Water Quality Analysis of Chromium and Lead for the Liberty Reservoir Impoundment in Baltimore and Carroll Counties, Maryland

FINAL

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CBL	Chesapeake Biological Laboratory
cm	Centimeter
COMAR	Code of Maryland Regulations
Cr	Chromium
CWA	Clean Water Act
DOC	Dissolved Organic Carbon
EPA	Environmental Protection Agency
HAC	Hardness Adjusted Criteria
MDE	Maryland Department of the Environment
mg	Milligram
mg/l	Milligrams per Liter
NPDES	National Pollution Discharge Elimination System
Pb	Lead
SCS	Soil Conservation Service
SSURGO	Soil Survey Geographic
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WER	Water Effects Ratio
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
µg/l	Micrograms per Liter

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) 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 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.

The Liberty Reservoir (basin code 02-13-09-07), located in Baltimore and Carroll Counties, MD, was identified on the State's list of WQLSs as impaired by chromium (Cr) (1996 listing), lead (Pb) (1996 listing), nutrients (1996 listing), suspended sediments (1996 listing), fecal coliform (2002 listing), methylmercury (2002 listing) and evidence of biological impacts (2002 listing). The Cr, Pb, nutrients, suspended sediment and methylmercury impairments were listed for the impoundment, and the fecal coliform and biological impairments were listed for the non-tidal streams. This report provides an analysis of recent monitoring data, including hardness data, which shows that the aquatic life criteria for Cr and Pb and the designated uses supported by those criteria are being met in the Liberty Reservoir. The non-tidal streams are not listed for Cr or Pb, therefore they are not addressed in the water quality analysis (WQA). The analysis supports the conclusion that TMDLs for Cr and Pb are not necessary to achieve water quality standards in this case because the standards are already being met. Barring the receipt of any contradictory data, this report will be used to support the removal of the Liberty Reservoir impoundment from Maryland's list of WQLSs for Cr and Pb when the Maryland Department of the Environment (MDE) proposes the revision of Maryland's 303(d) list for public review in the future. A TMDL for methyl mercury in fish tissue was completed in 2002. The nutrient, suspended sediments, fecal coliform and biological impairments will be addressed separately at a future date.

Although the waters of the Liberty Reservoir do not display signs of toxic impairments due to Cr or Pb, the State reserves the right to require additional pollution controls in the Liberty Reservoir watershed if evidence suggests that Cr or Pb from the basin are contributing to downstream water quality problems.

1.0 INTRODUCTION

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.

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.

The Liberty Reservoir (basin code 02-13-09-07) was first identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment (MDE) as impaired by chromium (Cr), lead (Pb), suspended sediments and nutrients, with fecal coliform, methylmercury and biological impairments added to the list in 2002. The Cr, Pb, nutrients, suspended sediment and methylmercury impairments were listed for the impoundment, and the fecal coliform and biological impairments were listed for the non-tidal streams. The initial listings for Cr and Pb were questionable because: 1) the original listing was based on total recoverable metals (current standard is based on dissolved metals); 2) inappropriate sampling techniques were applied (lack of filtration); 3) supporting data needed to interpret criteria was not available (hardness); and 4) a default hardness of 100 mg/L was used to convert and relate the total recoverable metals to the dissolved criteria, which superceded the total recoverable metals criteria. A water quality analysis (WQA) of Cr and Pb in the Liberty Reservoir impoundment was performed using recent water column and sediment toxicity data. Results show no impairment for Cr or Pb. The non-tidal streams are not listed for Cr or Pb therefore they are not addressed in the WQA. A TMDL for methylmercury in fish tissue was completed in 2002. The nutrient, suspended sediments, fecal coliform and biological impairments will be addressed separately at a future date.

The remainder of this report lays out the general setting of the waterbody within the Liberty Reservoir watershed, presents a discussion of the water quality characterization process, and provides conclusions with regard to the characterization. The most recent data establishes that the Liberty Reservoir is achieving water quality standards for Cr and Pb.

2.0 GENERAL SETTING

The Liberty Reservoir watershed is located in the Patapsco region of the Chesapeake Bay watershed within Maryland (see Figure 1). The watershed covers portions of Baltimore and Carroll County. The watershed area covers 104,800 acres. The Reservoir is owned by the Baltimore City Department of Public Works and is situated in the Patapsco River watershed. The dam was constructed in 1953.

