A Methodology for Addressing Sediment Impairments in Maryland's Non-tidal Watersheds

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List of Abbreviations

B-IBI	Benthic Index of Biotic Integrity
CBP P5	Chesapeake Bay Program Phase V
CWA	Clean Water Act
EOF	Edge-of-Field
DNR	Department of Natural Resources
EOS	Edge-of-Stream
EPA	Environmental Protection Agency
ETM	Enhanced Thematic Mapper
F-IBI	Fish Index of Biotic Integrity
GIS	Geographic Information System
IBI	Index of Biotic Integrity
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
NPS	Non-Point Source
NRCS	Natural Resources Conservation Service
NRI	Natural Resources Inventory
RESAC	Regional Earth Science Applications Center
TMDL	Total Maximum Daily Load
TM	Thematic Mapper

Executive Summary

In 1996, as part of the requirements for the Clean Water Act, Maryland (MD) listed a total of 98 out of 138 potentially sediment impaired watersheds on the 303(d) list. The scale of these listings was based on Maryland 8-digit watersheds, which are on average approximately 75 square miles in area. The original 1996 sediment listings were determined based on watersheds expected or known to have relatively high sediment yield as a function of increased agriculture and/or development. In 2002, these sediment listings were then classified as either non-tidal, tidal or impoundments. The current 2004 State 303(d) list identifies a total of 29 non-tidal segments, 65 tidal segments, and 4 impoundments as impaired by sediment. This report proposes a methodology to address the non-tidal impairments in areas other than the coastal plain.

There are currently no specific numeric thresholds available in Maryland that correspond to the impact of sediment to the aquatic health of non-tidal stream systems. This report establishes a numeric sediment loading threshold that accounts for a sediment impact that is broadly defined to include erosional impacts, depositional impacts and water clarity, per the 2004 303(d) report. The numeric threshold will be based on the long-term average annual sediment load. Validation of the threshold will statistically identify a relationship between the sediment loading threshold and correlations with observed instream biological and physical habitat conditions.

Characterization of the stream aquatic health was based on the Maryland Department of Natural Resources (DNR) Maryland Biological Stream Survey (MBSS) survey fish and benthic Index of Biotic Integrity (IBI). Long-term average annual sediment loads were estimated for Maryland 8-digit watersheds using the CBP Phase V watershed model edge-of-stream (EOS) calibration target loading rates.

Maryland 8-digit watersheds were separated into groups either supporting benthic aquatic health or having an impaired benthic community. The groups were determined by the statistical analysis methodology applied in Maryland's biocriteria. This resulted in a total of 24 watersheds, with 12 watersheds in each group. Long-term average annual sediment loads were estimated for these watersheds using the CBP P5 watershed model EOS loads. Sediment loading distributions for the two watershed groups were compared using the sediment yield and the normalized sediment load (the load beyond the all-forested condition.) The normalized sediment load was determined to be the more robust indicator of a sediment impact to aquatic health, and showed a significant difference in reference versus impaired watersheds.

