Water Quality Analysis of Zinc and Lead in Bodkin Creek, Anne Arundel County, Maryland

FINAL

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Submitted to:

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List of Abbreviations

AVS	Acid Volatile Sulfide
BDL	Below Detection Limits
CBL	Chesapeake Biological Laboratory
cm	Centimeter
COMAR	Code of Maryland Regulations
Cu	Copper
CWA	Clean Water Act
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EPA	U.S. Environmental Protection Agency
ERL	Effects Range Low
ERM	Effects Range Median
HAC	Hardness Adjusted Criteria
LEL	Lowest-observed Effects Limit
LSD	Least Significant Difference
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MET	Minimum Effects Threshold
MRLC	Multi Resolution Land Cover
mg/l	Milligrams per Liter
NPDES	National Pollution Discharge Elimination System
NWS	National Weather Service
Pb	Lead
PEC	Probable Effects Concentration
PEL	Probable Effects Limit
ppt	Parts per Thousand
SCS	Soil Conservation Service
SEL	Severe Effects Limit
SEM	Simultaneously Extracted Metals
SHA	State Highway Administration
SQG	Sediment Quality Guideline
SSURGO	Soil Survey Geographic
TEC	Threshold Effects Concentration
TEL	Threshold Effects Limit
TET	Toxic Effects Threshold
TMDL	Total Maximum Daily Load
UMCES	University of Maryland Center for Environmental Sciences
USGS	United States Geological Survey
WER	Water Effects Ratio
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
µg/l	Micrograms per Liter
Zn	Zinc

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. 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) for the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

Bodkin Creek (basin code 02130902), located in Anne Arundel County, was identified on the State's list of WQLSs as impaired by nutrients (1996 listing), suspended sediments (1996 listing), copper (Cu) (1996 listing), zinc (Zn) (1996 listing), lead (Pb) (1996 listing), and impacts to biological communities (2004 listing). All impairments were listed for the tidal waters except for impacts to biological communities, which are listed for the non-tidal region. Code of Maryland Regulations (COMAR) 26.08.02.03-1-B(3)(j)(i) defines Bodkin Creek, as an estuarine waterbody. This report provides an analysis of recent monitoring data, including hardness data, which shows that the aquatic life criteria and designated uses associated with Zn and Pb are being met in Bodkin Creek. In addition, the results of an ambient sediment bioassay conducted in Bodkin Creek, by the University of Maryland Wye Research Center, established that there is no toxicity in the sediment as a result of Zn and Pb or other toxics contamination. The information (P. Jiapizian, personal communication 2001) used for listing Zn and Pb is suspect due in part to sampling and analysis methods available at the time, and assessment inconsistencies that led to the listing in 1996.

This report provides an analysis of recent monitoring data, including hardness data, which shows that the aquatic life uses and criteria are being met in Bodkin Creek watershed, and 303(d) impairment listings associated with Zn and Pb are not supported by the analyses contained herein. The analyses support the conclusion that a TMDL for Zn and Pb is not necessary to achieve water quality standards. Barring the receipt of any contradictory data, this report will be used to support the removal of Bodkin Creek from Maryland's list of WQLSs for Zn 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. The listings for nutrients, suspended sediments, Cu, and impacts to biological communities will be addressed separately at a future date.

Although the waters of Bodkin Creek watershed do not display signs of toxic impairments due to Zn and Pb, the State reserves the right to require additional pollution controls in Bodkin Creek watershed if evidence suggests that Zn and/or Pb from the basin is 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) for 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 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 standards being met; or 4) correction to errors made in the initial listing.

Bodkin Creek (basin code 02130902) was identified on the State's 1996 303(d) list as impaired by nutrients, suspended sediments, copper (Cu), lead (Pb), and zinc (Zn) with an additional listing of impacts to biological communities in 2004. All impairments were listed for the tidal waters except for the impacts to biological communities, which are listed for the non-tidal region. Code of Maryland Regulations (COMAR) defines the Bodkin Creek area, as a tidal estuarine waterbody.

The informational basis (P. Jiapizian, personal communication, 2001) for this listing contended that mean levels of Pb and Zn exceeded the EPA chronic aquatic life criteria for Pb, and both the acute and chronic criteria for Zn at the time of listing (1996). Although criteria were "exceeded", several methodological flaws in the monitoring and listing assessment used in 1996 exist. First, unfiltered (total metals) samples were compared to dissolved criteria. Second, current criteria for Zn and Pb rely on a hardness correction – since no hardness data existed, criteria thresholds using a 100 mg/L "default" hardness value were used for the assessment. Finally, station means for each analyte were calculated setting non-detects at ½ the detection limit. While this procedure may have been appropriately conservative at the time, the sensitivity of analytical instrumentation has improved dramatically, and samples taken currently for Zn and Pb have appropriate detection limits that are well below their respective criteria values.

A Water Quality Analysis (WQA) of Zn and Pb for the tidal waters of Bodkin Creek was conducted by the Maryland Department of the Environment (MDE) using recent water column chemistry data and sediment toxicity data. A data solicitation for these metals was conducted by MDE and all readily available data from the past five years was considered. Results show no impairment for Zn and Pb. This report will be used to support the removal of the 8-digit basin from Maryland's list of WQLSs for Zn and Pb. Accordingly, TMDLs for Zn and Pb are not required for Bodkin Creek. The listings for nutrients, suspended sediments, copper, and impacts to biological communities will be addressed separately at a future date.

The remainder of this report lays out the general setting of the waterbody within the Bodkin Creek watershed, presents a discussion of the water quality characterization process, and provides conclusions with regard to the characterization.