Inflow to Liberty Reservoir is primarily via the northern branch of the Patapsco River with additional inflow from Morgan Run and several small tributaries. Discharge from the reservoir is into the Lower North Branch of the Patapsco River. The reservoir is currently used for recreational activities (swimming, fishing and boating) and as a major water supply for the City of Baltimore. Upstream watershed usage includes a water supply for the Carroll County Department of Public Works, an unnamed park surrounding the reservoir and Soldiers Delight Natural Environmental area. Downstream usage includes Patapsco Valley State Park. The physical characteristics of the Liberty Reservoir are shown in Table 1.

Table 1: Physical Characteristics of the Liberty Reservoir

Location:	Baltimore County, Maryland Latitude 39.28 Longitude 76.89 (Dam)
Surface Area:	12.6 km^2
Normal Depth:	40.5 m
Normal Volume:	1.63 * 10^8 m^3
Drainage Area to Lake:	424.1 km^2
Average Annual Flow:	5.5 m^3/s

The Liberty Reservoir watershed lies within the Piedmont province of Central Maryland. The Piedmont province is characterized by gentle to steep rolling topography, low hills and ridges. The surficial geology is characterized by crystalline rocks of volcanic origin consisting primarily of schist and gneiss. These formations are resistant to short-term erosion and often determine the limits of stream bank and stream bed. These crystalline formations decrease in elevation from northwest to southeast and eventually extend beneath the younger sediments of the Coastal Plain. (Coastal Environmental Services, 1995).

The Liberty Reservoir watershed drains from northwest to southeast, following the dip of the underlying crystalline bedrock in the Piedmont province. The surface elevations range from approximately 980 feet to 420 feet at the Liberty Reservoir Spillway. Stream channels of the sub-watersheds are well incised in the Eastern Piedmont, and exhibit relatively straight reaches and sharp bends, reflecting their tendency to following zones of fractured or weathered rock. (Coastal Environmental Services, 1995).

