Water Quality Analysis of Mercury for Broadford Lake in Garrett County, Maryland

FINAL

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List of Abbreviations

AAWCC	Allowable Ambient Water Column Concentration
CWA	Clean Water Act
COMAR	Code Of Maryland Regulations
DNR	Maryland Department of Natural Resources
Eh	Oxidation Potential
EPA	U.S. Environmental Protection Agency
ft^3/s	Cubic feet per second
g	gram
Hg	Mercury
kg	kilogram
km^2	Square kilometers
L	liter
µg/l	micrograms per liter = ppm (parts per billion)
µg/kg	micrograms per kilogram = ppm (parts per billion)
MDE	Maryland Department of the Environment
MD	Maryland
MeHg	Methylmercury
MGD	Millions of gallons per day
m	Meter
m^3/s	Cubic meters per second
mm	millimeter
mi^2	Square miles
m^3/s	Cubic meters per second
ng/l	nanograms per liter = ppt (parts per trillion)
NADP-MDN	National Atmospheric Deposition Program – Mercury Deposition Network
ppb	Parts per billion
ppm	Parts per million
TMDL	Total Maximum Daily Load
UMCES	University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory
WQLS	Water Quality Limited Segments
WWTP	Wastewater Treatment Plant
yr	Year

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and U.S. Environmental Protection Agency (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. This list of impaired waters is commonly referred to as the "303(d) list". For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

Broadford Lake (basin code 05-02-02-02) is an impoundment on Broadford Run (a tributary of the Little Youghiogheny River) located near Oakland in Garrett County, Maryland. Broadford Lake was identified on the State of Maryland's 2002 list of Water Quality Limited Segments [303(d) list] as impaired by mercury contamination based on data for mercury concentrations in fish tissue. This report provides an analysis of the data, which shows a TMDL for mercury, is not necessary in this case. Barring the receipt of any contradictory data, this report will be used to support the removal of Broadford Lake from Maryland's list of WQLSs for mercury when the Maryland Department of the Environment (MDE) proposes the revision of Maryland's 303(d) list for public review in the future.

Although Broadford Lake does not display signs of toxic impairments due to mercury, the State reserves the right to require additional pollution controls in the Broadford Lake watershed if evidence suggests that mercury from the basin is contributing to downstream water quality problems.

1.0 INTRODUCTION

The federal Clean Water Act (CWA) and Maryland regulations require the State to maintain water quality that supports fish and aquatic life, and fishing as a recreational activity. The U.S. Environmental Protection Agency (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. In other words, "fishable" means that not only can fish and shellfish survive in a waterbody, but when harvested, can also be safely eaten by humans and terrestrial wildlife (OWOW Memorandum # WQSP-00-03, October 2000; and COMAR 26.08.02.03-1(2)(c)).

Based on mercury data in fish tissue from a subset of lakes across the State, Maryland Department of Environment (MDE) announced a statewide fish consumption advisory for lakes in December 2001. This advisory has been established statewide as a precautionary measure because the primary source of mercury is understood to be atmospheric deposition, which is widely dispersed.

Section 303(d) of the federal CWA and 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. This list of impaired waters is commonly referred to as the "303(d) list." For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

A segment identified as a WQLS may not require the development and implementation of a TMDL if current information contradicts the previous finding of an impairment. The most common factual scenarios obviating the need for a TMDL are as follows: 1) more recent data indicating that the impairment no longer exists (i.e., water quality criteria are being met); 2) more recent and updated water quality modeling demonstrates that the segment is now attaining criteria; 3) refinements to water quality criteria, or the interpretation of those standards, which result in criteria being met; or 4) correction to errors made in the initial listing.

Broadford Lake was identified on the 2002 303(d) list, submitted to EPA by the Maryland Department of the Environment (MDE), as being impaired by mercury. MDE's 2002 303(d) listing methodology for methylmercury in fish tissue involves computing a geometric mean of the fish tissue concentrations measured in at least five trophic level 4 fish. This mean value is compared to a maximum threshold of 235 µg/kg. Broadford Lake was included on MDE's 2002 303(d) list, citing a value of 263 µg/kg. The listing was in error, because the value of 263 µg/kg is the arithmetic mean of the fish tissue concentrations, rather than the geometric mean. The correct, geometric mean of the fish tissue samples is 228 µg/kg, which is below the maximum threshold of 235 µg/kg. This report provides an analysis of the monitoring data that supports the removal of the mercury listing for Broadford Lake when the 303(d) list is revised; therefore, the aforementioned fourth scenario applies.

A TMDL of phosphorus for Broadford Lake to address a 1998 impairment listing was completed and approved by EPA in 1999. There being no other impairments, MDE has now addressed all impairments concerning this watershed.

The remainder of this report lays out the general setting of the waterbody within the Broadford Lake watershed, presents a discussion of the water quality characterization process, and provides conclusions with regard to the characterization. The data will establish that Broadford Lake is achieving water quality standards.