2.0 GENERAL SETTING

The Bodkin Creek watershed is located on the western shore of the Chesapeake Bay, near the confluence of the Patapsco River and the Chesapeake Bay. The watershed has 896 acres of open water and drains 5,683 acres of land within Maryland's Western Shore (Figure 1). It is located in Anne Arundel County and is bounded by the Baltimore Harbor watershed to the west and by the Chesapeake Bay proper to the east. Bodkin Creek proper is composed of three small creeks Back Creek, Main Creek, and Wharf Creek with ninety percent of the watershed being tidal. Of the approximately 24 stream miles in the watershed only 2.5 miles of Main Creek's headwaters is non-tidal. The tidal portion of the river is approximately 24.01 miles (38.6 km) in length, from its confluence with Chesapeake Bay. The depths of the river range from about 6 inches (0.15 m) in the headwaters to greater than 8-10 feet (2.4-3.0 m) at the middle of the river. At the mouth of the river, the depth ranges from 7-9 feet (2.1-2.7 m). Based on Maryland Department of Planning (MDP) 2002 GIS land use data, the Bodkin Creek watershed land use are divided as follow: urban 2,730 acres (48%), agriculture 176 acres (3%), forest 2,761 acres (49%), and wetland 16 acres (<1.0%). The urban land use identified includes medium–density and high-density residential (Figure 2).

The Bodkin Creek watershed is entirely within the coastal plain**.** The Atlantic Coastal Plain surficial geology is characterized by thick, unconsolidated marine sediments deposited over the crystalline rock of the neighboring piedmont province *(Coastal Environmental Services, 1995).*

Limited commercial fishing is conducted in the tidal zone of the Bodkin Creek. Recreational fishing and general water contact recreation can be found most of the year.