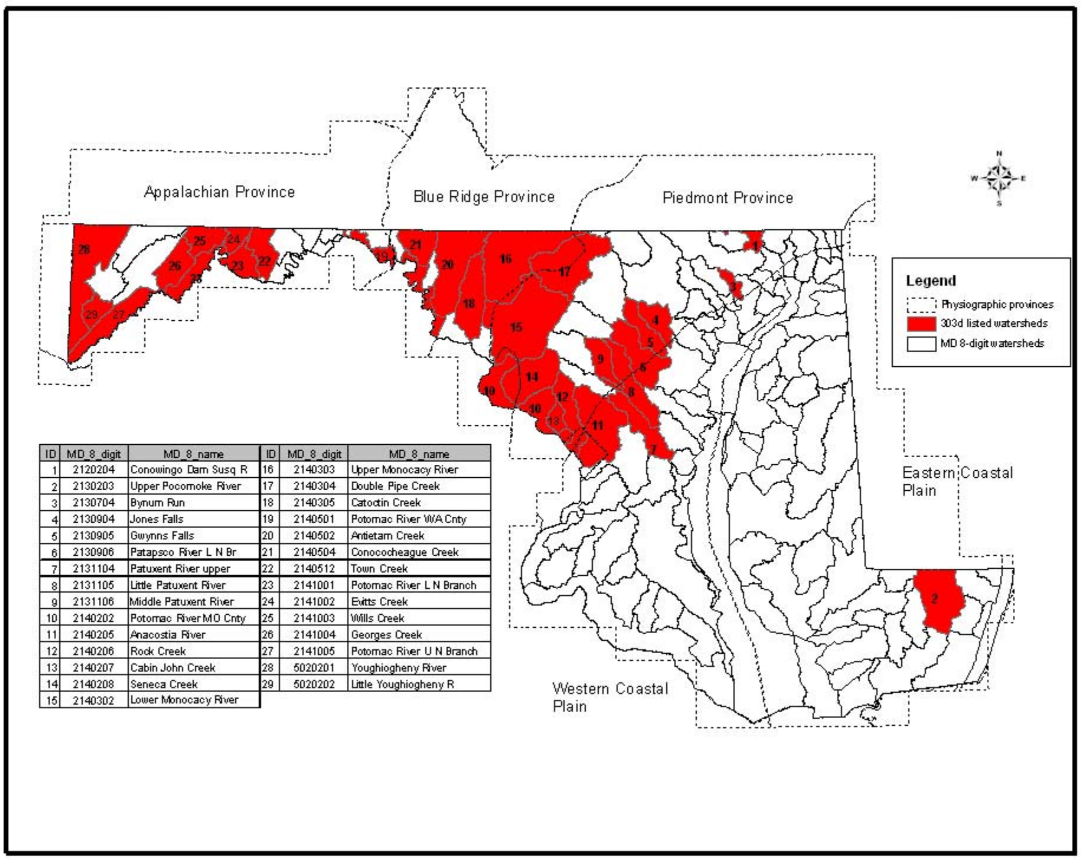
Validation steps were performed to support the use of the sediment load beyond the all-forested condition as the target indicator for determining a sediment impairment. The first validation identified a clear difference in the normalized sediment loads between reference and impaired watersheds. The second validation step supported that there was a significant correlation between the normalized sediment load and the watershed average embeddedness and epifaunal substrate scores.

Additionally, land use characteristics were compared between the watersheds identified as having a healthy benthic community (reference) and those where the benthic community is impaired. Land uses were grouped into four broad categories – crop, forest, pasture and urban. In general, there is some overlap within individual land use distributions between the reference and impaired watersheds for all four categories. Crop and pasture exhibit the most overlap, with no significant difference between reference and impaired conditions in either case. Urban land use has some overlap between the upper quartile of the reference group and the lower quartile of the impaired group. Forest land use shows the most difference between the reference and impaired groups.

A threshold value for the normalized sediment load was determined using both an EPA proposed methodology and logistic regression analysis. Results of the analysis indicated a target value of approximately 3.6 – 3.7 times the all-forested watershed sediment load, with an 80% confidence interval of between 3.3 and 4.1. It is recommended that when selecting the final threshold value, the more environmentally conservative (lower) confidence limit be used.

1.0 Introduction

In 1996, as part of the requirements for the Clean Water Act, Maryland listed a total of 98 out of 138 potentially sediment impaired watersheds on the 303(d) list. The scale of these listings was based on Maryland 8-digit watersheds, which are on average approximately 75 square miles in area. The original 1996 sediment listings were determined based on watersheds expected or known to have relatively high sediment yield or to have been subject to land use change due to row crop agriculture or development. In 2002, these sediment listings were then classified as either non-tidal, tidal or impoundments. The current 2006 State 303(d) list identifies a total of 29 non-tidal, 65 tidal, and 4 impoundments as impaired by sediment. The 65 tidal impairments are planned to be developed in coordination with the EPA Chesapeake Bay Program and the four impoundments are being developed based on criteria developed for reservoirs. This report proposes a methodology to address the non-tidal stream impairments in areas other than the coastal plain region (see Figure 1).



