas will be included in the WLA portion of the TMDL; however, it is assumed that the origin of any urban stormwater mercury loadings would be from atmospheric deposition. Therefore, the TMDL allocation consists of an LA (i.e., the nonpoint source loads within the watershed), which is furthermore entirely from atmospheric deposition, and an NPDES Regulated Stormwater WLA (i.e., the regulated urban stormwater loads within the watershed), which is also entirely from atmospheric deposition. The separation of the TMDL (total loading including atmospheric deposition to both the lake's surface and watershed) into LA and WLA was done based on the proportion of urban land use in the watershed (11%) (including water surface area). The resultant urban load equates to the NPDES Regulated Stormwater WLA, and the remainder is assigned to the LA. The State, however, reserves the right to allocate the TMDL among different sources, should different sources arise in the future, in any manner that protects the "fishing" designated use of the impoundments (COMAR 2010d).

An LA has been assigned to the nonpoint source atmospheric deposition loadings to the surface of the lake and the surrounding watershed area, and a WLA has been assigned to the NPDES regulated stormwater atmospheric deposition loadings to the surrounding watershed area. The required reductions in mercury loadings from atmospheric deposition are expected to take place over time as mercury emissions decline as a result of controls that are to be installed due to the recently established Clean Air Interstate Rule (CAIR), which will be replaced by the Clean Air Transport Rule (once the latter is finalized), and Maryland's Healthy Air Act (HAA) (COMAR 2010f,h). The allocations presented herein demonstrate how the TMDL can be implemented to achieve water quality standards in Cash Lake.

[2] Includes Redington Lake surface water area. Atmospheric deposition to Redington Lake = 2.53 g/yr (2.85%).

4.5 Seasonal Variations and Critical Conditions

Seasonal Variations: This TMDL represents an allowable depositional load that is designed to reduce mercury concentrations in fish tissue, thus protecting human health by minimizing exposure to mercury via fish consumption. Although many factors may vary over a given year, the effect is averaged out over several years during which fish bioaccumulate mercury. An analysis of the length and weight of individual fish sampled (Table E-1 of Appendix E) indicates they were of legal (keepable) size. The averaging effect of long-term bioaccumulation is reflected in the analysis and supports the use of an average annual load. Specifically, the fish tissue concentration at the time of sampling is the result of long-term accumulation in fish that are several years old.

Critical Conditions: Critical conditions are implicitly included in the threshold mercury concentration used to calculate the maximum allowable mercury loading, as it is based on human fish consumption over a long time period, which averages out critical events. Also, the TMDL is protective of human health at all times via fish consumption, thereby indicating that any “critical conditions” within that time frame are considered. Finally, the TMDL established to be protective of human health is more conservative than the mercury levels to protect environmental resources (i.e., EPA recommended and the State of Maryland adopted mercury criteria in fish tissue of 300 µg/kg), implying that critical conditions for environmental resources are also addressed by the reasoning that is applied to human health.

The average annual load is the appropriate maximum allowable loading characterization for this TMDL since mercury bioaccumulation and the resulting risk to human health that results from fish consumption is a long-term phenomenon. Therefore, shorter seasonal inputs are less meaningful than total annual loads over many years. The use of annual loads allows for integration of short-term or seasonal variability. MDLs are provided for informational purposes only.

Modeled and observed mercury deposition and resultant fish tissue concentrations assume and reflect ‘steady state’ conditions over long periods of time, thus taking into account any temporal hydrological or seasonal differences.

4.6 Margin of Safety

All TMDLs must include a MOS to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2010b). Specifically, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural water bodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental and human health protection.

Based on EPA guidance, the MOS can be achieved through one of two approaches (US EPA 1991). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (i.e., TMDL = WLA + LA + MOS). The second approach is to incorporate the MOS as conservative assumptions in the design of the TMDL analysis. For purposes of this mercury TMDL, Maryland has adopted a MOS that makes use of conservative assumptions within the methodology (i.e., a built-in MOS). The following are several components of the implicit MOS:

(1) The analyses presented in this TMDL assume that anglers consume only trophic-level four fish. Trophic level-four fish are near the top of the food chain and thus consistently have the highest observed fish tissue mercury concentrations due to bioaccumulation and biomagnification. Adopting the assumption that people eat only trophic-level four fish represents a conservative assumption of mercury exposure to humans.