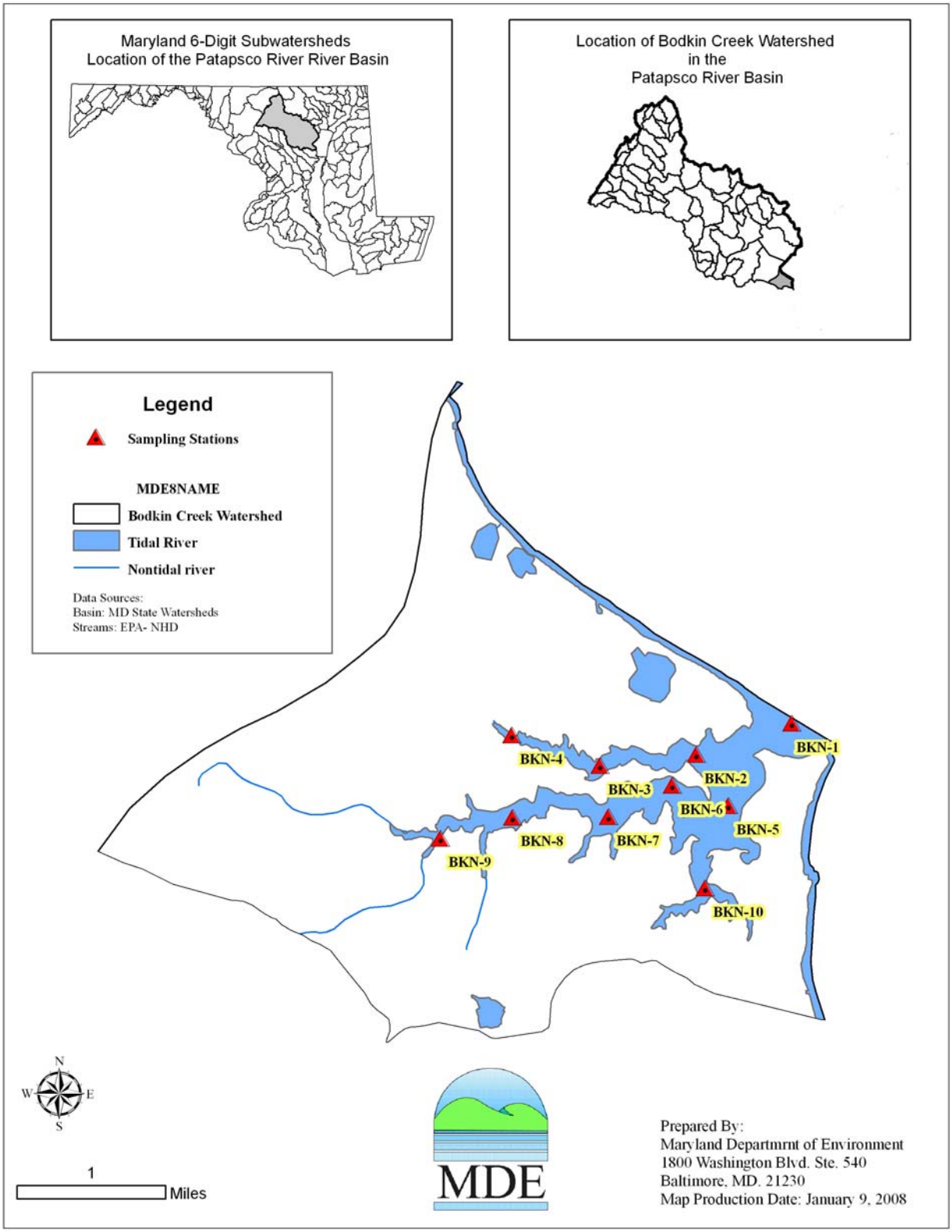

Figure 1: Location Map of the Bodkin Creek Drainage Basin

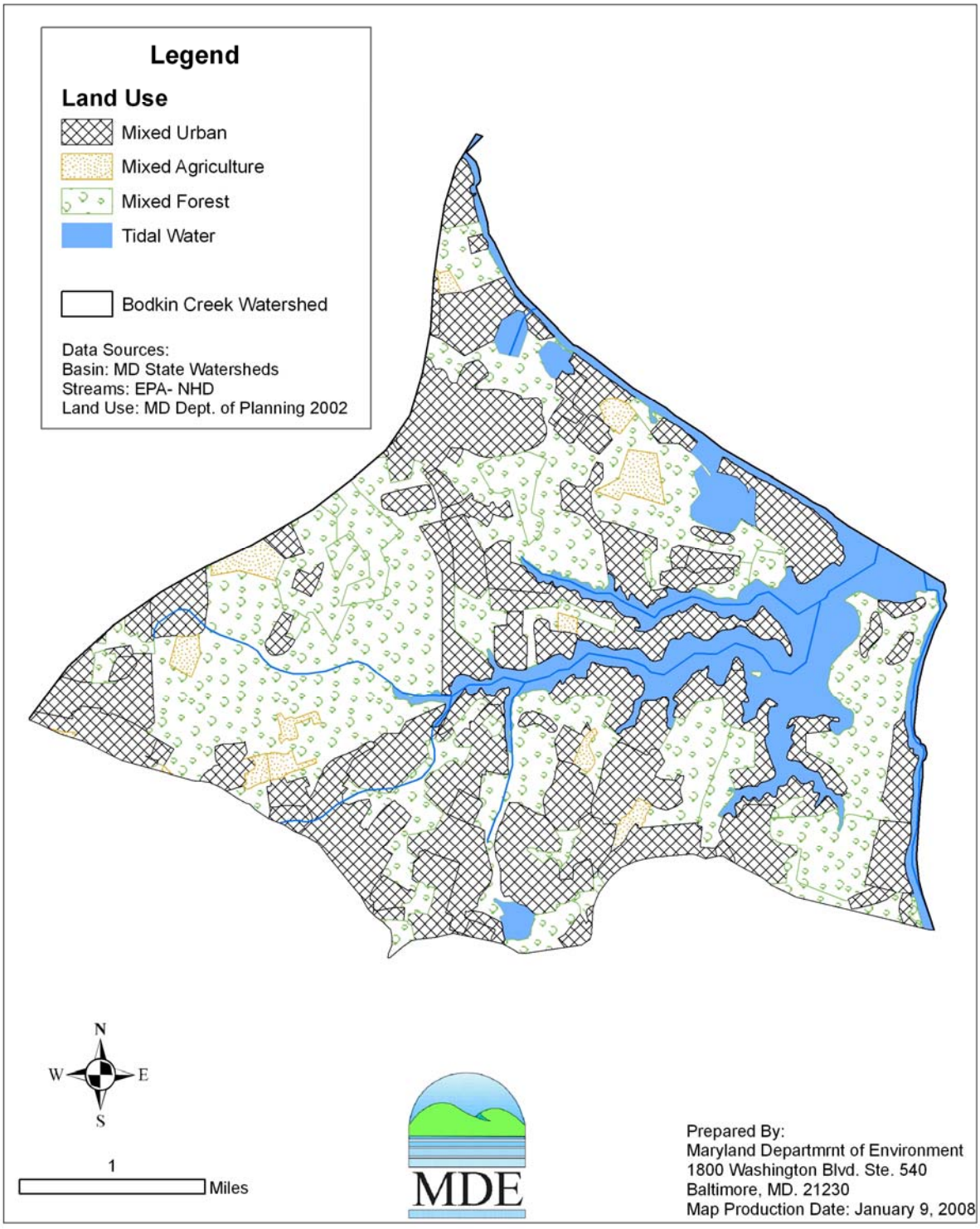

Figure 2: Land Use Map of the Bodkin Creek Drainage Basin

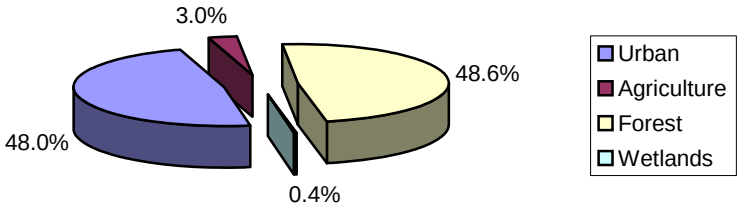

Figure 3: Proportions of Land Use in the Bodkin Creek Watershed

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 different designated uses 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 (COMAR 26.08.02.08K) for the Bodkin Creek is Use I – water contact recreation, fishing, and protection of aquatic life and wildlife. COMAR 26.08.02.03-1(B)(3)(j)(i) defines the Bodkin Creek basin considered in this WQA as being estuarine. Salinity concentrations for Bodkin Creek are between 2.7 and 9.1 ppt. Based on EPA guidance, when salinity concentrations are between 1.0 and 10.0 ppt the more stringent of the freshwater and saltwater criteria is applied (EPA, Nov. 2001). Table 1 displays the numeric water quality criteria (COMAR 26.08.02.03-2G). The water column data presented in Section 3.1, Table 5, shows that concentrations of Zn and Pb in the water column do not exceed water quality criterion. An ambient sediment bioassay conducted in 2006 by the University of Maryland Wye Research Center and sediment chemistry analysis conducted by the University of Maryland Center for Environmental Science (UMCES) in Bodkin Creek establishes that there is no toxicity in the sediment bed as a result of Zn and/or Pb contamination. The water column and sediment in the Bodkin Creek are therefore, not impaired by Zn or Pb. Thus the designated uses are supported and the water quality standard is being met.

Water column surveys, used to support this WQA, were conducted by UMCES at ten stations throughout Bodkin Creek from November 2005 to April 2007. The sampling dates were as follows: 11/01/05 (winter dry weather); 4/30/07 (spring wet weather), 6/14/06 (summer dry weather).

Table 1: Numeric Water Quality Criteria*

Metal	Freshwater Hardness Adjusted Criteria (□g/l)	Salt Water Aquatic Life Acute Criteria (□g/l)	Salt Water Aquatic Life Chronic Criteria (□g/l)
Zn	382.4	90	81
Pb	10.94	210	8.1

*Criteria based on default hardness of 100 mg/L

Sediment bulk samples were also collected on 6/14/06 at five stations. Sediment samples were chemically analyzed for total metals in the sediment, dissolved metals in the porewater and toxicity using a standard EPA 28 day amphipod test. Table 2 shows the list of stations with their geographical coordinates. The station locations are presented in Figure 4.