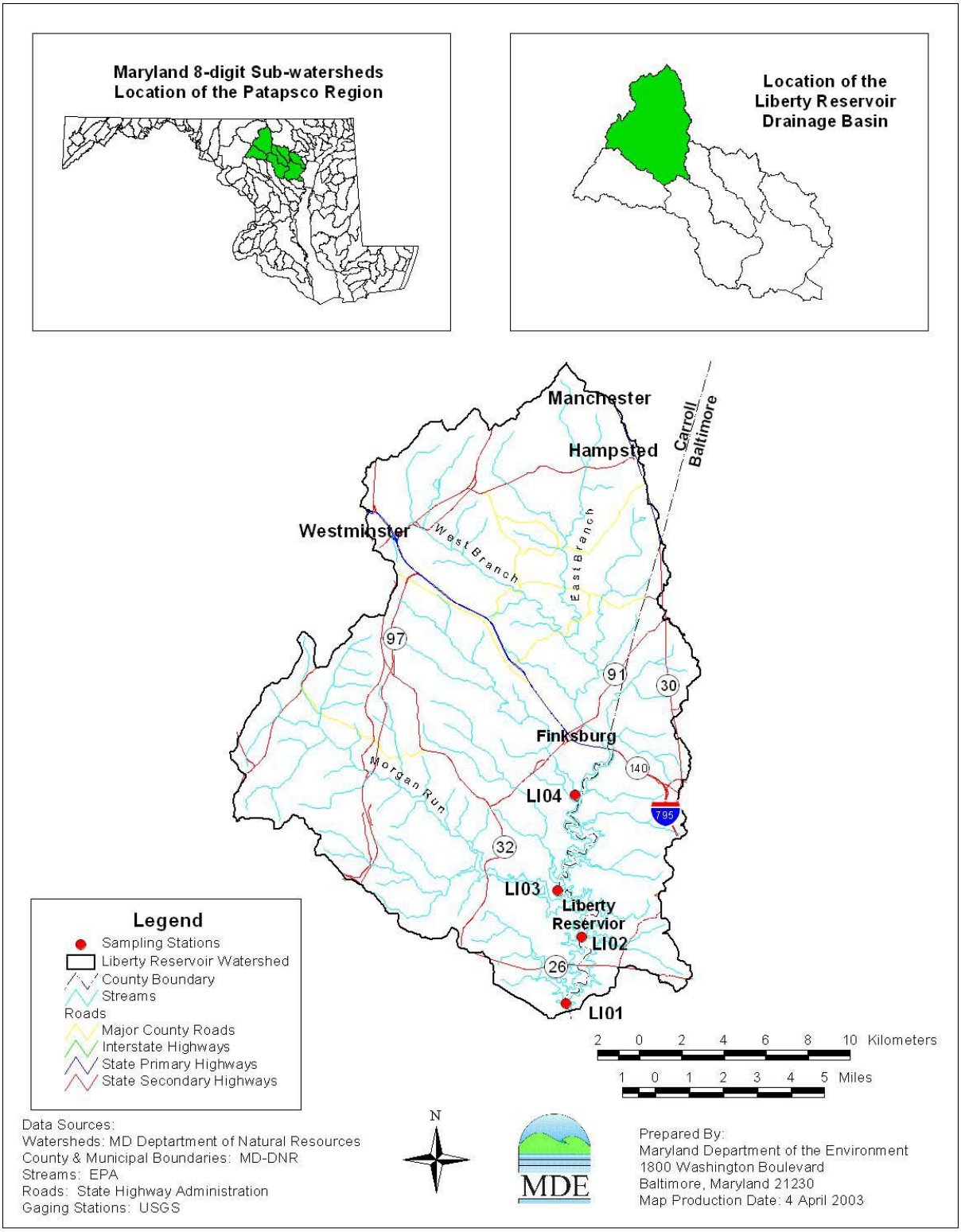

Figure 1: Watershed Map of the Liberty Reservoir

The watershed is comprised primarily of A and B type soils. Soil type is categorized by four hydrologic soil groups developed by the Soil Conservation Service (SCS). The definitions of the groups are as follows (SCS, 1976):

> Group A: Soils with high infiltration rates, typically deep well-drained to excessively drained sands or gravels.
> Group B: Soils with moderate infiltration rates, generally moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
> Group C: Soils with slow infiltration rates, mainly soils with a layer that impedes downward water movement or soils with moderately fine to fine texture.
> D: Soils with very slow infiltration rates, mainly clay soils, soils with a permanently high water table, and shallow soils over nearly impervious material.

The soil distribution within the watershed is approximately 22.3% soil group A, 63.0% soil group B, 7.4% soil group C and 7.3% soil group D. Soil Data was obtained from Soil Survey Geographic (SSURGO) coverages created by the National Resources Conservation Service.

Land use within the Liberty Reservoir watershed is a mixture of agricultural, urban and forestland (see Figure 2). No major point sources discharge Cr or Pb within the watershed. The land use distribution in the watershed is approximately 41% agricultural, 31% forest/herbaceous, 25% urban and 3% water (Maryland Department of Planning, 2000).

3.0 WATER QUALITY CHARACTERIZATION

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 support of aquatic life, primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody. Maryland's water quality standards presently include numeric criteria for metals and other toxic substances based on the need to protect aquatic life, wildlife and human health. Water quality standards for toxic substances also address sediment quality to ensure the bottom sediment of a waterbody is capable of supporting aquatic life, thus protecting the designated uses.

The Maryland Surface Water Use Designation (Code of Maryland Regulations (COMAR) 26.08.02.08J) for the Liberty Reservoir is Use I-P – *water contact recreation, fishing, protection of aquatic life and wildlife and public water supply.* The applicable numeric aquatic life and human health (drinking water) criteria for dissolved Cr and Pb in freshwater are described below in Table 2 (COMAR 26.08.02.03-2G). There are two species of chromium, trivalent Cr (III) and hexavalent Cr (VI). Cr (VI) has the highest toxicity of the Cr species, therefore the numeric criteria is more stringent. Total chromium concentrations were analyzed in the water column survey and are compared with the Cr (VI) numeric water quality criterion. The Liberty Reservoir is designated a public water supply, therefore the human health (drinking water) criteria for Cr and Pb must also be achieved. The water column data presented in Section 3.1,