(2) EPA's recommended threshold for mercury in fish tissue is 300 µg/kg, and MDE uses this value as a threshold for determining impairment. However, MDE is using a value of 235 µg/kg as the TMDL goal. This lower threshold is based on a risk analysis used for Maryland's fish consumption procedures. The analysis assumes that some people consume more meals of fish over a given period of time than is assumed by EPA. This constitutes an implicit MOS of about 21.67%.

(3) Methylated mercury, not total mercury, is the actual impairing substance as per the 2008 Integrated Report. For the purposes of issuing fish consumption advisories, however, Maryland now analyzes fish tissue for total mercury rather than methylmercury. This adds the equivalent of a 5% - 10% additional MOS to the TMDL, since best estimates are that about 90% – 95% of the total mercury content in fish tissue is in its methylated form.

(4) The calculations involve deposition to the watershed as a whole, not making a distinction between the actual waterbody and the land surrounding it. This effectively assumes that land deposition has the same impact as deposition to the surface water itself. While it can be assumed that under steady-state conditions, a large portion of the mercury deposited to the watershed reaches the waterbody, it is also true that a portion of the mercury is bound to sediments, and therefore not all of it will reach the actual impoundment due to sediment deposition within the watershed. This adds another conservative assumption, although it cannot be quantified.

4.7 Summary of Total Maximum Daily Loads

The average annual TMDL for mercury is calculated from the equation:

TMDL = WLA + LA + MOS

Where: WLA = Waste Load Allocation
LA = Load Allocation
MOS = Margin of Safety

The TMDL for mercury is presented in g/yr in Table 5 below.

Table 5: Summary of Mercury TMDL for the Cash Lake Watershed

TMDL (g/yr)	=	**NPDES Stormwater WLA** (g/yr)	+	**LA** (g/yr)	+	**MOS**
88.83		9.77		78.86		Implicit

On average, the TMDL will result in an MDL of approximately 0.2434 grams per day (g/day).

5.0 ASSURANCE OF IMPLEMENTATION

Cash Lake is located in a watershed in which the mercury impairment is driven exclusively by nonpoint source mercury contributions in the form of atmospheric deposition. The EPA considers coal-fired electric power generating plants to be the largest anthropogenic source of mercury emissions in the nation. As such, the TMDL implementation provisions and achievement of the specified source sector allocations, both the LA and NPDES Regulated Stormwater WLA, may differ from the implementation of TMDLs from other pollutant types. The EPA expects to see reduced emissions of mercury from this industry sector as regulations (e.g., provisions under the CAIR/Clean Air Transport Rule) are implemented to control oxides of sulfur and nitrogen (COMAR 2010h). This is due both to the fact that some control technologies used to limit these pollutants provide ancillary mercury emissions reductions to some degree, and because reductions in sulfur deposition to an aquatic environment make it less favorable for the methylation of mercury. While not quantifiable at this point, the benefit is expected to be significant. The controls for atmospheric emissions are expected to be implemented in phases.

At the State level, Maryland passed the HAA in 2007. The HAA impacts Maryland's largest coal-burning power plants, which account for over 95% of the state's power plant emissions. Facilities covered include: Constellation Energy Group's Brandon Shores, Crane, and Wagner plants; Mirant Corporation's Chalk Point, Morgantown, and Dickerson plants; and the R. Paul Smith Plant located in Washington County, Maryland. Under full implementation of the HAA in 2013, mercury emissions will have been reduced by 90% at these plants from 2002 levels (COMAR 2010f). The HAA is projected to result in a reduction of 45.12 g/yr in mercury deposited to the Cash Lake watershed when fully implemented. This equals approximately a 31% reduction in total deposition and a 91% reduction in deposition originating from EGUs in Maryland. It also accounts for about 77% of the reduction required to meet this TMDL.

In addition to controls on mercury air emissions, proper management of mercury-containing products and source reduction are critical components to reducing mercury in the waste stream and to the environment. To this end, MDE has published extensive information for consumers and businesses concerning the reduction of mercury levels in Maryland's environment at http://www.mde.state.md.us/programs/landprograms/hazardous_waste/mercury/mercuryinfo.asp. Information includes descriptions of mercury in the home and the environment, alternative products to mercury-containing products, mercury spill cleanup safety, and mercury recycling resources (MDE 2010a).