Table 2: Sample Stations for Bodkin Creek

Station	Station Description	Latitude	Longitude
BKN-1	Rock Run (west bank) discharge to LSR @ Rock Run Rd.	39.135	-76.435
BKN-2	Back Creek at discharge	39.132	-76.447
BKN-3	Main Creek at discharge	39.131	-76.459
BKN-4	Southern embayment outlet	39.134	-76.470
BKN-5	Southern embayment outlet at convergence of two creeks	39.127	-76.443
BKN-6	Main Creek halfway up creek	39.129	-76.450
BKN-7	Back Creek halfway up creek	39.126	-76.458
BKN-8	Watershed input from southern trib of Main Creek	39.126	-76.470
BKN-9	Watershed input from western trib of Main Creek	39.124	-76.479
BKN-10	Watershed input from western trib of Back Creek	39.119	-76.446

Since Bodkin Creek is defined as an estuarine water body the hardness adjusted freshwater chronic criteria will be calculated and compared to the saltwater chronic criteria. The criteria with the lowest value will be compared with the sample concentration to determine if there is a violation. For the water quality evaluation, a comparison is made between Zn and Pb dissolved water column concentrations and saltwater aquatic life chronic criterion, the most stringent of the numeric water quality criterion for Zn and Pb.

The State uses water hardness adjustment to calculate fresh water aquatic life chronic criteria for those metals whose toxicity is a function of total hardness. According to EPA's National Recommended Water Quality Criteria (EPA, November 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 criterion (EPA, July 2002). A lower limit may result in criteria that is less protective of the water quality standard. In analyses where available hardness data indicates a value below 25 mg/L, the Department may perform additional analyses to insure data quality objectives for the assessments were met. When data is of questionable quality, the Department will take additional samples to establish the validity of the initial assessment.

Under circumstances where a water quality criterion exceedance is the result of a hardness adjustment below 25 mg/l, the State will perform a scientific review of the following conditions to determine if the exceedance is valid:

A. Presence/absence of sensitive species in the water body of concern.
B. Existence of other environmental conditions (e.g. high Dissolved Organic Carbon (DOC)), which might mitigate the toxicity of metals due to competitive binding/complexation of metals.

This review is necessary because of the scientific uncertainty existing for hardness-toxicity relationships below 25 mg/l due to limited toxicity test data used to develop the relationship.

The HAC equation for Zn is as follows (EPA, 2002):

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

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

The HAC parameters for Zn and Pb are presented in Table 3 (EPA, 2002).

Table 3: HAC Parameters (Fresh Water Aquatic Life Chronic Criteria)

Chemical	Slope (m)	Y Intercept (b)	Conversion Factor (CF)
Zn	0.8473	0.884	0.978
Pb	1.273	-4.705	1.46203-[(In hardness)(0.145712)]