ID	MD_8_digit	MD_8_name	ID	MD_8_digit	MD_8_name
1	2120204	Conowingo Dam Susq R	16	2140303	Upper Monocacy River
2	2130203	Upper Pocomoke River	17	2140304	Double Pipe Creek
3	2130704	Bynum Run	18	2140305	Catoctin Creek
4	2130904	Jones Falls	19	2140501	Potomac River WA Cnty
5	2130905	Gwynns Falls	20	2140502	Antietam Creek
6	2130906	Patapsco River L N Br	21	2140504	Conococheague Creek
7	2131104	Patuxent River upper	22	2140512	Town Creek
8	2131105	Little Patuxent River	23	2141001	Potomac River L N Branch
9	2131106	Middle Patuxent River	24	2141002	Evitts Creek
10	2140202	Potomac River MO Cnty	25	2141003	Wills Creek
11	2140205	Anacostia River	26	2141004	Georges Creek
12	2140206	Rock Creek	27	2141005	Potomac River U N Branch
13	2140207	Cabin John Creek	28	5020201	Youghiogheny River
14	2140208	Seneca Creek	29	5020202	Little Youghiogheny R
15	2140302	Lower Monocacy River			

Figure 1:Maryland 303(d) non-tidal sediment impairments

It was outlined in the Maryland 2006 303(d) report that degraded stream water quality resulting in a non-tidal sediment impairment is characterized by erosional impacts, depositional impacts, and decreased water clarity (MDE, 2006). The pollutant, defined as sediment, is expected to have a negative impact on the aquatic health (fish and benthic community) of the stream system at increasing levels. It is important to note that the sediment impacts to aquatic health tend to be cumulative and thus occur over time.

The average annual sediment load accounts for the cumulative erosional, depositional and water clarity impacts to the aquatic (fish and benthic) community. An elevated sediment load can be a result of increased total suspended solids (TSS), which reduces water clarity thus inhibiting sight feeders and also causes abrasion to gills. The source of the increased sediment load can be from either terrestrial or channel sediment. If the total sediment load is beyond the transport capacity of the stream, then depositional impacts are possible. Increased deposition would result in filling of the interstitial spaces in the stream bottom, thus increasing embeddedness and resulting in a decrease in available habitat for the benthic community. Over time, erosion of the channel system further reduces available habitat for the benthic community.

There are currently no specific numeric thresholds available in Maryland that correspond to the impact of sediment on the aquatic health of non-tidal stream systems. This report attempts to establish a numeric sediment loading threshold that accounts for a sediment impact that is broadly defined to include erosional impacts, depositional impacts and water clarity per the 2004 303(d) report. The numeric threshold will be based on the long-term average annual sediment load. Validation of the threshold will statistically identify a relationship between the sediment loading threshold and correlations with observed instream biological and physical habitat conditions.

2.0 Monitoring Data

The Maryland Department of Natural Resources (DNR) conducted the Maryland Biological Stream Survey (MBSS) from 1995-2004, to provide critical information regarding the condition of the State's streams and rivers. Broadly stated, the MBSS was designed to take snapshots of the streams, identify the best and worst areas, find out what caused them to become degraded or stay healthy, and help target streams and watersheds for protection, restoration, or both. The MBSS was based on a probabilistic stream sampling approach where random selections are made from all sections of streams in the State that can physically be sampled. The approach supports statistically valid population estimation of variables of interest. (DNR website, http://www.dnr.state.md.us/streams/mbss/synopsis.html)

The MBSS dataset includes physical, chemical, and biological data collected on randomly selected, non-tidal, first through fourth order streams throughout Maryland (Roth et al., 1999). The lattice sampling designs of Round 1 (1995-1997) and Round 2 (2000-2004) stratify by year and by either major drainage basin or Maryland 8-digit watershed; therefore, sampling each year covers one third or one fifth of Maryland per round, respectively. Approximately 300 stream segments (210 in the core survey) of fixed length (75 m) are sampled each year, with biological, chemical, and physical parameters measured at each segment using standardized methods (Kazyak, 2001). Since 2000, the MBSS has sampled 10 or more sites in each of 85 primary sampling units comprising individual or combined Maryland 8-digit watersheds (134 total).

The MBSS dataset includes the following biological measurements: the abundance, size, and individual health of fish; taxa composition of benthic macroinvertebrates; and presence of amphibians, reptiles, mussels, and aquatic vegetation. More important for this study, these biological data have been consolidated into two robust indicators of biological condition, the Fish Index of Biotic Integrity (F-IBI) and Benthic Macroinvertebrate Index of Biotic Integrity (B-IBI) (Roth *et al* 2000 and Stribling *et al* 1998). Individual metric scores are based on comparison with the distribution of metric values at reference sites within each geographic region (*e.g*., Highland, Eastern Piedmont, Coastal Plain). An IBI > 3 indicates the presence of a biological community with attributes (metric values) comparable to those of reference sites. An IBI < 3 indicates that, on average, metric values fall short of reference expectations. These IBI scores have been incorporated into biological criteria as part of Maryland's water quality standards, and thus provide the most appropriate means for determining if a stressor is having a biologically important impact.