2.0 GENERAL SETTING

Broadford Lake is an impoundment located near Oakland in Garrett County, Maryland (Figure 1). The impoundment, which is owned by the City of Oakland, lies on Broadford Run, a tributary of the Little Youghiogheny River. An earthen dam was installed for the purpose of flood control, water supply and for recreational uses in 1971.

The Broadford Lake watershed lies in the Allegheny Plateau. The geological strata include shale, coal, and sandstone. Soils are formed in material weathered from bedrock of shale, sandstone and siltstone (Maryland Department of Planning, 1973). Soils in the watershed are primarily Brinkerton and Andover silt loam, Elkins silt loams and Cookport channery loams. The soils consist of either deep, moderately well drained to very poorly drained soils on floodplains (U.S. Department of Agriculture, Soil Survey of Garrett County, 1974).

Inflow to the lake is primarily via Broadford Run and one unnamed tributary. Discharge from the lake is to Mountain Lake, which discharges to the Little Youghiogheny River. The watershed map (Figure 2) shows that land use in the watershed draining to Broadford Lake is predominantly forested/herbaceous. Land use distribution in the watershed is approximately 63% forested/herbaceous, 25% agricultural, 9% developed and 3% water (Figure 3) (Maryland Office of Planning, 2000).

Several relevant statistics for Broadford Lake are provided below in Table 1 (Maryland Department of Natural Resources, Inventory of Dams and Assessment of Hydropower Resources, 1985).

Table 1: Current Physical Characteristics of Broadford Lake

Location:	Garrett County, MD lat. 39^{o} 24’ 29” long. 79^{o} 22’ 20”
Surface Area:	138 acres = (6,011,280 ft^{2})
Length:	1.24 mi
Maximum Width:	1200 feet
Average Lake Depth:	10.2 feet
Maximum Depth:	28.5 feet
Volume of Lake:	1407.6 acre-feet (2,383,199 m^{3})
Drainage Area to Lake:	6.8 mi²
Average Discharge:	14.9 cfs