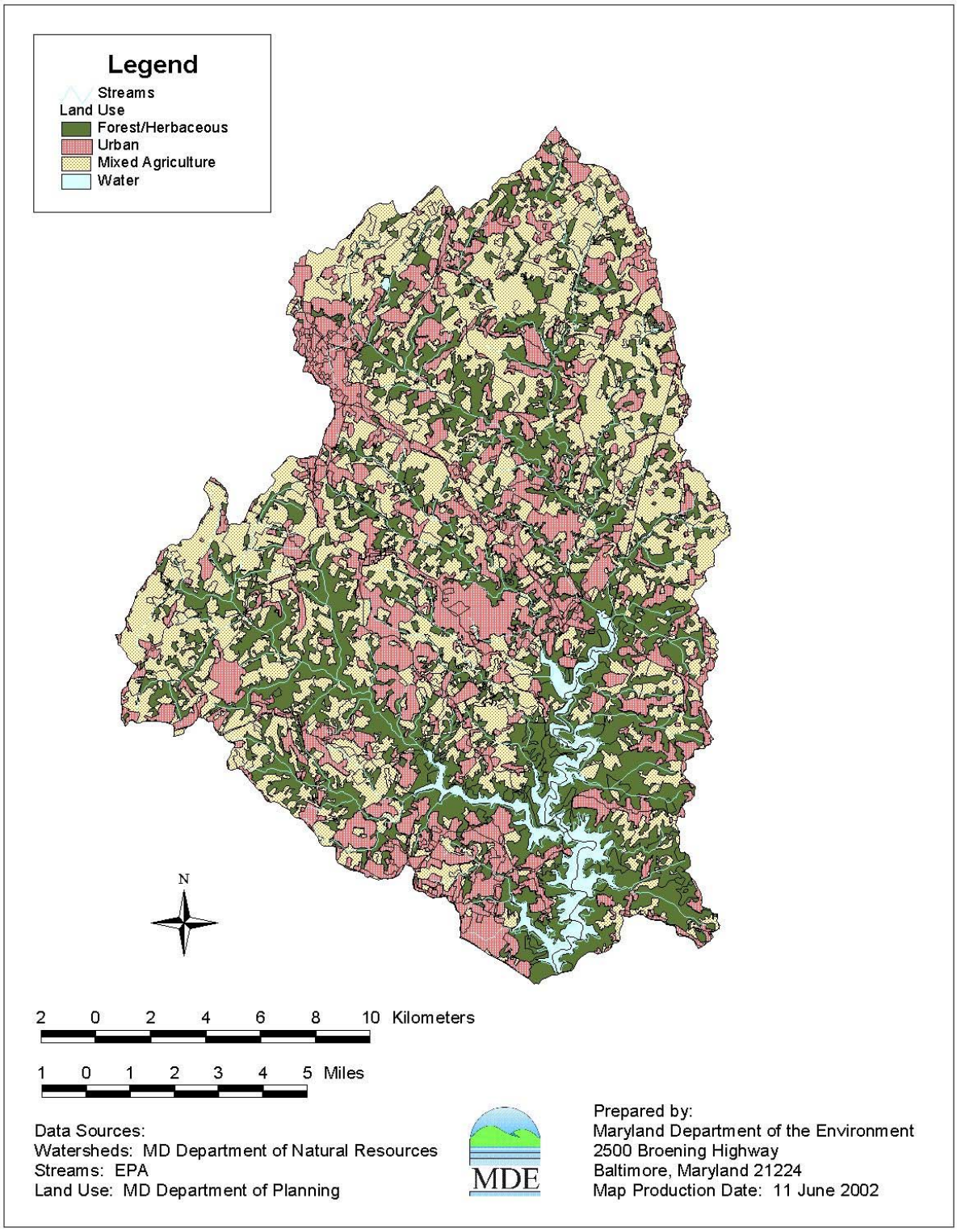

Figure 2: Land Use Map of Liberty Reservoir Watershed

Table 6 through Table 9, shows that concentrations of Cr and Pb in the water column do not exceed the aquatic life or human health (drinking water) criteria. An ambient sediment bioassay conducted in Liberty Reservoir establishes that there is no toxicity in the sediment bed of the impoundment (Fisher, 2002). Sediment chemistry analysis was not conducted because toxicity was not observed in the ambient sediment bioassay. The water column and sediment in the Liberty Reservoir impoundment are therefore not impaired by Cr or Pb, thus the designated uses are supported and the water quality standard is being met for these substances.