Maryland's biological criteria (biocriteria) method relies on statistical measures of uncertainty (90% one-sided confidence interval) to determine whether the mean of the results from the sites sampled in a watershed is above or below the Index of Biotic Integrity (IBI) value considered indicative of satisfactory water quality. Where at least 10 sites have been sampled in a watershed (8-digit), watershed-specific confidence intervals were calculated. If the lower bound of the confidence interval is greater than 3, the watershed is determined to meet water quality criteria ("Pass"). If the upper bound of the confidence interval is less than 3, the watershed is determined to not meet water quality criteria ("Fail"). All other cases are considered inconclusive.

3.0 Estimating Sediment Loads for Maryland 8-digit Watersheds

Long-term average annual nonpoint source sediment loads for Maryland 8-digit watersheds are estimated based on the Chesapeake Bay Program Phase 5 (CBP P5) watershed model[1] edge-of-stream (EOS) calibration target loading rates. The EOS sediment load is calculated per land use as a product of the land use area, land use target loading rate and loss from the edge-of-field (EOF) to the main channel. The sediment delivery ratio is used because not all of the EOF sediment load is delivered to the stream or river. Some of it is stored on fields down slope, at the foot of hillsides, or in smaller rivers or streams that are not represented in the model. The sediment delivery ratio is the ratio of the sediment load at a watershed outlet to the EOF load generated in the watershed.

3.1 Land Use Methodology

The land use framework used to develop this TMDL was originally developed for the CBP P5 watershed model. The CBP P5 land use Geographic Information System (GIS) framework was based on two distinct layers of development. The first GIS layer was developed by the Regional Earth Science Applications Center (RESAC) at the University of Maryland and was based on satellite imagery (Landsat 7-Enchance Thematic Mapper (ETM) and 5-Thematic Mapper (TM)) (Goetz et al., 2004). This layer did not provide the required level of accuracy, which is especially important when developing the agricultural land uses. In order to develop accurate agricultural land use calculations, the CBP P5 used county level U.S. Agricultural Census data as a second layer.

The result of this approach is that CBP P5 land use does not exist in a single GIS coverage, but instead is only available in a tabular format. The CBP P5 watershed model is comprised of twenty-five land uses. Most of these land uses are differentiated only by their nitrogen and phosphorus loading rates. The land uses are aggregated into thirteen classes with distinct sediment erosion rates. Details of the land use development methodology are being summarized in the report "Chesapeake Bay Phase V Community Watershed Model: Tracking Nutrient and Sediment Loads on a Regional and Local Scale" (USEPA - CBP, 2006b).

3.2 General load estimation methodology

Nonpoint source sediment loads are estimated based on the *edge-of-stream (EOS) calibration target loading rates* from the CBP P5 model. This approach is based on the fact that not all of the *edge-of-field* (EOF) sediment load is delivered to the stream or river (some of it is stored on fields down slope, at the foot of hillsides, or in smaller rivers or streams that are not represented in the model). To calculate the actual EOS loads, *sediment delivery ratio* (the ratio of sediment reaching a basin outlet compared to the total erosion within the basin) is used. Details of the

[1] The EPA Chesapeake Bay Program developed the first watershed model in 1982. There have been many upgrades since the first phase of this model. The CBP P5 was developed to estimate flow, nutrient, and sediment loads to the Bay.

methods used to calculate sediment load have been summarized in the report titled "Chesapeake Bay Phase V Community Watershed Model: Tracking Nutrient and Sediment Loads on a Regional and Local Scale" (USEPA - CBP, 2006b).

EOF target erosion rates for agricultural land uses and forest were based on erosion rates determined by the National Resource Inventory (NRI). NRI is a statistical survey of land use and natural resource conditions conducted by the Natural Resources Conservation Service (NRCS) (USDA – NRCS, 2006). Sampling methodology is explained by Nusser and Goebel (1997).