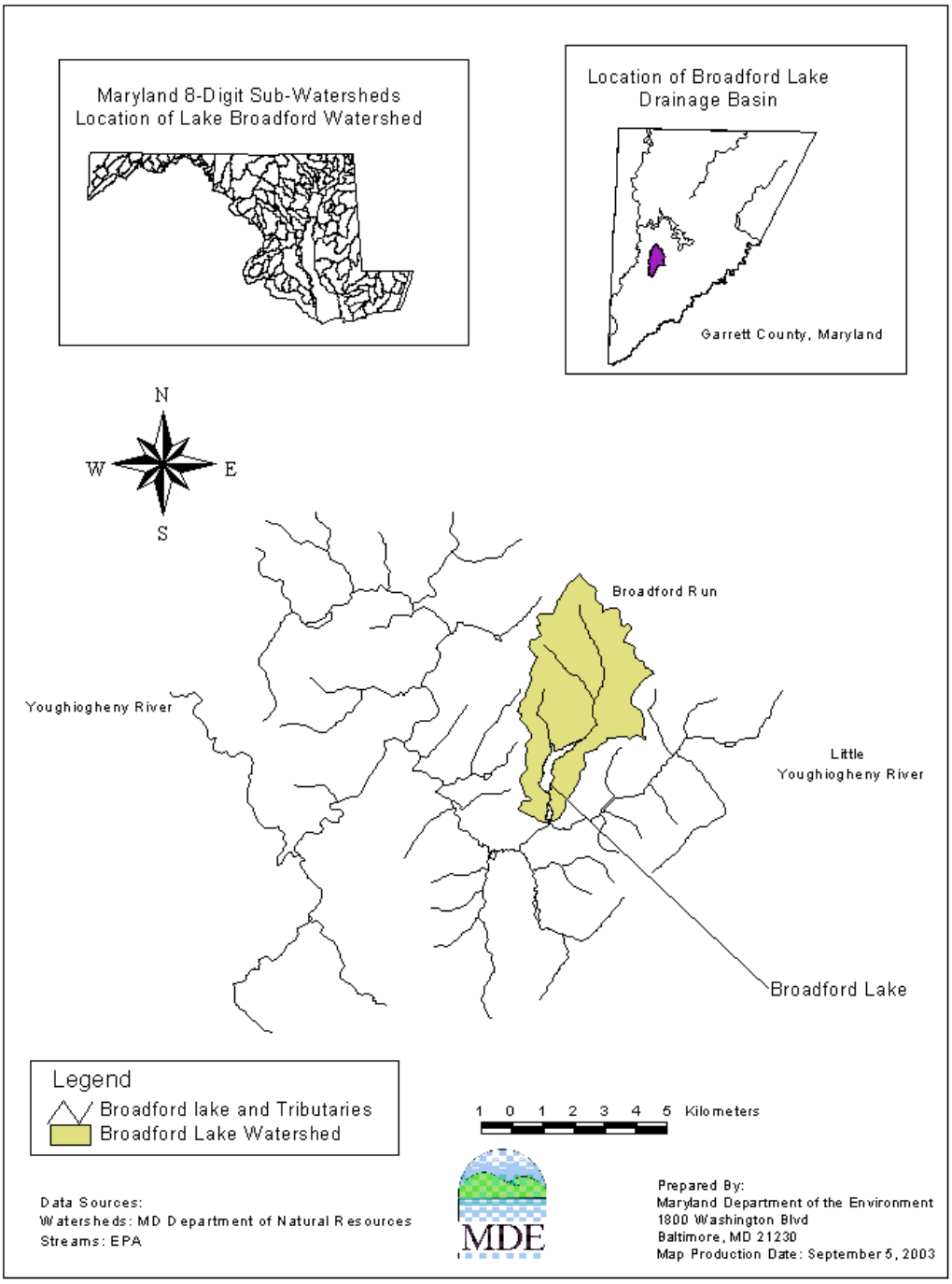

Figure 1: Watershed Map of Broadford Lake

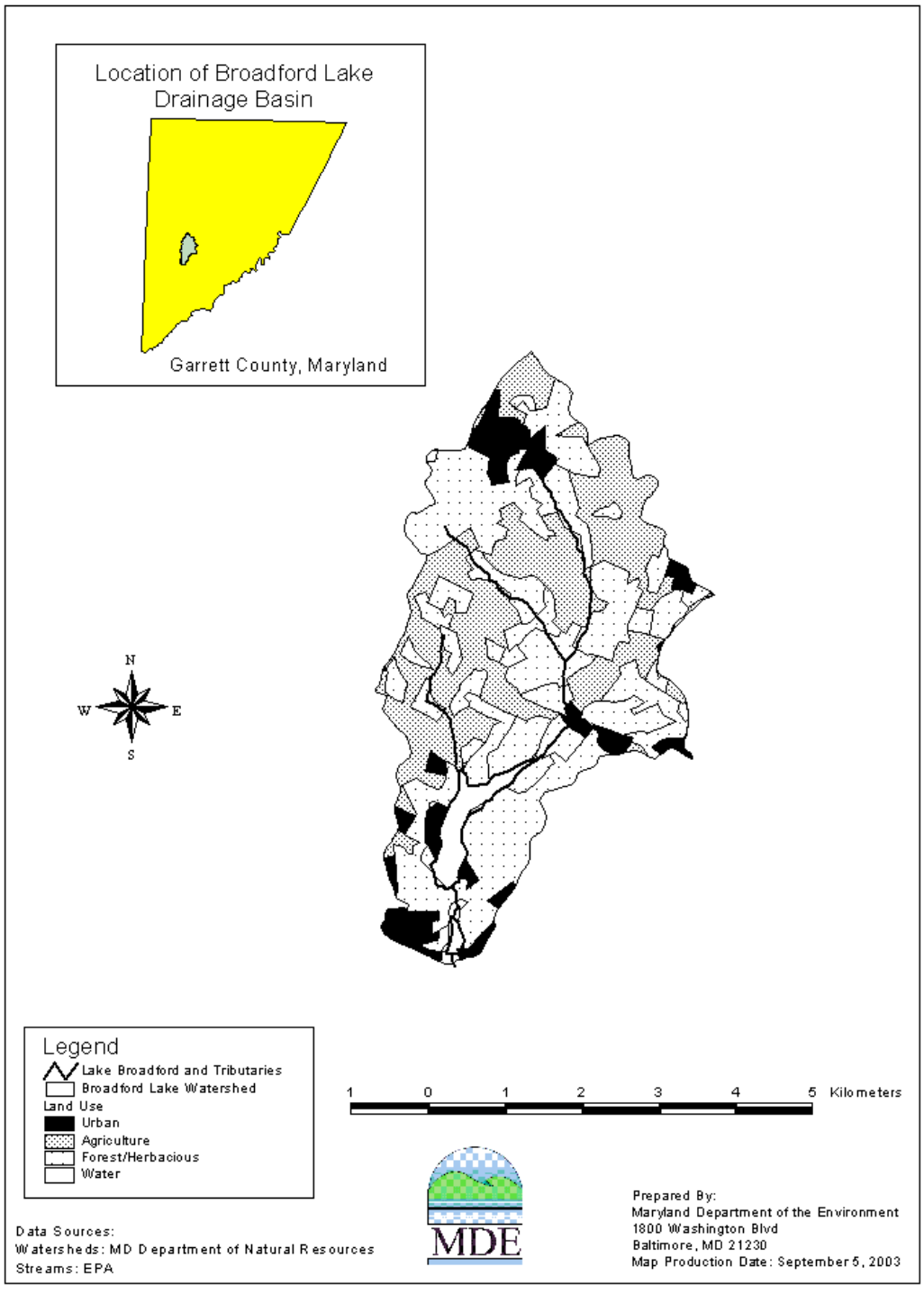

Figure 2: Land Use Map of the Broadford Lake Watershed

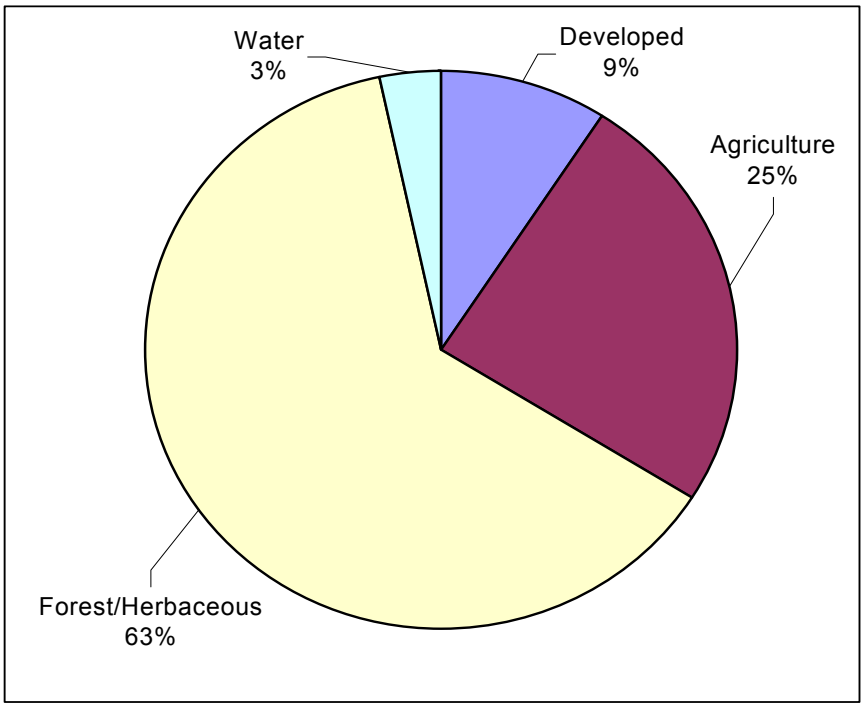

Figure 3: Land Use Distribution in the Broadford Lake Watershed

Broadford Lake is located in a watershed in which the mercury loadings are dominated by nonpoint source contributions (via atmospheric deposition). The EPA considers coal-fired electric power generating plants to be the largest anthropogenic source of mercury emissions in the nation (EPA, 2000). Therefore an essentially one-to-one relationship between the Allowable Ambient Water Column Concentration (AAWCC) and atmospheric deposition of mercury is assumed.

In Maryland, the major sources of mercury air emissions are as follows: 43% attributed to power plants; 31% to municipal waste combustors; 19% to medical waste incinerators; 6% to Portland Cement plants; and 1% other (e.g., landfills, oil-fired power plants, other industries).[1]

US industrial demand for mercury dropped 75% from 1988 to 1997. This drop can be attributed to actions including:

- Federal bans on mercury additives in paint and pesticides;
- Industry efforts to reduce mercury in batteries;

[1] www.mde.state.md.us/programs/landprograms/hazardous_waste/mercury/mercuryinfo.asp

- Increasing state regulation of mercury emissions and mercury in products;
- State-mandated recycling programs; and
- Voluntary actions by industry.[2]

There are three point sources in the Broadford Lake watershed (Table 2). Their combined discharge flows (less than 0.1 cfs) are not significant relative to the total estimated flow of 14.96 cfs through Broadford Lake (MDE 1999). These dischargers are not expected to receive or generate significant amounts of mercury, so there is no reasonable potential for these dischargers to cause or contribute to the impairment of their