Table 2: Numeric Water Quality Criteria (Cr and Pb)

Metal	Fresh Water Aquatic Life Acute Criteria (µg/l)	Fresh Water Aquatic Life Chronic Criteria (µg/l)	Human Health Criteria Drinking Water (µg/l)
Cr (VI)	16	11	100 *
Pb	65	2.5	15

* Human health criterion (drinking water) is designated for Cr

Water column surveys conducted at four stations in the Liberty Reservoir from May 2001 to July 2001 were used to support the WQAs. For every sample, dissolved concentrations of Cr and Pb were determined. Sediment samples were also collected at all four monitoring stations for the sediment bioassay. Table 3 shows the list of stations with their geographical coordinates and descriptive location in the Liberty Reservoir. Refer back to Figure 1 for station locations.

Table 3: Water Quality Analysis Stations for Liberty Reservoir

Station I.D.	GPS coordinates	Station Description
LI01	39.380 76.892	Reservoir
LI02	39.408 76.883	Reservoir
LI03	39.428 76.569	Reservoir
LI04	39.469 76.887	Reservoir

Water column sampling was performed four times at each station from May 2001 to July 2001 to capture seasonal variation. The sampling dates were as follows: 5/21/01 (spring wet weather); 6/14/01 (spring dry weather); 7/26/01 (summer dry weather) and 7/30/01 (summer wet weather).

For the water quality evaluation a comparison is made between the water column concentrations of Cr and Pb and fresh water aquatic life chronic criteria, the more stringent of the numeric water quality criteria for Cr (VI) and Pb. Hardness concentrations were obtained for each station to adjust the fresh water aquatic life chronic criteria that are established at a hardness of 100 mg/l for Cr (VI) and Pb. The State used hardness adjustment to calculate fresh water aquatic life chronic criteria for Pb for which toxicity is a function of total hardness. The fresh water aquatic life chronic criterion is not adjusted for Cr (VI) because hardness either does not affect the bioavailability of this metal to aquatic life or there is significant uncertainty in the correlation between hardness and criterion. According to EPA's National Recommended Water Quality

Criteria (EPA, 2002), allowable hardness values must fall within the range of 25 - 400 mg/L. MDE uses an upper limit of 400 mg/l in calculating the hardness adjusted criteria (HAC) when the measured hardness exceeds this value. Based on technical information, EPA's Office of Research and Development does not recommend a lower limit on hardness for adjusting criteria (EPA, 2002). MDE adopts this recommendation. The HAC equation for Cr and Pb is as follows (EPA, 2002):

$$HAC = e^{(m[\ln(\text{Hardness(mg/l)})]+b)} * CF$$

Where,

HAC = Hardness Adjusted Criterion (µg/l)
m = slope
b = y intercept
CF = Conversion Factor (conversion from totals to dissolved numeric criteria)

The HAC parameters for metals are presented in Table 4.

Table 4: HAC Parameters (Fresh Water Aquatic Life Chronic Criteria)

Chemical	Slope (m)	y Intercept (b)	Conversion Factor (CF)
Pb	1.2730	-4.705	1.426 - ln(hardness)*0.146

The State will perform a scientific review of all data submitted where a water quality criterion exceedance was the result of a hardness adjustment below 50 mg/L. This review is necessary because of the scientific uncertainty existing for hardness-toxicity relationships below 50 mg/l due to:

A. Paucity of toxicity test data below 50 mg/L that was used to develop the relationship between hardness and toxicity.
B. Presence/absence of sensitive species in the waterbody of concern.
C. Existence of other environmental conditions (e.g. high Dissolved Organic Carbon (DOC)), that may mitigate the toxicity of metals due to competitive binding/complexation of metals.

In instances where hardness data is not available, the State will calculate an average of existing hardness concentrations for each station. In applying average hardness, the sampling date for which hardness data is unavailable must not fall during a storm event substantially greater than the sampling dates used to calculate the average. A major rainfall event has the potential to reduce hardness below the average. An analysis of rainfall data from the National Weather Service (NWS) precipitation gauge (0180465) at Baltimore/Washington International Airport (BWI) shows no significant variation in storm events for the sampling dates, thus the average will apply. This is the closest gauge to Liberty Reservoir and is likely to be representative of the rainfall events that occur within the watershed.