Estimates of average annual erosion rates for pasture and cropland are available on a county basis at five year intervals, starting in 1982. Erosion rates for other land uses are not available on a county basis from NRI, however for the purpose of the CBP Phase 2 watershed model, NRI calculated average annual erosion rates for forest land use on a watershed basis. These rates are still being used as targets in the Phase V model.

The average value of the 1982 and 1987 surveys was used as the basis for EOF target loads. The erosion rates from this period do not reflect best management practices (BMPs) or other soil conservation policies introduced in the wake of the effort to restore the Chesapeake Bay.

The base formula for calculating sediment delivery ratios in the CBP Phase V Model is the same as the formula used by the NRCS (USDA-NRCS, 1983). In order to account for the differences in sediment loads due to distance traveled to the stream, the CBP P5 model uses the sediment delivery ratio. Land cover specific sediment delivery ratios were calculated for each river segment.

3.3 Edge-of-Stream Loads

The final EOS loads are the loads that actually enter the river reaches (*i.e.* the mainstem of a watershed). Such loads represent not only the erosion from the land, but also all of the intervening processes of deposition on hillsides and sediment transport through smaller rivers and streams. These loads are calculated as the product of the land use area, the target sediment yield and the land use specific sediment delivery ratio.

4.0 Analysis

The approach used to develop a threshold sediment load for determination of a sediment impairment and subsequent TMDL is based on a reference watershed methodology. A reference watershed approach evaluates a watershed by comparing it to a single watershed or group of watersheds that are identified as meeting the narrative water quality standard of supporting aquatic health. In this analysis, groups of reference watersheds and watersheds not supporting aquatic health (impaired) are identified. A reference sediment-loading rate was determined based on the distribution of sediment loads in the reference watershed group. The distributions of sediment loads were compared between the reference and impaired watershed groups with a validation to show that the sediment loads for the impaired groups are larger than those in the reference group.

4.1 Watershed Groups

Watersheds for inclusion in this analysis were limited to areas other than the coastal plain region of Maryland. This region is consistent with the non-coastal region that was identified in the 1998 development of F-IBI and subsequently used in the development of the BIBI (Roth *et al.*, 1998 and Stribling *et al.*, 1998) and was determined to have a similar bethic macroinvertebrate and fish community structure. This region also accounts for 28 of the 29 non-tidal sediment impairments reported on the Maryland 303(d) list.

Watersheds were placed into six groups. The first three groups represent reference watersheds. Group one contains watersheds with a average watershed B-IBI significantly greater than three (Pass), group two contains watersheds with average watershed F-IBI significantly greater than three and group three contains watershed with both the B-IBI and F-IBI significantly greater than three. Likewise, the next three groups, identify impaired watershed (IBI significantly less than 3.0), for B-IBI, F-IBI and B/F-IBI, respectively. Watersheds and corresponding groups are presented in Table 1.

Table 1: Non-coastal plain watersheds and groups considered for inclusion in analysis.

MD 8-digit	Name	Region	Group						Total Groups
			B-IBI Pass	F-IBI Pass	B/F-IBI Pass	B-IBI Fail	F-IBI Fail	B/F-IBI Fail	
2140305	Catoctin Creek	Highland					X		1
2140501	Potomac River WA Cnty	Highland					X		1
2140502	Antietam Creek	Highland				X			1
2140504	Conococheague Creek	Highland				X			1
2140511	Fifteen Mile Creek	Highland	X						1
2140512	Town Creek	Highland	X						1
2141001	Potomac River L N Branch	Highland	X				X		2
2141002	Evitts Creek	Highland				X			1
2141004	Georges Creek	Highland					X		1
2141005	Potomac River U N Branch	Highland					X		1
2141006	Savage River	Highland	X	X	X				3
2120202	Deer Creek	Piedmont	X						1
2120205	Broad Creek	Piedmont	X						1
2130804	Little Gunpowder Falls	Piedmont	X						1
2130806	Prettyboy Reservoir	Piedmont	X	X	X				3
2130905	Gwynns Falls	Piedmont				X	X	X	3
2130906	Patapsco River L N Br	Piedmont				X			1
2130907	Liberty Reservoir	Piedmont	X	X	X				3
2130908	S Branch Patapsco	Piedmont	X	X	X				3
2131105	Little Patuxent River	Piedmont		X		X			2
2131107	Rocky Gorge Dam	Piedmont	X	X	X				3
2131108	Brighton Dam	Piedmont	X						1
2140202	Potomac River MO Cnty	Piedmont		X					1
2140205	Anacostia River	Piedmont				X			1
2140208	Seneca Creek	Piedmont				X			1
2140301	Potomac River FR Cnty	Piedmont				X			1
2140302	Lower Monocacy River	Piedmont				X			1
2140303	Upper Monocacy River	Piedmont				X			1
2140304	Double Pipe Creek	Piedmont				X			1
	Total Watersheds		12	7	5	12	6	1	