As additional data and information are collected for Cash Lake and as new legal requirements are imposed under the Clean Air Act (CAA) and other environmental statutes, MDE will continue to evaluate the effectiveness of the regulatory and non-regulatory programs in achieving the water quality targets used to establish this TMDL. Currently, it is anticipated that both the LA and NPDES Stormwater WLA will be implemented and subsequently achieved via the expected reductions in mercury loadings from atmospheric deposition resultant from Maryland's HAA and the regional CAIR/Clean Air Transport Rule (COMAR 2010f,h).

For public health purposes, MDE has the responsibility to monitor and evaluate Maryland's fish, shellfish, and crabs to determine if contaminant levels are within limits established as being safe for human consumption. The currently issued fish consumption advisories are the result of the execution of this responsibility.

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Appendix A: Mercury Air Deposition

Summary

Mercury air deposition loads to the Cash Lake watershed were estimated under a number of scenarios using the CALPUFF model, which is an advanced, non-steady-state Gaussian meteorological and air quality modeling system, approved by EPA for many atmospheric pollutant modeling purposes. The CALPUFF scenario runs and output were made available to MDE from Maryland DNR's PPRP. The scenarios were conducted and analyzed in the following manner (Sherwell et al. 2006):

- Baseline loads were calculated based on the 2007 stack test for Maryland sources and 2002 National Emissions Inventory (NEI) for other sources (NEI 2010). This calculation was representative of typical conditions over the last decade, assuming no reductions from Maryland's HAA;
- Loads reflecting reduced emissions resulting from full implementation of the HAA in 2013 as specified in COMAR (2010f) were calculated;
- Analysis to separate loads originating from the following sources were performed:
    - Within the state of Maryland:
        - EGUs vs. non-EGUs;
    - Outside of Maryland, but within the model domain (roughly the eastern third of the United States):
        - EGUs vs. non-EGUs;
    - Global background loads, including natural loads (Sherwell et al. 2006).

Tables A-1 and A-2 below show the loads and proportions thereof from these source sectors under baseline and full-HAA implementation scenarios, respectively.

Table A-1: Modeled Total Baseline Mercury Loads to Cash Lake

BASELINE CONDITIONS		
SOURCE CATEGORY	**LOAD (g/yr)**	**PERCENT**
Maryland Non-EGU Total	6.57	4.45%
Maryland EGU Total	49.69	33.67%
Non-Maryland Non-EGU	12.16	8.24%
Non-Maryland EGU	42.05	28.49%
Global Background	37.13	25.15%
TOTAL	147.60	100.00%

Table A-2: Modeled Total Mercury Loads to Cash lake Under Full Implementation of Maryland's HAA

FULL HAA IMPLEMENTATION CONDITIONS		
SOURCE CATEGORY	**LOAD (g/yr)**	**PERCENT**
Maryland Non-EGU Total	6.57	6.42%
Maryland EGU Total	4.58	4.47%
Non-Maryland Non-EGU	12.16	11.86%
Non-Maryland EGU	42.05	41.03%
Global Background	37.13	36.23%
TOTAL	102.5	100.00%

The model output also 'tags' certain individual emitters. This is not presented in the course of the development of this TMDL, but is available and remains a viable option for use during the course of TMDL implementation.

Appendix B: Mercury Chemistry

Mercury is a Group IIB (Periodic Table) element, as are zinc and cadmium. Elemental metallic mercury exists as a high luster silver-colored liquid at room temperature. Key physical properties are listed in Table B-1. Some of the varied industrial and consumer uses of mercury are electrical apparatus, such as fluorescent light tubes, and control instruments - including thermometers and barometers. It is also used in the manufacture of pharmaceuticals, antifouling paints, mercury fulminate, electrolytic cells, and dental amalgams. Mercury is a constituent of a number of antiseptics such as *mercurochrome, merthiolate and mercressin*. Mercury and all its compounds are toxic. Mercury fulminate, $Hg(CNO)_2$, is used as a detonator for initiating the explosion of smokeless powder and various high explosives (i.e., TNT, dynamite, etc.). Mercury fulminate is very unstable and can be exploded by shock; its explosion causes the main explosive to be detonated. Mercury electrolytic cells are used in a manufacturing process for chlorine/alkali production. Liquid mercury dissolves many metals, especially the softer ones such as copper, silver, gold, and the alkali elements. The resulting alloys, which may be solids or liquids, are called amalgams. Dental amalgam is an alloy of mercury and silver.