3.1 WATER COLUMN EVALUATION

A data solicitation for metals was conducted by the MDE and all readily available data from the past five years was considered in the WQA. The water column data is presented in Table 6 through Table 9 for each station and is evaluated using the fresh water aquatic life chronic HAC, the more stringent of the numeric water quality criteria for Cr and Pb (Baker, 2002). Each table displays hardness (mg/l), sample concentrations (µg/l) and fresh water aquatic life chronic HAC (µg/l) by sampling date. For example, in Table 6 for the sampling date of 7/26/01 the hardness is 27.3 mg/L, hardness adjusted criterion for Pb is 0.60 µg/l and the Pb sample concentration is 0.014 µg/l. The hardness concentrations reported in bold are for sampling dates in which hardness was not measured and an average value was applied. Detection limits for the metals analyses are displayed in Table 5.

Table 5: Metals Analysis Detection Limits

Analyte	Detection Limit (µg/l)
Cr	0.03
Pb	0.003

Table 6: Station LI01 Water Column Data

Sampling Date	5/21/01		6/14/01		7/26/01		7/30/01	
Hardness (mg/l)	29		**28.1**		27.3		**28.1**	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
Cr	0.07	11	0.11	11	0.06	11	0.21	11
Pb	ND	0.64	0.007	0.61	0.014	0.60	ND	0.61

* Fresh Water Aquatic Life Chronic HAC
  A) Cr (VI) criterion is applied
  B) Hardness adjustment is unnecessary for Cr (VI)

ND - Not detected

Table 7: Station LI02 Water Column Data

Sampling Date	5/21/01		6/14/01		7/26/01		7/30/01	
Hardness (mg/l)	28.7		27.6		27.7		**28**	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
Cr	0.08	11	0.11	11	0.05	11	0.2	11
Pb	ND	0.63	0.005	0.63	0.013	0.61	ND	0.61

Table 8: Station LI03 Water Column Data

Sampling Date	5/21/01		6/14/01		7/26/01		7/30/01	
Hardness (mg/l)	29		28.5		27.8		**28.4**	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
Cr	0.1	11	0.07	11	0.03	11	0.2	11
Pb	ND	0.64	0.011	0.63	0.007	0.61	ND	0.62

* Fresh Water Aquatic Life Chronic HAC
A) Cr (VI) criterion is applied
B) Hardness adjustment is unnecessary for Cr (VI)
ND - Not detected

Table 9: Station LI04 Water Column Data

Sampling Date	5/21/01		6/14/01		7/26/01		7/30/01	
Hardness (mg/l)	32.1		30.15		30.06		**30.8**	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
Cr	0.09	11	0.11	11	ND	11	0.19	11
Pb	0.041	0.72	0.031	0.67	0.025	0.67	ND	0.68

The range of concentrations for Cr and Pb sampled in the field survey are as follows:

Cr = ND to 0.21 µg/l
Pb = ND to 0.041 µg/l

Hardness ranged from 27.3 mg/l to 32.1 mg/l. The concentration ranges of Cr and Pb are well below their associated fresh water aquatic life chronic HAC. The criteria were not exceeded by any of the Cr or Pb samples.

3.2 SEDIMENT TOXICITY EVALUATION

To complete the WQA, sediment quality in the Liberty Reservoir was evaluated using 10-day survival and growth whole sediment tests with the freshwater amphipod *Hyallela azteca.* This species was chosen because of its ecological relevance to the waterbody of concern. *H. azteca* is an EPA-recommended test species for assessing the toxicity of freshwater sediments (EPA, 2000). Four surficial sediment samples were collected using a petite ponar dredge (top 2 cm) by Chesapeake Biological Laboratory (CBL) from Liberty Reservoir. The sediment stations