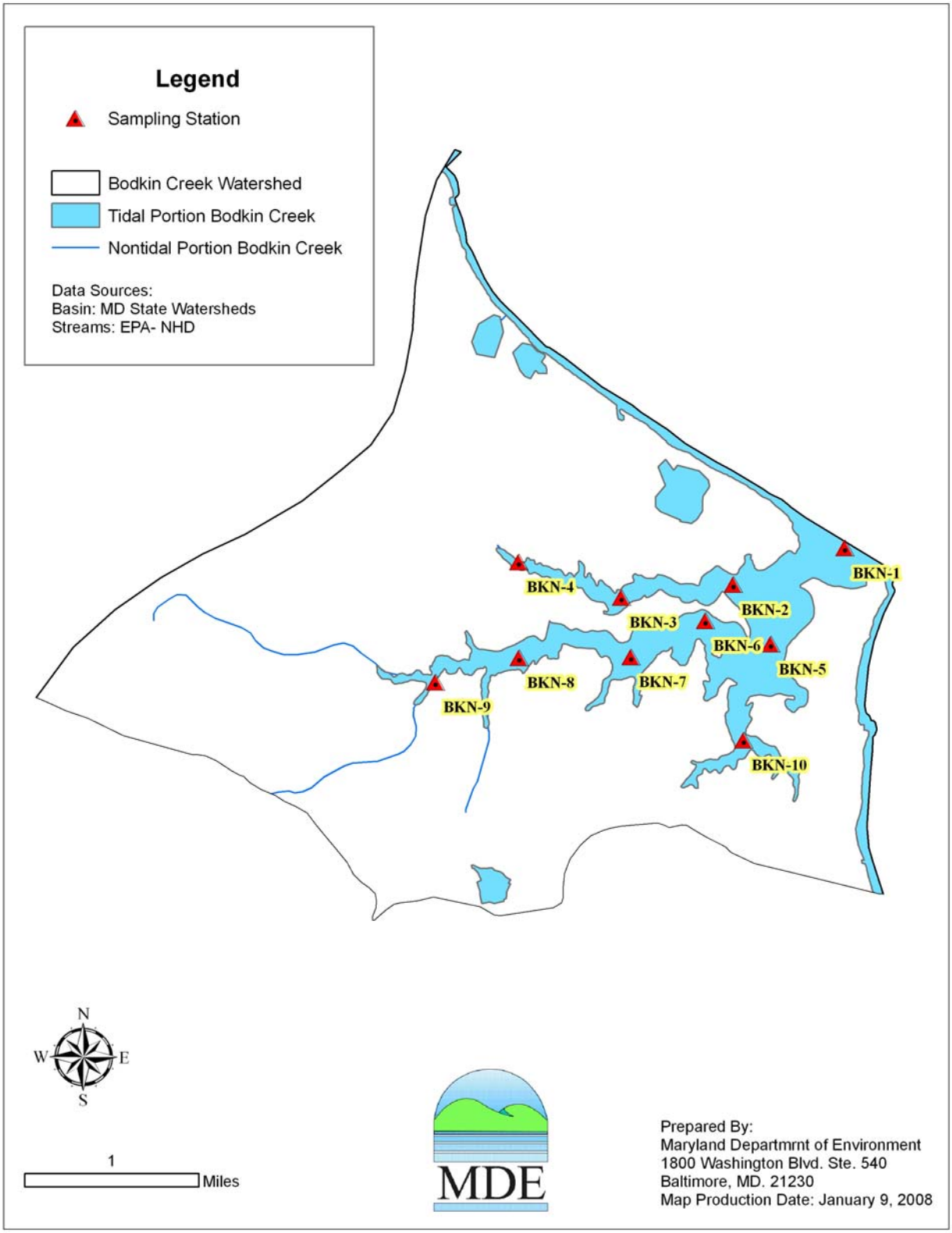

Figure 4: Bodkin Creek Sample Station Location Map

3.1 WATER COLUMN EVALUATION

A data solicitation for metals was conducted by MDE, and all readily available data from the past five years was considered in the WQA. The water column data, are presented in Table 4 for freshwater and saltwater criteria (Heyes, 2006). The criteria with the lowest value will be compared with the sample concentration. Since all hardness values are above 400 (mg/l), MDE will use the upper limit of 400 mg/l in calculating the hardness adjusted criteria (HAC). Table 4 displays hardness (mg/l), detection limit (µg/l), sample concentration (µg/l) freshwater HAC criteria (µg/l), saltwater chronic criteria, by sampling date. For example, in Table 4 for the sampling date of 11/01/2005 at station BKN1 the hardness is 1438 mg/l (the upper limit of 400 mg/l will be used), the hardness-adjusted chronic criterion for Zn is 382.40 (µg/l). The saltwater chronic criteria is 8.1 and the Zn sample concentration is 1.33 µg/l. The Zn water column data is also presented in Figure 5.

Table 4: Bodkin Creek Water Column Data (Zn)

Station	Hardness (mg/l)	Salinity (g/L)	Sampling Date	Detection Limit (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Saltwater Chronic Criteria (µg/l)
BKN1	1438	7.3	11/01/2005	0.08	BDL**	382.40	81
	1451	9.1	06/14/2006		1.91	382.40	81
	542.3	3.1	04/30/2007		BDL**	382.40	81
BKN2	1246	7.6	11/01/2005	0.08	2.45	382.40	81
	1121	9	06/14/2006		2.64	382.40	81
	523.6	2.7	04/30/2007		2.46	382.40	81
BKN3	1285	8.3	11/01/2005	0.08	1.77	382.40	81
	1190	8.6	06/14/2006		3.49	382.40	81
	561	3	04/30/2007		BDL**	382.40	81
BKNR4	1208	8.3	11/01/2005	0.08	3.86	382.40	81
	1344	8.5	06/14/2006		3.92	382.40	81
	486.2	2.8	04/30/2007		3.15	382.40	81
BKN5	1198	8	11/01/2005	0.08	2.50	382.40	81
	1346	8.9	06/14/2006		2.09	382.40	81
	561.0	2.8	04/30/2007		2.91	382.40	81
BKN6	1342	8.4	11/01/2005	0.08	1.60	382.40	81
	1140	8.8	06/14/2006		2.16	382.40	81
	512.4	3	04/30/2007		2.92	382.40	81

* Fresh Water Aquatic Life Chronic Criterion (hardness adjusted)
** Below Detection Limit

Table 4: Bodkin Creek Water Column Data (Zn) Cont'd

BKN7	1342	8.4	11/01/2005	0.08	3.77	382.40	81
	1280	8.6	06/14/2006		2.65	382.40	81
	542.3	3.2	04/30/2007		BDL**	382.40	81
BKN8	1198	8.4	11/01/2005	0.08	9.84	382.40	81
	1281	8.3	06/14/2006		5.60	382.40	81
	561.0	3.4	04/30/2007		4.13	382.40	81
BKN9	1131	8	11/01/2005	0.08	3.92	382.40	81
	1109	7.6	06/14/2006		4.71	382.40	81
	475.0	3.2	04/30/2007		3.73	382.40	81
BKN10	2128	8.1	11/01/2005	0.08	2.73	382.40	81
	1467	8.8	06/14/2006		3.13	382.40	81
	467.5	3	04/30/2007		BDL**	382.40	81
	508.6	3	04/30/2007		7.83	382.40	81

* Fresh Water Aquatic Life Chronic Criterion (hardness adjusted)
** Below Detection Limit

The range of concentrations for Zn and Pb sampled in the field survey is as follows:

Zn = 0.99 to 9.84 µg/l
Pb = 0.01 to 0.94 µg/l

Hardness ranged from 475.0 mg/l to 1451 mg/l. The observed concentrations for Zn in the water column were between 8 and 80 times lower than their respective saltwater chronic criteria, on average, for each sample. The observed concentrations for Pb in the water column were between 3 and 250 times lower than their respective saltwater chronic criteria, on average, for each sample.

Table 5: Bodkin Creek Water Column Data (Pb)

Station	Hardness (mg/L)	Date	Detection Limit (µg/l)	Sample (µg/L)	Criteria* (µg/l)	Saltwater Chronic Criteria
BKN-1	1438	11/01/05	0.078	BDL**	10.94	8.1
	1451	06/14/06		0.08	10.94	8.1
	542.3	04/30/07		BDL**	10.94	8.1
BKN-2	1246	11/01/05	0.078	BDL**	10.94	8.1
	1121	06/14/06		0.25	10.94	8.1
	523.6	04/30/07		BDL**	10.94	8.1
BKN-3	1285	11/01/05	0.078	BDL**	10.94	8.1
	1190	06/14/06		0.43	10.94	8.1
	561.0	04/30/07		BDL**	10.94	8.1
BKN-4	1208	11/01/05	0.078	BDL**	10.94	8.1
	1344	06/14/06		0.55	10.94	8.1
	486.2	04/30/07		BDL**	10.94	8.1
BKN-5	1198	11/01/05	0.078	BDL**	10.94	8.1
	1346	06/14/06		0.24	10.94	8.1
	561.0	04/30/07		BDL**	10.94	8.1
BKN-6	1342	11/01/05	0.078	BDL**	10.94	8.1
	1140	06/14/06		0.25	10.94	8.1
	512.4	04/30/07		BDL**	10.94	8.1
BKN-7	1342	11/01/05	0.078	BDL**	10.94	8.1
	1280	06/14/06		0.25	10.94	8.1
	542.3	04/30/07		BDL**	10.94	8.1
BKN-8	1198	11/01/05	0.078	0.12	10.94	8.1
	1281	06/14/06		0.82	10.94	8.1
	561.0	04/30/07		BDL**	10.94	8.1
BKN-9	1131	11/01/05	0.078	0.08	10.94	8.1
	1109	06/14/06		0.94	10.94	8.1
	475.0	04/30/07		BDL**	10.94	8.1
BKN-10	2128	11/01/05	0.078	0.02	10.94	8.1
	1467	06/14/06		0.27	10.94	8.1
	467.5	04/30/07		BDL**	10.94	8.1
	508.6	04/30/07		0.15	10.94	8.1