Table B-1: Physical Properties of Metallic Mercury[1]

Atomic Number	80
Atomic Weight	200.59
Density[2,3]	13.5 g/cm^3 @ 25^0C
Melting Point	-39^0C
Boiling Point	357^0C
Water Solubility (molarity)[4]	3.0 x 10^{-7} (mol/L) @25^0C
Water Solubility (mass basis)[5]	60 µg/L @ 25^0C

Notes: [1] Source: (Dean 1992).
[2] g/cm^3 = grams per centimeters cubed
[3] C = Celcius
[4] Mol/L = mols per Liter
[5] µg/L = micrograms per Liter

Mercury exists in three oxidation states: the metallic, uncharged state (Hg^0); the mercurous state (Hg^{+1}); and the mercuric state (Hg^{+2}). These states are separated by only a small oxidation potential (Eh), and the metal readily participates in redox chemical reactions. In particular, Hg^{+1} salts disproportionate under many conditions to yield the Hg^{+2} salt and metallic mercury. Reduction of both the mercurous and the mercuric salts normally yields the metal state (PPRP 1994).

Mercury in natural waters may assume any of the three oxidation states. The predominate state is determined by the hydrogen ion concentration (described as pH) and the Eh of the water. Since chloride and sulfide complex Hg^{+1} and Hg^{+2} ions, concentrations of these compounds also affect the relative species distribution (Gilmour and Henry 1991; Shimomora 1989). Ammonium, carbonate, bicarbonate, and phosphate concentrations do not affect speciation (PPRP 1994).

In natural systems, pH is generally in the range of 5 to 8 and the Eh is typically less than 0.5 Volts. For these systems, HgS and metallic mercury are the most likely solids to be found in equilibrium with saturated solutions of mercury salts at moderate Cl^{-1} and S^{-2} concentrations. The predominant species in the corresponding solutions will be $Hg(OH)_2$ and $HgCl_2$ in well oxygenated waters and Hg metal in poorly oxygenated waters (Gavis and Ferguson 1972). In reducing sediments, HgS will predominate the solid phase (PPRP 1994).

Methylated forms of mercury, CH_3HgCl and $(CH_3)_2Hg$, are formed in both aerobic and anaerobic sediments through the action of bacteria. Methylated mercury is thought to be thermodynamically unstable in water; quantities of organic mercury found in surface waters are probably preserved through reaction barriers that prevent degradation. Methylation does not occur in the presence of moderate to high sulfide concentrations which immobilize the Hg^{+2} ion (PPRP 1994).

In fish tissue, mercury is not usually found in concentrations high enough to cause fish to exhibit signs of toxicity, but the mercury in sport fish (trophic-level four) can present a potential health risk to humans. The health risk to humans represented by the mercury content in consumed fish tissue is due to methylmercury. Typically, almost all of the mercury found in fish tissue (90 to 95%) is in the methylmercury form. Mercury chemistry in the environment is complex and not totally understood. It has the properties of a metal, specifically, persistence in the environment because it is not chemically broken down beyond the elemental mercury form (Hg^0) or its ionic forms (Hg^+ and Hg^{+2}). It also has properties similar to a hydrophobic organic chemical due to its ability to be methlyated through a bacterial process. Methylation of mercury can occur in water, sediment, and soil matrices under anaerobic conditions, and to a lesser extent, under aerobic conditions. In water, methylation occurs mainly at the water-sediment interface and at the oxic-anoxic boundary within the water column. Methylmercury is readily taken up by organisms and will bioaccumulate as it has a strong affinity for fish muscle tissue. It is effectively transferred through the food web, with tissue concentrations magnifying at each trophic-level. This process can result in high levels of methylmercury in organisms high on the food chain, despite nearly immeasurable quantities of mercury/methylmercury concentrations in the water column.

Appendix C: Risk Assessment

Fish consumption advisory thresholds were determined by utilizing human health risk assessment procedures presented in US EPA (1997) and modifications as in MDE (2002). These advisories recommend that a certain number of meals per month of a particular fish species not be exceeded in order to avoid long-term health effects from exposure to methylmercury.