4.2 Comparison of Sediment Loads for Watershed Groups

Sediment loads for the 24 watersheds listed in Table 1 were estimated using the EOS targets from the CBP P5 watershed model. Sediment loads were estimated for the Maryland region of the watershed only to maintain consistency with the MBSS sampling units (random sampling of MD streams). Comparison of loads requires normalization due to varying watershed areas and physical characteristics. The first normalization divides the current load by the watershed area, resulting in a sediment yield defined in tons per acre per year. The second normalization accounts for the varying physical characteristics of the watersheds by dividing the current sediment load by the watershed load assuming an all-forested condition. The latter normalization compares the current sediment load that of an all-forested or natural condition. EPA Region 10 used a similar approach for sediment TMDLs in California (Navarro River, Trinity River), where the sediment loading capacity was based on an analysis of the amount of human-caused sediment delivery that can occur in addition to natural sediment delivery without causing adverse impacts to aquatic life.

Comparison of sediment loads for the six watershed groups are presented as box and whisker plots in Figure 2 and Figure 3. Figure 2 is based on the sediment yield and Figure 3 is based on the normalized load. Figure 1 indicates that there is minimal difference between healthy and impaired watersheds when using the sediment yield. This is mostly like due to the variability in background sediment loads across the different physiographic regions. However, in Figure 2, there is a clear difference between normalized sediment loads in healthy and impaired watersheds. Furthermore, all three watershed groups (B-IBI pass, F-IBI pass, and B/F-IBI pass) show similarities in median and interquartile range of the normalized sediment load, and reduced variability.