receiving water. Consequently, these facilities have not been required to monitor for mercury concentrations in their past discharge permits[3]. To assess the potential influence of the point source contributions, relative to other sources, a sensitivity analysis was conducted. In the absence of observed data, literature values were considered for the analysis.

In Maine, 75 municipal wastewater treatment plants (WWTPs) were analyzed using Mercury Method 1631, which has a detection level of 0.5 ng/l (Maine's information was referenced by a document produced by the State of Michigan, February 2000). The mean value of these samples was 11 ng/l. The maximum value was 59 ng/l (Waldoboro Sewer District). As a conservative assumption, a concentration of 60 ng/l was assumed from the point source sensitivity analysis.

Table 2: NPDES Permit Holders in the Broadford Lake Subwatershed (05-02-02-02)

Permittee	NPDES Permit No.	SIC Description	County	Average Annual Flow (MGD)
Deer Park Spring Water, Inc.	MD0060844	Groceries and related products	Garrett	0.041
Peters Fuel Corp. - Oakland	MD0064505	General automotive repair shops	Garrett	Not Applicable
Wood Products, Inc.	MD0053546	Logging	Garrett	Not Applicable

Flow Source: EPA's Permit Compliance System (PCS) Database

3.0 WATER QUALITY CHARACTERIZATION

3.1 General Discussion

Trophic level 4 fish (Largemouth Bass) were harvested from Broadford Lake and were analyzed for mercury tissue concentrations. Water column samples were also taken and analyzed for mercury concentrations. Fish samples were collected by the Maryland Department of Natural Resources (DNR). Water column samples were collected by University of Maryland Center for

[2] Source: www.epa.gov/mercury/information1.htm

[3] A program is under development to conduct periodic monitoring using a new analytical technique that will provide meaningful estimates of potential point source contributions.