Variables considered in the advisory risk assessment included: 1) meal frequency (zero, one, two, four, eight, or unlimited meals per month); 2) meal size (eight ounces for people 18-75 of the general population and women 18-45 years of age, and three ounces for children zero to six years of age); and 3) population weights of 70.0 kilograms (kg) for the general population, 64.0 kg for women, and 14.5 kg for children. A methylmercury RfD of 0.1µg/kg-day, based on neurological and developmental studies of infants chronically exposed to methylmercury through fish consumption, was also used in the risk analysis. These factors are shown in Table E1.

Table C-1: Human Health Risk Assessment Parameters for MDE's Fish Consumption Advisories[1]

RfD (ug/kg-day)	Body Weight (kg)	Meal Size (ounces/meal)	Fish Consumption Rate (kg/day)	Recommended Meal Frequency (meals/month)	Mercury Concentration in Fish Tissue (ppm)		
Men and Women 18 - 75 Years Old							
0.1	70	8	3.7	No Consumption		>	0.939
0.1	70	8	7.5	1	0.470	-	0.939
0.1	70	8	14.9	2	0.236	-	0.469
0.1	70	8	29.8	4	0.118	-	0.235
Women 18 - 45 Years Old							
0.1	64	8	3.7	No Consumption		>	0.858
0.1	64	8	7.5	1	0.430	-	0.858
0.1	64	8	14.9	2	0.216	-	0.429
0.1	64	8	29.8	4	0.108	-	0.215
Children 0 - 6 Years Old							
0.1	14.5	3	1.4	No Consumption		>	0.519
0.1	14.5	3	2.8	1	0.260	-	0.519
0.1	14.5	3	5.6	2	0.131	-	0.259
0.1	14.5	3	11.2	4	0.066	-	0.130

Note: [1] Source: (US EPA 2000b)..

Appendix D: Addendum For Toxics Methodology in Maryland's 2002 Integrated Report: Designated Use Impairments Based on Fish Tissue.

Background

Section 101(a)(2) of the CWA establishes as a national goal "water quality which provides for the protection and propagation of fish, shellfish, wildlife, and recreation in and on the water, wherever attainable." These are commonly referred to as the "fishable/swimmable" goals of the Act. Section 303(c)(2)(A) requires water quality standards to protect the public health and welfare, enhance the quality of water, and serve the purposes of the CWA. EPA, along with MDE, has interpreted these regulations to mean that not only should waters of the State support thriving and diverse fish and shellfish populations, but when caught, may also be safely consumed (COMAR 2010d). Some water bodies may have elevated levels of contaminants, especially in the sediment. Some of these contaminants (especially mercury and PCBs) tend to bioaccumulate to elevated levels in the tissues of game fish and "bottom-feeders" (largemouth bass and catfish, respectively). When tissue levels of a contaminant are sufficiently elevated to increase the risk of chronic health effects if the fish is consumed regularly, the State has the responsibility to issue a fish consumption advisory to protect public health. Fish consumption advisories are designed to protect the general population as well as sensitive populations (i.e., young children and women who are or may become pregnant). If a consumption advisory is issued for a waterbody, its designated use may not be supported and that waterbody may be listed as impaired for the contaminant(s) responsible for the fish consumption advisory.

MDE has defined "fishable" as the ability to eat AT LEAST four meals/month (general population level) for common recreational fish species from a given waterbody. The tissue level corresponding to this will be the upper threshold at the four meal/month level for a given contaminant. In addition to this, if the tissue concentration is within 5% of the threshold, the water body's designated use will be considered impaired. The 5% "safety factor" accounts for the uncertainty and spatial/temporal variability in monitoring data and sampling regimes. This safety factor is designed to protect and maintain the "fishable" designated use status of a waterbody. To determine if a waterbody is impaired, the appropriate measure of central tendency (i.e. geometric mean) for a contaminant from the fillet samples of common recreational fish species will be compared to the established threshold. If the threshold is exceeded, the water body's designated use is not met, and the waterbody is considered impaired.