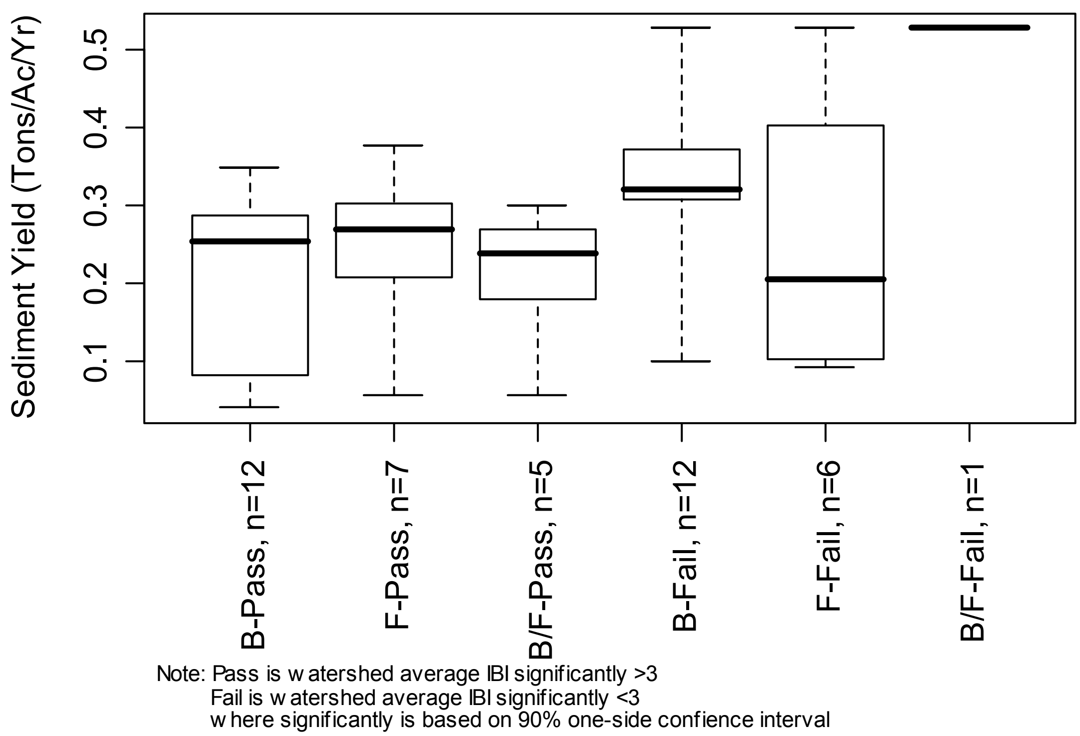


Figure 2 Comparison of watershed sediment yields for various aquatic health classifications (F is fish IBI and B is benthic IBI).

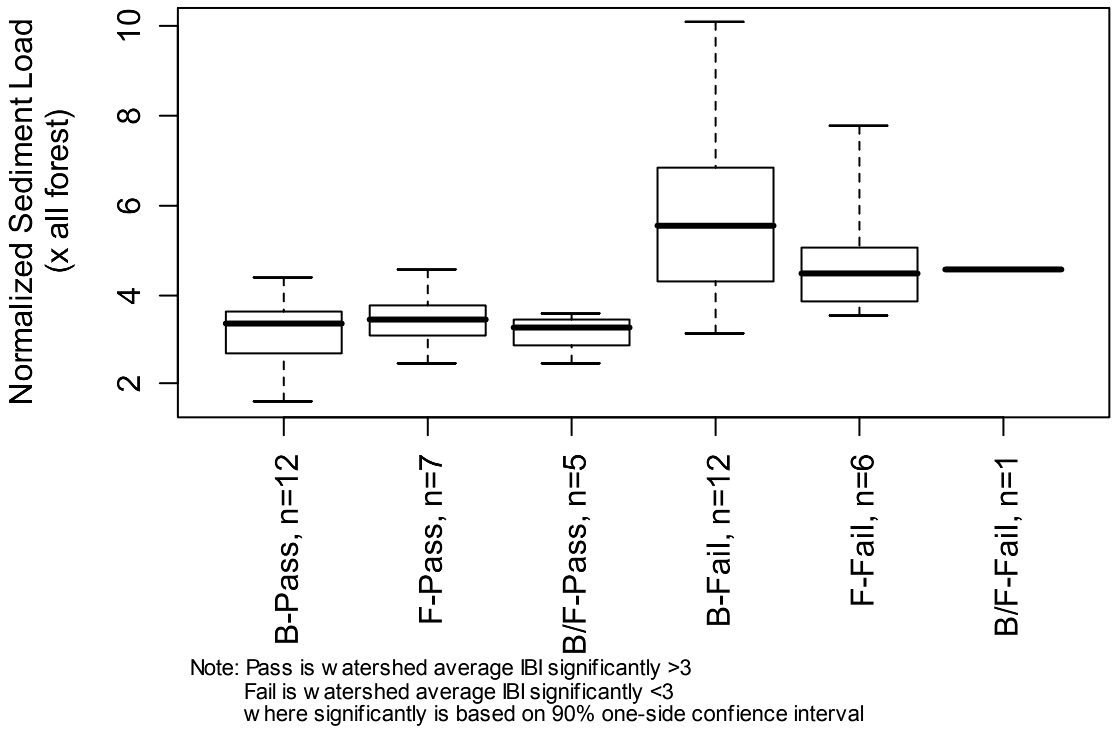


Figure 3 Comparison of watershed sediment loads beyond all forest conditions for various aquatic health classifications (F is fish IBI and B is benthic IBI).