Environmental Science, Chesapeake Biological Laboratory (UMCES). All were analyzed by UMCES.

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 4) 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. Mercury exhibits 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 methylated through a bacterial process. Methylation of mercury can occur in water, sediment, and soil solution 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.

For public health purposes, the MDE has the responsibility to monitor and evaluate the contaminant levels in Maryland fish, shellfish and crabs, and to determine if contaminant levels are within the limits established as safe for human consumption. In fulfillment of this public health responsibility, MDE has issued a statewide fish consumption advisory for mercury in fish. This advisory provides guidelines (Table 3) 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.

Table 3: Maryland Department of the Environment Fish Consumption Guidelines

Total mercury residue in fish tissue Range (μg/kg)	Recommended fish consumption (maximum meals per month based on an 8 oz. meal size)
117 – 235	7 - 4
236 – 322	3
322 – 409	2
410 – 939	1
> 939	< 1

These 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 of four fish meals per month. An allowable maximum of 235 μg/kg mercury in fish tissue ensures safety at this level

of consumption; thus, levels of total mercury in fish tissue above 235 µg/kg are an indication of impairment. When data for total mercury concentrations in fish tissue is not available, data for methylmercury concentrations is used alternately for impairment decisions.

The Maryland Surface Water Use Designation (Code of Maryland Regulations (COMAR) 26.08.02.07) for Broadford Lake is Use I-P – *Water Contact Recreation, and Protection of Aquatic Life and Public Water Supply*.

3.2 Mercury Residue in Fish Tissue Data

Samples of fish were taken from Broadford Lake on 06/28/2000. Trophic level 4 (largemouth bass) fish were targeted in the collection because they represent the species of fish that are caught and kept by anglers and consumed as a source of food. The fish fillets obtained during the sampling effort were analyzed for total mercury and methylmercury concentrations and were measured for length and weighed. Table 4 lists the individual fish data. A statistical analysis of the individual fish samples is presented in Table 5.

Table 4: Individual Fish Sample Data For Mercury Residue in Fish Tissue from Broadford Lake

Sample ID No.	Trophic Level	Species	Collection date	Methyl Mercury (ppb) wet weight	Total Mercury (ppb)	Length (mm)	Weight (gm)
BFL062700LMB1	4	Largemouth Bass	06/28/2000	348.2	250.3	332	496
BFL062700LMB2	4	Largemouth Bass	06/28/2000	138.0	170.1	303	358.7
BFL062700LMB3	4	Largemouth Bass	06/28/2000	20.0	107.8	312	360.6
BFL062700LMB4	4	Largemouth Bass	06/28/2000	119.1	122.9	338	520.7
BFL062700LMB5	4	Largemouth Bass	06/28/2000	388.4	363.9	332	398.2
BFL062700LMB6	4	Largemouth Bass	06/28/2000	148.8	126.1	333	525.6
BFL062700LMB7	4	Largemouth Bass	06/28/2000	233.8	230.6	386	753.1
BFL062700LMB8	4	Largemouth Bass	06/28/2000	209.7	266.6	361	652.0
BFL062700LMB9	4	Largemouth Bass	06/28/2000	616.3	401.2	390	738.6
BFL062700LMB10	4	Largemouth Bass	06/28/2000	230.7	571.9	385	782
BFL062700LMB11	4	Largemouth Bass	06/28/2000	445.8	484.6	426	1,172.9

Table 5: Analysis of Mercury in Fish Tissue Residue Concentrations from Broadford Lake

Trophic Level	Sample Count	Avg. Conc. Methylmercury (ppb)	Avg. Conc. Total Mercury (ppb)	Ratio Methylmercury to Total Mercury	Geometric mean Methyl mercury Concentration (ppb)
4	11	263.5	281.5	0.936	200.1

One fish tissue sample (BFL062700LMB2), with a concentration of 20 µg/kg, required additional inquiry and warrants further discussion. Without this sample, the geometric mean of MeHg in largemouth bass tissue would have been 252 µg/kg, which is above the threshold of impairment and would necessitate a TMDL. MDE and UMCES checked and verified the accuracy of this sample. MDE explored several analytical and managerial options, including omitting this sample in the interest of erring on the side of protection of human health. The sample, while low, was validated and cannot be considered a statistical outlier. It is toward the low end of the log-normal distribution, and the frequency distribution for Broadford Lake matches that of the population of Maryland lakes - see Figure 4 and Figure 5, respectively.

Additionally, Section 101(a)(2) of the CWA establishes as a national goal "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable." These are commonly referred to as the "fishable/swimmable" goals of the Act. The Department of the Environment has defined “fishable” as the ability to eat at least 4 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 4 meal/month level for a given contaminant.