Table 10: Sediment Toxicity Test Results

Sample	Amphipod Survival (#)	Amphipod Weight (mg)	Average Amphipod Survival (%)	Average Amphipod Weight (mg)
Control A	9	0.159	91.3	0.172
Control B	9	0.181		
Control C	10	0.182		
Control D	10	0.183		
Control E	7	0.184		
Control F	9	0.156		
Control G	10	0.176		
Control H	9	0.157		
LI-01	10	0.274	97.5	0.244
LI-01	10	0.231		
LI-01	9	0.227		
LI-01	10	0.224		
LI-01	9	0.269		
LI-01	10	0.243		
LI-01	10	0.223		
LI-01	10	0.262		
LI-02	9	0.257	95	0.252
LI-02	10	0.252		
LI-02	10	0.307		
LI-02	9	0.258		
LI-02	9	0.24		
LI-02	9	0.23		
LI-02	10	0.221		
LI-02	10	0.252		
LI-03	10	0.244	97.5	0.241
LI-03	10	0.204		
LI-03	10	0.234		
LI-03	10	0.205		
LI-03	8	0.233		
LI-03	10	0.26		
LI-03	10	0.281		
LI-03	10	0.264		
LI-04	10	0.219	97.5	0.213
LI-04	9	0.199		
LI-04	10	0.213		
LI-04	10	0.197		
LI-04	10	0.226		
LI-04	10	0.218		
LI-04	9	0.227		
LI-04	10	0.201		

correspond to the four monitoring stations sampled in the water column surveys. Refer back to Figure 1 for station locations. Sediment toxicity test results are presented in Table 10. Ten amphipods were exposed to the sediment in each sample test. The table displays amphipod survival (#), amphipod weight (mg), average amphipod survival (%), and average amphipod weight (mg).

The test considers two performance criteria, which are survival and growth. For the test to be valid the average survival in control samples must be greater than 80% and there must be sufficient growth. Survival of amphipods in the field sediment samples was not significantly different than the 91.3 % average survival demonstrated in the control samples [$p < 0.05$]. Field sediment sample average survival results were 97.5, 97.5, 95 and 97.5 percent. No sediment samples in the Liberty Reservoir exhibited toxicity contributing to mortality. Similarly, measured growth in the field sediment samples was not significantly different than in the control samples [$p < 0.05$]. In fact, growth in all of the reservoir samples was greater than in the control sediments. The weight of amphipods at the end of the growth period observed in the field sediment samples ranged from 0.213 g to 0.252 g while the weight observed in the control sample was 0.172 g. No sediment samples exhibited toxicity contributing to a reduction in growth.

4.0 CONCLUSION

The WQA shows that water quality standards for Cr or Pb are being achieved. Water column samples collected at four monitoring stations in the Liberty Reservoir, from May 2001 to July 2001, demonstrate that numeric water quality criteria are being met. Bottom sediment samples collected at four monitoring stations, and used for bioassay toxicity tests, demonstrate no impacts on survival and growth. Barring the receipt of any contradictory data, this information provides sufficient justification to revise Maryland's 303(d) list to remove Cr and Pb as impairing substances in the Liberty Reservoir impoundment.

5.0 REFERENCES

Baker, J.E., Ko, F., Burrell, T., Falco, K., Burley, E. *Upper Western Shore Chemical Contaminant Survey 2001 - 2002, Final Data Report: Streamwater Trace Metals and Nutrients*. University of MD, Chesapeake Biological Laboratory, August 20, 2002.

Coastal Environmental Service, Inc. *Patapsco/Back River Watershed Study*, prepared for the MDE and TARSA, September 30, 1995.

COMAR 26.08.02.02-2G. *Numerical Criteria for Toxic Substances in Surface Waters*.

COMAR 26.08.02.08J. *Stream Segment Designations***.**

Fisher, D., Yonkos, L., Ziegler, G., Shepard, M. *Assessment of Sediment Toxicity in Back River, Middle River and in Three Reservoirs*. University of MD, Wye Research and Education Center, May 20, 2002.

Maryland Department of Planning, 2000, 2000 Land Use, Land Cover Map Series.

Soil Conservation Service (SCS). *Soil Survey of Baltimore County, MD*, 1976

U.S. Environmental Protection Agency. *Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates*. Second Ed. EPA-600-R-99-064. U.S. Environmental Protection Agency, Duluth, MN. 192 pp. 2000.

U.S. Environmental Protection Agency. *National Recommended Water Quality Criteria: 2002*. EPA-822-R-02-047. November 2002.