Data Requirements

The data required to list a waterbody as impaired are similar to the data requirements for the development of a fish consumption advisory. The same decision rules are used to test data adequacy as well as spatial and temporal representation. Consumption advisories based on the minimum required samples that resulted in an impairment decision will be re-sampled prior to TMDL development to insure that the advisory was not due to a localized condition, and that the impairment is still temporally relevant. The data requirements for listing a waterbody are:

a. The advisory is based on fish and shellfish tissue data. All available data will be used.
b. The data are collected from the specific waterbody in question.
c. A minimum of five fish from a given species (individual or composite analysis) for a given waterbody.
d. The species used to determine impairment should be representative of the waterbody; migratory and transient species may be used if they are the dominant recreational species, but should only be used in conjunction with resident species, especially in the case of tidal rivers of the Chesapeake Bay.
e. Contaminant thresholds used will reflect concentrations used to set consumption recommendations for the general population. The general population is defined as women beyond the years of childbirth (~45) and adult males.

In some instances, it may be inappropriate to consider certain fish and shellfish consumption advisories in making an impairment determination. For example, a State may have issued a statewide or regional warning, based on data from a subset of water bodies and species or a higher consumption value may have been used in determining the need for an advisory to protect a specific sensitive population compared to the value used in establishing water quality criteria for the protection of human health. In such instances, these types of advisories were not considered for making an impairment determination. This approach is consistent with EPA's current recommendations regarding impairment determinations using contaminant data from fish advisories.

Appendix E: Composite Sample Data and Analysis

This appendix presents all of the data for fish tissue samples and water column samples. The data reduction steps are also described.

Table E-1: Cash Lake Composite Fish Sample Data for Mercury Residue in Fish Tissue

Sample ID.	**Trophic-Level**	**Species** (gender)	**Sex**	**Collection Date**	**Composite Samples**	**Total Mercury Wet Weight** (ppb)[1]	**Length** (mm)[2]	**Weight** (gm)[3]
CASH1119-01	4	Largemouth Bass	F	03/17/2010	Composite #1	N/A[4]	410	976
CASH1119-02	4	Largemouth Bass	F	03/17/2010	Composite #1	N/A	395	1005
CASH1119-03	4	Largemouth Bass	M	03/17/2010	Composite #1	N/A	370	780
CASH1119-04	4	Largemouth Bass	F	03/17/2010	Composite #1	N/A	360	729
CASH1119-05	4	Largemouth Bass	F	03/17/2010	Composite #1	N/A	360	612
Composite 1[5]						400.9	379.0	820.4
CASH1119-06	4	Largemouth Bass	M	03/17/2010	Composite #2	N/A	330	562
CASH1119-07	4	Largemouth Bass	F	03/17/2010	Composite #2	N/A	310	425
CASH1119-08	4	Largemouth Bass	M	03/17/2010	Composite #2	N/A	305	365
CASH1119-09	4	Largemouth Bass	F	03/17/2010	Composite #2	N/A	305	385
CASH1119-10	4	Largemouth Bass	F	03/17/2010	Composite #2	N/A	310	375
Composite 2[5]						380.1	312.0	422.4
Total[6]						390.5	346.0	621.0

Notes: [1] ppb = parts per billion.
[2] mm = millimeters.
[3] g = grams.
[4] N/A = Not Applicable.
[5] Composite mercury concentrations are average calculations from filets of the individual samples.
[6] The total is an average of the two composites.

An analysis of the length and weight of these fish indicates that they were of legal (keepable) size.

Water column samples were collected from the lake, one each at the inflow and the lower lake (near the dam). Water column data are shown in Table E-2 for informational purposes only (they were not necessary in the calculation of the TMDL).

The analytical method used for these analyses (U. S. EPA Method 1631) has a minimum detection level of 0.5 ng/L. One ng/L represents a detection level of one part per trillion. Method 1631 has an inherent variability of about +/- 15% (US EPA 2002b). All the data was subject to laboratory quality assurance/quality control procedures, prior to being released to MDE (such as blanks, spiked samples, etc.). However, due to the sensitive nature of this test, there are cases in which the results from the same sample show a larger concentration of dissolved mercury than the total concentration. When this occurs, and the difference is within the inherent range of variability, the two values must be interpreted as being the same. To check this, a data reduction process was developed and employed as described below.

Water Column Data Reduction Process

The TMDL analysis requires that we aggregate a number of samples into a single value that represents an estimate of the central tendency of the data. This data reduction process also must account for any data that we suspect is not valid.