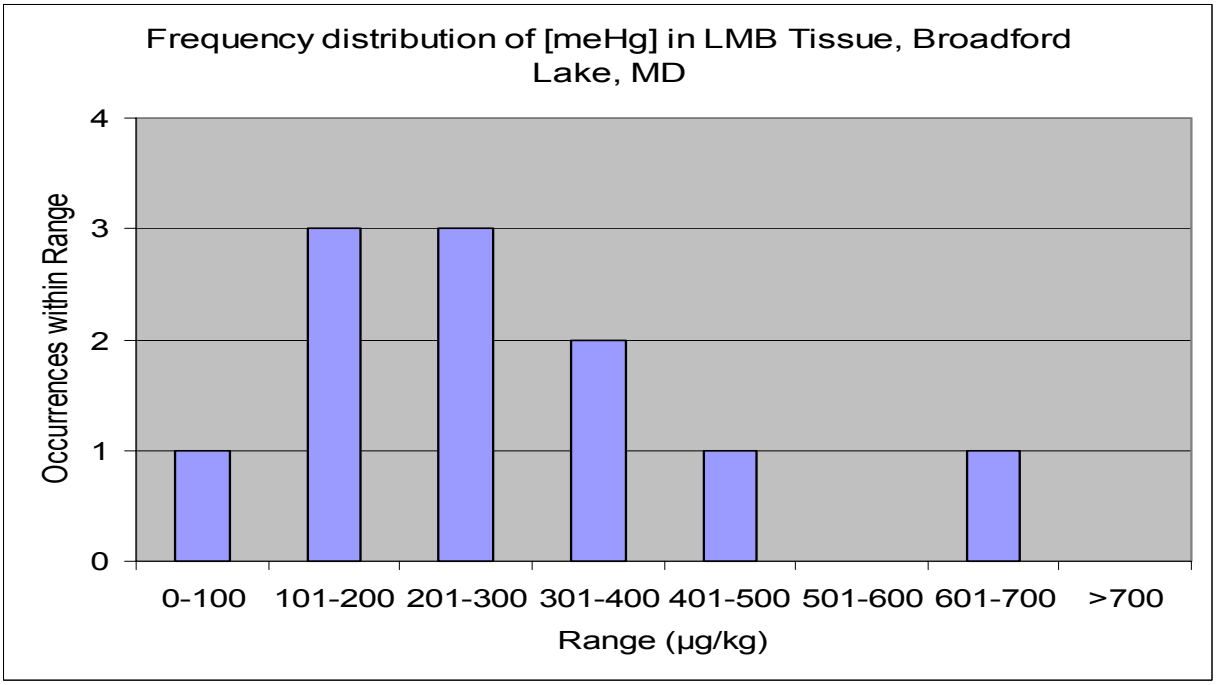

Figure 4: Frequency Distribution of [meHg] in Largemouth Bass Tissue in Broadford Lake.