* Fresh Water Aquatic Life Chronic Criterion (hardness adjusted)
** Below Detection Limit

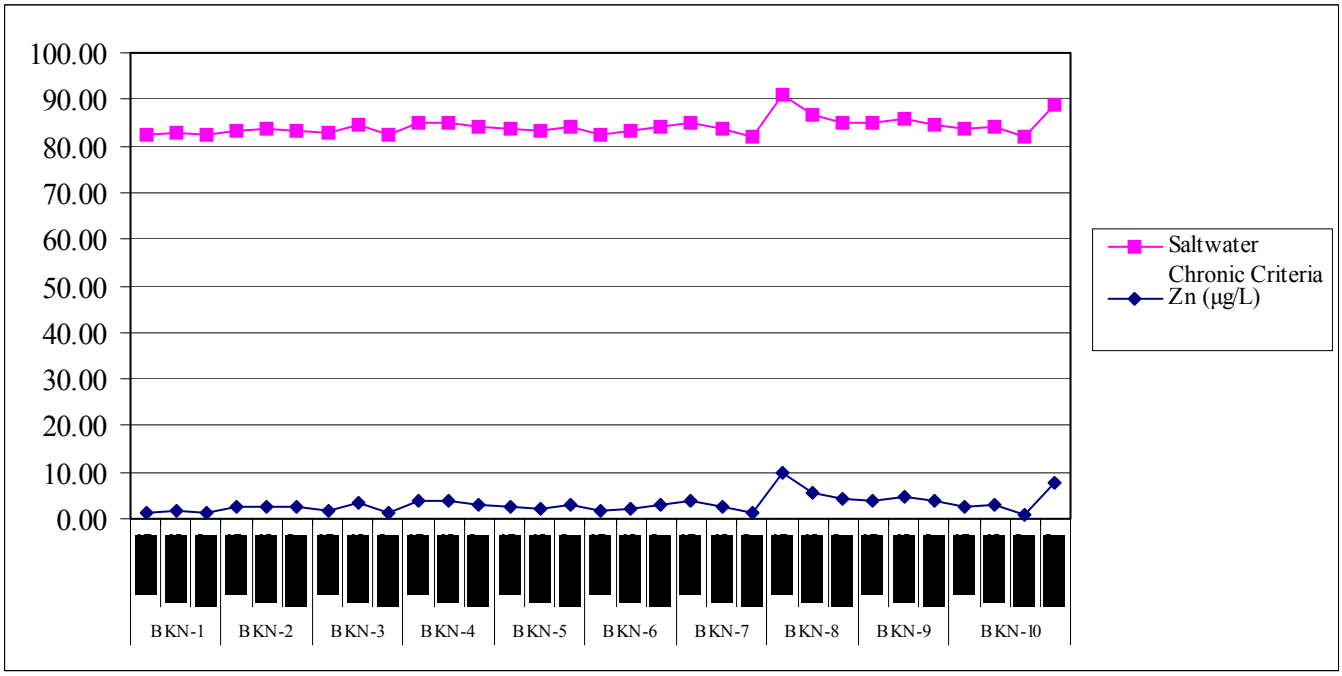

Figure 5: Bodkin Creek Water Column Data (Zn)

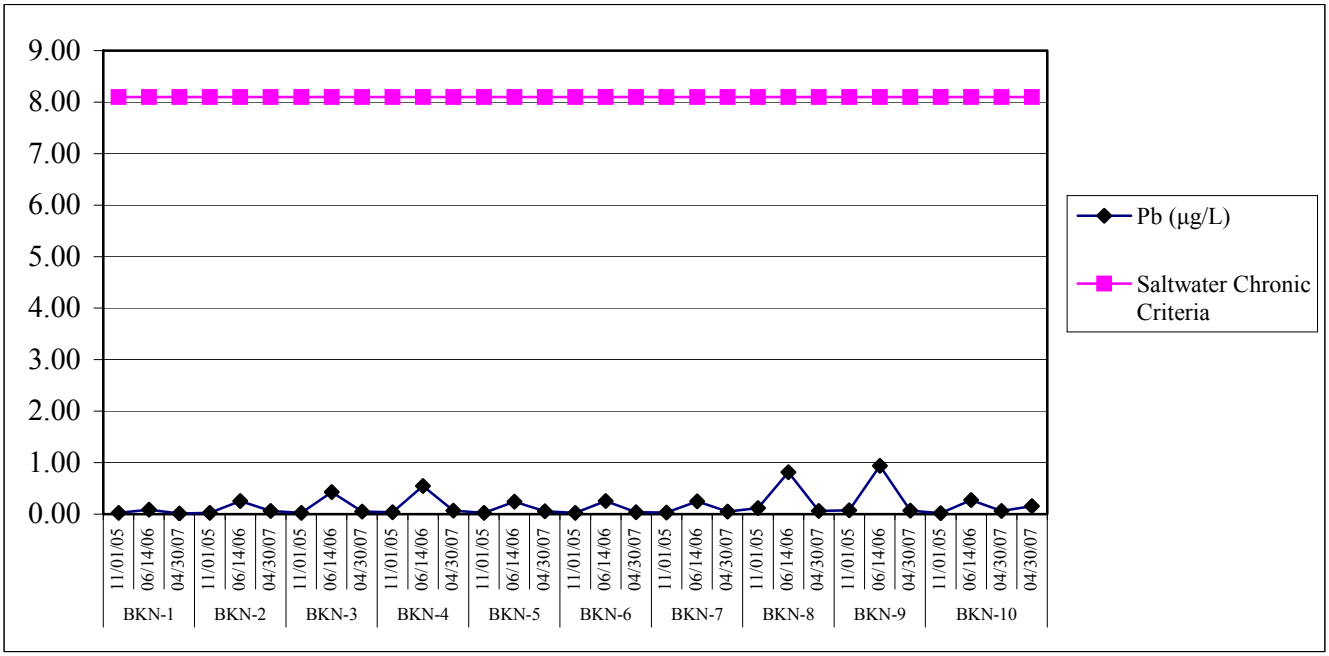

Figure 6: Bodkin Creek Water Column Data (Pb)