Performing a laboratory analysis for trace elements is a very sensitive undertaking. The potential error in the measurements for total mercury in the water column is about 15 % in either direction (over or under estimation). This implies that two samples that are within 30% of each other cannot be considered different.

The measurement of whole concentrations (dissolved plus particulate) is less subject to error than measurements of dissolved concentrations. This is because measuring whole concentrations does not require a filtration step, which can introduce error. In cases where the dissolved values are significantly greater than the whole sample (20% or more), it has been advised by the UMCES laboratory that the dissolved sample not be used due to the potential contamination during the filtration process (Mason, 2002, personal communications).

The data reduction process described below addresses pairs of water column samples of total mercury representing whole samples and dissolved samples. It is outlined in the form of decision rules to address all of the different cases that can be confronted.

For each pair of results from a given sample, whole and dissolved:

i. If the whole sample is more than 20% greater than the dissolved sample, keep both numbers as good, and interpret the difference as being the particulate fraction.

ii. If the whole sample and dissolved are within 20% of each other, compute the arithmetic mean of the two numbers. Use this average value to represent both whole and dissolved values in future calculations.

iii. If the dissolved number is more than 20% greater than the whole, discard the dissolved as being contaminated. Interpret the whole value as dissolved, and use this value to represent both whole and dissolved values in future calculations.

Table E-2: Water Column Total Mercury Concentration Data from Cash Lake

Date Sampled	**Sample Site**	**Total Mercury Concentration (Whole)** (ng/L)	**Total Mercury Concentration (Dissolved)** (ng/L)	**Difference** (%)
03/22/2010	Inflow	4.497	2.475	81.72
03/22/2010	Lower Lake	3.205	2.070	54.86
Geometric Mean Value		**3.796**	**2.263**	**N/A**

In each case, the percentage difference is greater than 20 %, and case (i) applies. The value of 3.796 ng/L represents the expected whole water column concentration for total mercury. The value of 2.263 ng/L represents the expected water column concentration of dissolved mercury. The difference represents the expected particulate fraction.

Appendix F: Permit Information

Table F-1: NPDES Stormwater Permits

MDE Permit #	Facility Name	Stormwater Permit Type	NPDES Group
N/A	PHASE II FEDERAL MS4	General Phase II MS4	Phase II
96DP2831	NATIONAL WILDLIFE VISITOR CENTER WWTP[1]	N/A	Phase I
02SW0314	SANDY HILL MUNICIPAL LANDFILL	General Industrial Stormwater	Phase I

Notes: [1] The facility has an individual municipal surface water discharge permit; all municipal surface water discharge permits include stormwater requirements when the applicable facility does not have a separate permit regulating urban stormwater discharges.

APPENDIX G: Municipal Point Sources in the Cash Lake Watershed

There is one municipal point source (Permit # MD0065358) currently discharging to the Cash Lake watershed. The source, at the PWRC Visitor Center, discharges into Redington Lake via a series of man-made wetlands. The design flow for this facility is 6,700 gpd. MDE Water Management Administration staff report that actual discharges are much lower, probably only several hundred gpd, and, according to a recent site visit report, the facility must pump water from Redington Lake into the facility to keep the equipment running. Thus, 6,700 gpd is likely to be a very high flow estimate (MDE 2010d).

Concentrations of mercury in the effluent of the PWRC Visitors' Center are not known. However, in 2008, MDE sampled a large number of WWTPs in Maryland (as well as Blue Plains WWTP in Washington, DC) to determine representative concentrations of mercury in WWTP effluent, specifically for use in developing mercury TMDLs. At each site, two samples were collected, one during high-flow (spring) conditions, and one during low-flow (summer/fall) conditions. Whole and filtered (dissolved) fractions were analyzed and reported. Summary statistics for the entire dataset are presented in Table G-1 below.