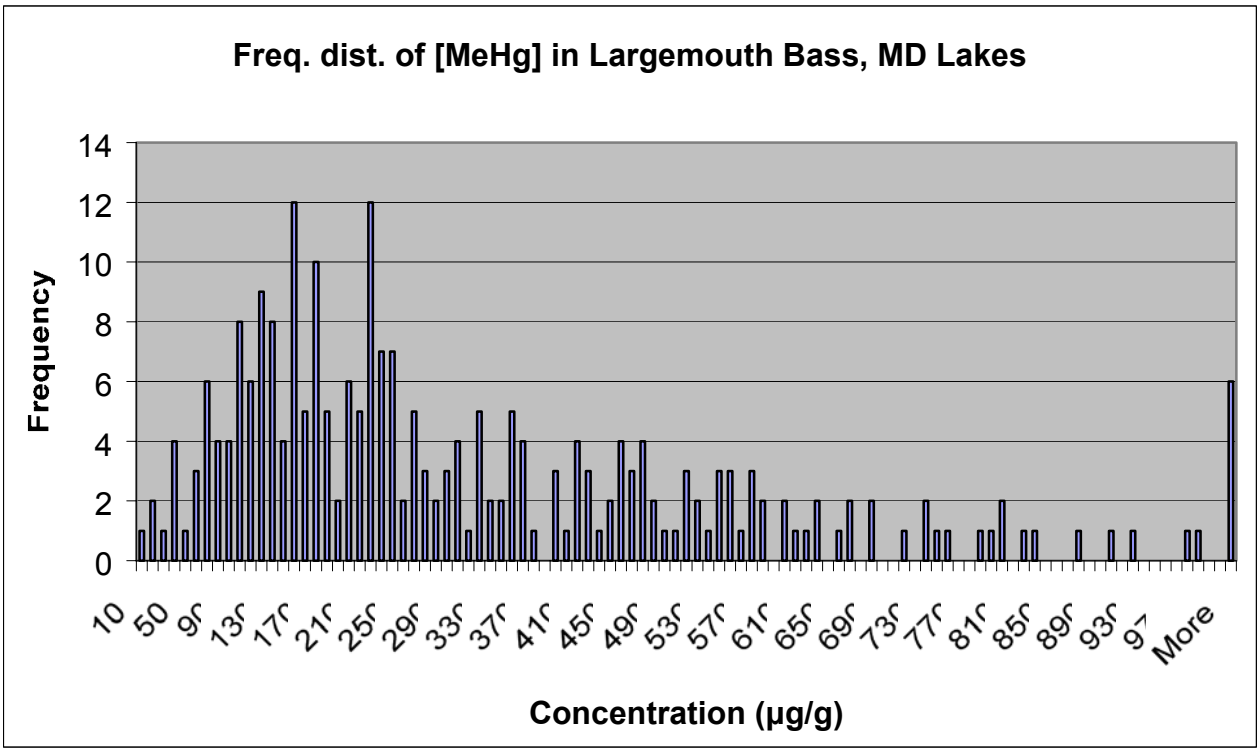

Figure 5: Frequency Distribution of [meHg] in Largemouth Bass in All Sampled Maryland Lakes.

Broadford Lake is about 5 mi (8 km) southwest of Deep Creek Lake, for which Maryland has already developed a TMDL for methylmercury in fish tissue. The Deep Creek Lake TMDL calls for a 56.5% reduction in mercury, primarily from atmospheric deposition resulting from emissions due to combustion. MDE has conducted an analysis to estimate the effect of the reductions necessary to meet the Deep Creek Lake TMDL on the airshed of Broadford Lake.

Based on guidance from U.S. EPA Region III (S. Sciarratta, pers. comm., 2003), a rough estimate of the airshed depositing to a watershed can be described by circumscribing a "buffer" of 100 km around the watershed. Based on this assumption, the airsheds of Deep Creek Lake and Broadford Lake overlap by about 87.5% (Figure 6). Accordingly, the 56.5% reduction in mercury deposition to the watershed of Deep Creek Lake will result in an estimated 0.875(56.5)% or 49% reduction in mercury deposition to Broadford Lake.