3.2 SEDIMENT QUALITY EVALUATION

To complete the WQA, whole sediment toxicity at all stations was assessed using a 10-d survival and growth test with the freshwater amphipod *Hyalella azteca* (Fisher, 2007). In addition, for the estuarine stations in Bodkins Creek, both a 28-d survival, growth and reproduction test and a 10-d survival and growth test with the estuarine amphipod *Leptocheirus plumulosus* were used to assess whole sediment toxicity (Fisher, 2007). These species was chosen because of their practical and ecological relevance and for the availability of U.S. Environmental Protection Agency (U.S. EPA) recommended test methods for assessing the toxicity of freshwater and marine/estuarine sediments (U.S. EPA, 2000; U.S. EPA/U.S. ACE, 2001). Five surficial sediment samples were collected on 6/14/06 using a petite ponar dredge (top 2-3 cm) in Bodkin Creek. Control sediments were collected from the Wye River, from a depositional area previously characterized as low in contaminants (Fisher, personal communication). Refer back to Figure 4 for station locations. The results are presented in Table 6. Five replicates containing ten amphipods each were exposed to the contaminated sediment, as well as a control sediment, for testing. Table 6 displays the average survival and growth rate for each station and control. Table 6 (A) displays amphipod survival (#), amphipod growth rate (mg/day), neonates (#), average amphipod survival (%), average amphipod growth rate (mg/day) and average amphipod reproduction (neonates per survivor) for *Leptocheirus plumulosus* 28 day. Finally Table 6 (B) displays average amphipod survival (%) and average amphipod growth (mg dry weight) for *Hyalella azteca* 10 day.

The test considers three performance criteria: survival, growth rate, and reproduction. For the test to be valid the survival of control sample replicates must be greater than 80%, and there must be a measurable growth rate and reproduction of neonates in the control samples. Survival of amphipods in the field sediment samples was not significantly less than the average survival demonstrated in the control samples. This comparison was made using Fisher's Least Significance Difference (LSD) test ($\acute{\alpha} = 0.05$). The average survival for control samples in the test was 98.8%. The field sediment sample average survival results were no lower than 93.8%. No sediment samples in Bodkin Creek exhibited toxicity contributing to mortality.

Similarly, measurable average amphipod reproduction observed in the field sediment samples, which ranged from 0.17 to 0.27 growth for *Hyalella azteca* and 0.16 to 0.36 growth for *L. plumulosus* were not significantly less than the reproduction of 0.18 and 0.23 growth observed in the control samples for the test. This comparison was also made using Fisher's LSD test ($\acute{\alpha} = 0.05$). No sediment samples exhibited toxicity contributing to a lower reproduction.

Although there was some reduction in *L. plumulosus* growth in the BKN-5 sediments in both the 10-d and 28-d tests, these reductions were not significantly different from the control amphipod growth. The minimum significant difference (MSD) from the control amphipod weight that could be detected for the BKN-5 10-d *L. plumulosus* test was 46%, which is somewhat higher than normal due to replicate variability. The actual difference in weight at BKN-5 from the control amphipod weight was 30.4% in the 10-d test. The MSD was better (33%) for growth rate in the 28-d *L. plumulosus* test and much better for growth in the *H azteca* 10-d test (8.8%) in sediment from this station. The lack of a statistically significant growth reduction in either of these tests indicates that the sediment from BKN-5 was not toxic.

Table 6: Bodkin Creek Sediment Toxicity Test Results

	H. azteca 10-d		*L. plumulosus* 10-d		*L. plumulosus* 28-d		
	Survival	Growth	Survival	Growth	Survival	Growth Rate	Reproduction
	%	(mg)	%	(mg)	%	mg/Lepto/day	young/Lepto
Control*	98.8	0.18	81.3	0.23	87.0	0.064	5.1
BKN-1	95.0	0.27	71.3	0.19	89.0	0.045	3.1
BKN-3	93.8	0.18	81.3	0.36	77.0	0.071	7.3
BKN-5	97.5	0.17	67.5	0.16	71.0	0.044	5.1
BKN-7	98.8	0.19	80.0	0.24	84.0	0.076	11.8
BKN-10	93.8	0.19	61.3	0.27	82.0	0.074	9.4

Summary of results from the 2006 Metals Monitoring sediment toxicity tests

Table 6 (A): Metals Monitoring 2006 amphipod *Leptocheirus plumulosus* 28 day survival and growth sediment toxicity test results for Bodkin Creek

Sample	Amphipod Surviving #	Amphipod Growth rate[1] (mg/l)	Neonates #	Average Amphipod % Survival	Average Amphipod Growth rate (mg/l)	Average Amphipod Neonates/ survivor
Control A	17	0.089	5.2	87.0	0.064	5.1
Control B	18	0.041	4.4			
Control C	17	0.067	7.2			
Control D	20	0.058	5.9			
Control E	15	0.064	2.9			
BKN-1 A	17	0.035	4.5	89.0	0.045	3.1
BKN-1 B	20	0.045	2.2			
BKN-1 C	20	0.052	2.9			
BKN-1 D	14	0.048	3.4			
BKN-1 E	18	0.043	2.4			
BKN-3 A	20	0.072	5.9	77.0	0.071	7.3
BKN-3 B	8	0.037	8.5			
BKN-3 C	17	0.079	7.7			
BKN-3 D	18	0.083	6.7			
BKN-3 E	15	0.084	8.0			