Table G-1: Summary Statistics for Total Mercury Measured in Effluent From Selected Maryland WWTPs (2008)[1]

	Spring (High Flow) Total Hg (ng/L)		**Summer/Fall (Low Flow) Total Hg** (ng/L)	
	Whole	**Filtered**	**Whole**	**Filtered**
Average	3.90	1.27	6.07	2.20
Median	2.35	1.21	1.42	1.02
Geo Mean	2.57	1.19	1.71	1.20
Maximum	22.29	2.17	113.07	27.14
Minimum	0.80	0.55	0.42	0.37
Standard Deviation	5.32	0.45	21.86	5.13

Using 6,700 gpd as a basis, an environmentally conservative estimate of total mercury loads to the system may be calculated. Table G-2 below displays seasonal estimated loads from the PWRC Visitors' Center WWTP based on the arithmetic mean ("AVERAGE"), median, and geometric mean ("GEOMEAN") of all WWTPs in the dataset. Table G-3 displays the respective annual load estimated the same way.

[1] The WWTPs in the 2008 study consisted of twenty-five major (defined as having a design flow of 0.5 Millions of Gallons per Day (MGD) or more) municipal facilities geographically representative of those throughout the state. For more details, see MDE 2010c.

Table G-2: Estimated Seasonal Loads of Total Mercury from PWRC Visitors' Center Effluent

	Spring (High Flow)		**Summer/Fall (Low Flow)**	
	Total Hg (g/season)		**Total Hg** (g/season)	
	Whole	Filtered	Whole	Filtered
AVERAGE	0.0179	0.0058	0.0283	0.0103
MEDIAN	0.0108	0.056	0.0066	0.0048
GEOMEAN	0.0118	0.055	0.0080	0.0056

Table G-3: Estimated Annual Loads of Total Mercury from PWRC Visitors' Center Effluent

	Annual Load (g)	
	Whole	Filtered
AVERAGE	0.0462	0.0161
MEDIAN	0.0174	0.0103
GEOMEAN	0.0198	0.0111

As can be seen in Table G-4, under the 'worst case' scenario (i.e., using the arithmetic mean ("AVERAGE") and a known overestimate of flow as the bases of the calculation), the estimated annual load of total mercury (whole fraction) from this point source is only about 0.05g. This is approximately 0.03% of the baseline atmospheric deposition load to the watershed (including Cash Lake), and 0.9% of the baseline load deposited to the surface of the lake itself. The load from this point source is 0.05% and 1.52% of the annual TMDL to the watershed and the lake surface, respectively.

Table G-4: Point source loads from PWRC Visitors' Center Effluent (Derived from Arithmetic Mean) as Percentage of Total Loads

	Atmospheric Deposition Load (g/yr)	**Point Source Load (Arithmetic Mean Estimate)** (g/yr)	**Point Source Load Percentage of Atmospheric Deposition Load** (%)
Baseline			
Total	147.60	0.05	0.03
Lake Surface Only	5.04	0.05	0.92
TMDL			
Total	88.83	0.05	0.05
Lake Surface Only	3.04	0.05	1.52

The arithmetic mean from the statewide database is positively skewed by large measurements at one facility each in the dry and wet season. Using an estimate derived from the geometric mean of the WWTP database, arguably a more appropriate statistical approach, the percentages are shown in Table G-5.

Table G-5: Point Source Loads from PWRC Visitors' Center effluent (Derived From Geometric Mean) as Percentage of Total Loads

	Atmospheric Deposition Load (g/yr)	**Point Source Load (Geometric Mean Estimate)** (g/yr)	**Point Source Load Percentage of Atmospheric Deposition Load** (%)
Baseline			
Total	147.60	0.02	0.01
Lake Surface Only	5.04	0.02	0.39
TMDL			
Total	88.83	0.02	0.02
Lake Surface Only	3.04	0.02	0.65

It must be emphasized that these estimates are in all likelihood extremely high, for two reasons. First, the actual discharge is most likely on the order of a few hundred gpd (MDE 2010d). Secondly, the statewide database from which these estimates are derived consists of 'typical' WWTPs, in which case a substantial amount of the observed mercury derives from groundwater inflow and infiltration into aging, cracked sewer lines[2]. Neither of these characteristics applies to the small "package" WWTP at the PWRC Visitors' Center (MDE 2010d). The actual mercury load from the PWRC Visitors' Center, while unknown, is most likely infinitesimal and immeasurable. Thus, the most appropriate way of addressing this situation is to consider the mercury loads from the PWRC Visitors' Center to be insignificant. Therefore, no WLA is necessary for the PWRC Visitors' Center.

[2] It should be noted that even in the case of inflow and infiltration, the ultimate source of most mercury in WWTP effluent is still from atmospheric deposition.