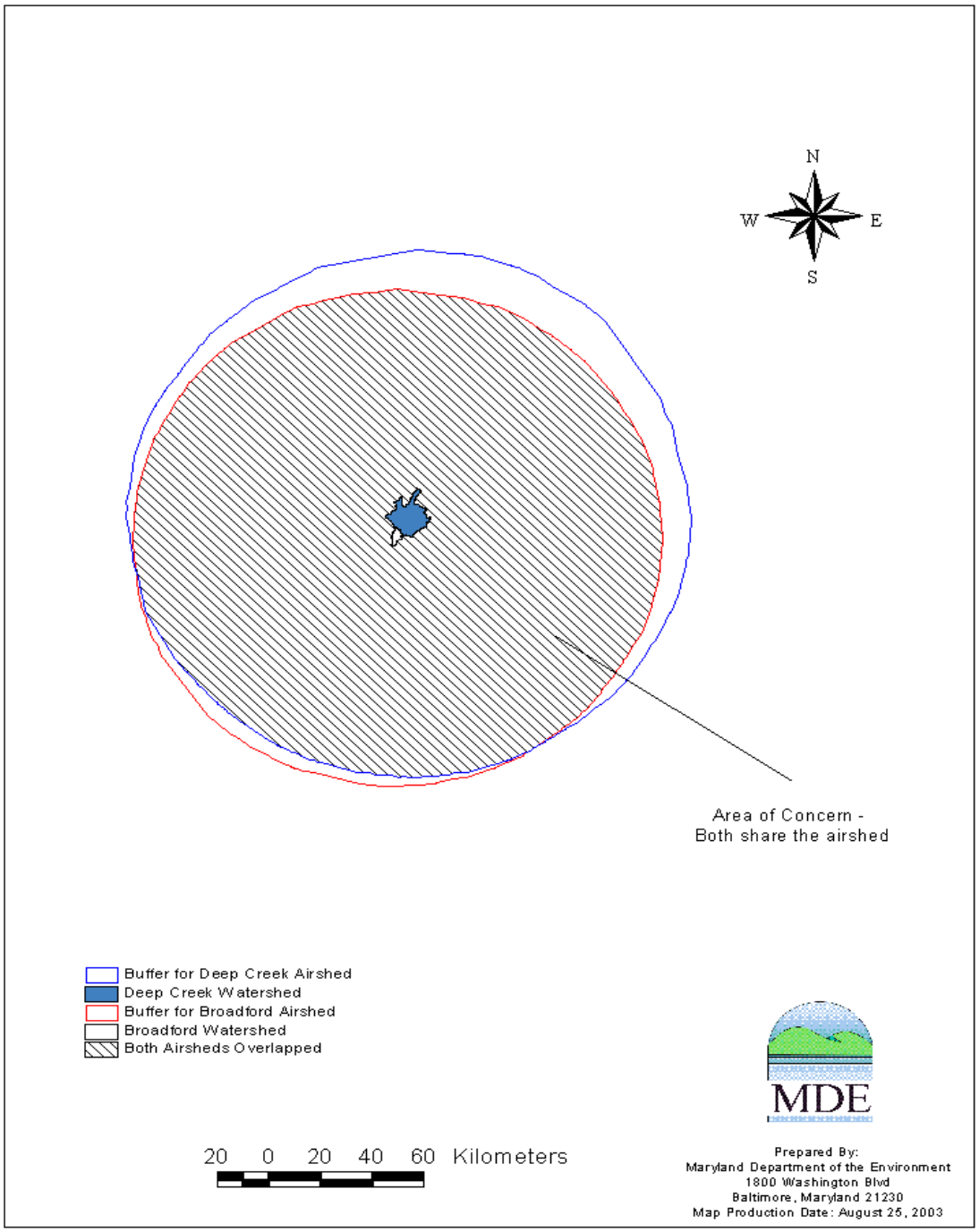

Figure 6. Airsheds for Broadford Lake and Deep Creek

3.3 Water Column Mercury Concentrations

[Note: Because a TMDL was initially thought necessary for Broadford Lake, water column mercury data were collected. The full analysis is not necessary, since a WQA is being developed instead. The data are presented here for informational purposes only.] Water column samples were taken from the same areas as the fish tissue samples and were analyzed for total mercury and methylmercury concentrations. Samples were analyzed for both constituents in both whole water and as dissolved (filtered). Table 6 and Table 7 present the data from both sets of analysis as well as a statistical analysis of each set.

Table 6: Water Column Mercury/Methylmercury Concentration Data from Broadford Lake – Whole Water Concentrations

Sample Site	Most Restrictive Total Mercury Criterion For Comparison Purposes[4] ng/l	Total Mercury Concentration ng/l	Methylmercury Concentration ng/l	Fraction Methylmercury/Total Mercury
Downstream of Inflow	51.0	1.22	.169	0.139
Mid Reservoir	51.0	1.42	.151	0.106
Mean Value	**51.0**	**1.320**	**0.160**	**0.122**
Geomean Value	**51.0**	**1.316**	**0.160**	**0.121**

Table 7: Water Column Mercury/Methylmercury Concentration Data From Broadford Lake - Dissolved Water Concentrations

Sample Site	Most Restrictive Total Mercury Criterion For Comparison Purposes[4] ng/l	Total Mercury Concentration ng/l	Methylmercury Concentration ng/l	Fraction Methylmercury/Total Mercury
Downstream of Inflow	51.0	1.00	.137	0.137
Mid Reservoir	51.0	0.98	.097	0.099
Mean Value	**51.0**	**0.99**	**0.117**	**0.118**
Geomean Value	**51.0**	**0.99**	**0.115**	**0.116**

4.0 CONCLUSION

Analysis of the fish tissue data for Broadford Lake indicates that the lake is not impaired by mercury in fish tissue. Because of the potential human health impact of mercury, Maryland has issued a statewide fish consumption advisory, which remains in effect. Additionally, controls to be implemented as a consequence of the Deep Creek Lake TMDL will facilitate a decrease of water column and fish tissue concentrations of mercury and methylmercury in Broadford Lake.

[4] COMAR 26.08.02.03-2 Numerical Criteria for Toxic Substances in Surface Waters; total mercury criterion (fish consumption, human health risk level = 10^{-5})

Deep Creek and Broadford Lake are located in a watershed in which the mercury impairment is dominated by nonpoint source mercury contributions (resulting from 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 may differ from the implementation of TMDLs from other pollutants (nutrients and toxics - other than mercury). EPA Region 4 and EPA Region 6 have indicated that reductions in atmospheric contributions will be accomplished over time through existing and proposed Clean Air Act regulatory controls that will ensure significant reductions in mercury loading on a nationwide basis by reducing atmospheric emissions. However, they believe it is too early to estimate the reductions in mercury emissions that may result from the future regulation of electric power generating utilities. The EPA expects to see reduced emissions of mercury from this industry sector as a number of regulations are implemented to control sulfur dioxide emissions and nitrous oxide emissions, since some control technologies used to limit these pollutants collaterally reduce mercury emissions to some degree. The controls for atmospheric emissions are expected to be implemented in phases.

For public health purposes, the MDE has the responsibility to monitor and evaluate the contaminant levels in Maryland fish, shellfish and crabs, and to determine if contaminant levels are within limits established as safe for human consumption. The currently issued fish consumption advisories are one result of the execution of this responsibility. MDE's website (http://www.mde.state.us) contains extensive information for consumers and businesses concerning reducing mercury in Maryland's environment. Information includes descriptions of mercury in the home and the environment, alternate products to mercury-containing products, mercury spill cleanup safety and mercury recycling resources. This will ensure that Broadford Lake likely will improve rather than degrade from its current condition.

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