Table 6 (A): Metals Monitoring 2006 amphipod *Leptocheirus plumulosus* 28 day survival and growth sediment toxicity test results for Bodkin Creek (Cont'd)

Sample	Amphipod Surviving #	Amphipod Growth rate[1] (mg/l)	Neonates #	Average Amphipod % Survival	Average Amphipod Growth rate (mg/l)	Average Amphipod Neonates/ survivor
BKN-5 A	4	0.033	8.3	71.0	0.044	5.1
BKN-5 B	15	0.074	9.0			
BKN-5 C	19	0.045	4.2			
BKN-5 D	13	0.025	2.5			
BKN-5 E	20	0.041	1.8			
BKN-7 A	18	0.078	9.5	84.0	0.076	11.8
BKN-7 B	16	0.070	14.0			
BKN-7 C	19	0.076	12.8			
BKN-7 D	16	0.080	10.0			
BKN-7 E	15	0.076	12.6			
BKN-10 A	18	0.071	6.6	82.0	0.074	9.4 (2.39)
BKN-10 B	19	0.078	7.1			
BKN-10 C	17	0.080	11.4			
BKN-10 D	14	0.056	11.7			
BKN-10 E	14	0.087	10.2			

Table 6 (B): 2006 Metals Monitoring amphipod *Hyalella azteca* 10-day survival and growth sediment toxicity test results for Bodkin Creek

Station	# Surviving amphipods	Amphipod dry wt. (mg)	Amphipod % Survival (SD)	Amphipod mg. dry wt. (SD)
Control A	10	0.18	98.8 (3.54)	0.18 (0.015)
Control B	9	0.20		
Control C	10	0.19		
Control D	10	0.18		
Control E	10	0.18		
Control F	10	0.15		
Control G	10	0.18		
Control H	10	0.19		
BKN-1 A	9	0.26	95.0 (7.56)	0.27 (0.013)
BKN-1 B	10	0.27		
BKN-1 C	9	0.28		
BKN-1 D	10	0.27		
BKN-1 E	8	0.27		
BKN-1 F	10	0.27		
BKN-1 G	10	0.24		
BKN-1 H	10	0.28		
BKN-3 A	9	0.16	93.8 (7.44)	0.18 (0.015)
BKN-3 B	10	0.18		
BKN-3 C	8	0.18		
BKN-3 D	10	0.19		
BKN-3 E	9	0.21		
BKN-3 F	10	0.19		
BKN-3 G	10	0.18		
BKN-3 H	9	0.17		
BKN-5 A	10	0.18	97.5 (4.63)	0.17 (0.006)
BKN-5 B	9	0.16		
BKN-5 C	10	0.17		
BKN-5 D	9	0.17		
BKN-5 E	10	0.17		
BKN-5 F	10	0.17		
BKN-5 G	10	0.17		
BKN-5 H	10	0.18		

4.0 CONCLUSION

The WQA establishes that the water quality standard for Zn and Pb are being met in the Bodkin Creek watershed. The water column data collected in November 2005, June 2006, and April 2007 at ten monitoring stations (presented in Section 3.1, Table 4) shows that concentrations of Zn and Pb in the water column do not exceed the water quality criterion. An ambient sediment bioassay conducted in Bodkin Creek, by the University of Maryland Wye Research Center, established that there is no toxicity in the sediment as a result of Zn and Pb or other toxics contamination. Therefore, Zn and Pb do not impair the water column and sediment in the Bodkin Creek. Thus, the designated uses are supported and the water quality standard is being met.

Barring the receipt of contradictory data, this report will be used to support a Zn and Pb listing change for Bodkin Creek from Category 5 ("water bodies impaired by one or more pollutants requiring a TMDL") to Category 2 ("Surface waters that are meeting some standards and have insufficient information to determine attainment of other standards"), when MDE proposes the revision of Maryland's 303(d) list for public review in the future. Although the waters of Bodkin Creek watershed do not display signs of toxic impairments due to Zn and Pb, the State reserves the right to require additional pollution controls in Bodkin Creek watershed if evidence suggests that Zn and Pb from the basin is contributing to downstream water quality problems.

5.0 REFERENCES

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

COMAR 26.08.02.03-2G. *Numerical Criteria for Toxic Substances in Surface Waters*.

COMAR 26.08.02.03-(B)(3)(g). *Toxic Substance Water Quality Criteria for Surface Waters.*

COMAR 26.08.02.08K. *Stream Segment Designations.*

Fisher, D., Osborn, M., Ziegler, G. *Toxicity of Sediments from the 2006 Metals Monitoring Program to Hyalella azteca and Leptocheirus plumulosus: Bodkins Creek, Northeast River, Little Patuxent River, Middle Patuxent River, and Lower Susquehanna River.* University of Maryland System – Agricultural Experiment Station (Wye Research and Education Center), November 2007.

Heyes, A. Baker, J., Fisher, D., *Maryland Metals Contaminant Survey of the: Lower Susquehanna River, Bodkin Creek, Jones Falls, Lower North Branch of Patapsco, Little Patuxent River and Middle Patuxent River*. University of MD, Wye Research and Education Center, 2006.

Maryland Department of the Environment. *2006 List of Impaired Surface Waters [303(d) List] and Integrated Assessment of Water Quality in Maryland: Submitted in Accordance with Sections 303(d) and 305(b) of the Clean Water Act.* April 2006.

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

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. Duluth, MN. 192 pp. 2000.

U.S. Environmental Protection Agency. *Consolidated Assessment and Listing Methodology: Toward a Compendium of Best Practices*. 1st edition. July 2002.

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

U.S. Environmental Protection Agency/U.S. Army Corp on Engineers. *Methods for Assessing the Chronic Toxicity of Sediment associated Contaminants with Leptocheirus plumulosus*. First Edition. EPA/600/R-01/020. Washington, D.C. 2001.