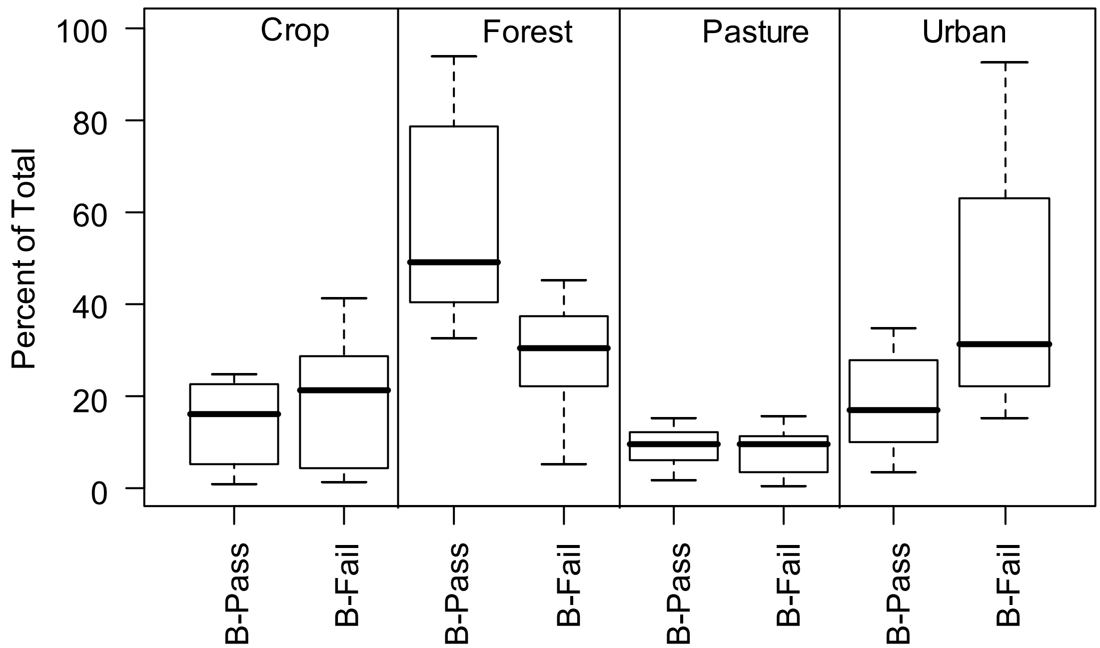
Results from this analysis suggest that using the normalized sediment load is the best approach for comparing sediment loads in the non-coastal plain watersheds. In addition, a clear difference is observed between healthy and impaired watersheds, thus indicating the impact of elevated sediment on the aquatic community. Given the similar medians and interquartile ranges for the three watersheds group of B-Pass, F-Pass, and B/F-Pass, it is recommended that group one (B-Pass) be used as a reference group due to its larger sample size. Likewise, it is recommend that group four (B-Fail) be used for the final validation of the methodology and support of a final threshold. The final watersheds and groups are presented in Table 2.

Table 2: Non-coastal plain watersheds with average B-IBI score of pass or fail.

MD 8-digit	Name	Region	Group		Total Groups
			B-IBI Pass	B-IBI Fail	
2140502	Antietam Creek	Highland		X	1
2140504	Conococheague Creek	Highland		X	1
2140511	Fifteen Mile Creek	Highland	X		1
2140512	Town Creek	Highland	X		1
2141001	Potomac River L N Branch	Highland	X		2
2141002	Evitts Creek	Highland		X	1
2141006	Savage River	Highland	X		3
2120202	Deer Creek	Piedmont	X		1
2120205	Broad Creek	Piedmont	X		1
2130804	Little Gunpowder Falls	Piedmont	X		1
2130806	Prettyboy Reservoir	Piedmont	X		3
2130905	Gwynns Falls	Piedmont		X	3
2130906	Patapsco River L N Br	Piedmont		X	1
2130907	Liberty Reservoir	Piedmont	X		3
2130908	S Branch Patapsco	Piedmont	X		3
2131105	Little Patuxent River	Piedmont		X	2
2131107	Rocky Gorge Dam	Piedmont	X		3
2131108	Brighton Dam	Piedmont	X		1
2140205	Anacostia River	Piedmont		X	1
2140208	Seneca Creek	Piedmont		X	1
2140301	Potomac River FR Cnty	Piedmont		X	1
2140302	Lower Monocacy River	Piedmont		X	1
2140303	Upper Monocacy River	Piedmont		X	1
2140304	Double Pipe Creek	Piedmont		X	1
	Total Watersheds		12	12	

4.3 Comparison of Land Use for Reference and Impaired Watersheds

Land use characteristics were compared between watersheds identified as having a healthy benthic community (reference) and those where the benthic community is impaired. Land uses were grouped into four broad categories – crop, forest, pasture and urban. For comparison, box and whisker plots are presented in Figure 4. In general there is some overlap in individual land use distributions between reference and impaired for all four categories. Crop and pasture exhibit the most overlap with no significant difference. Urban land use has some overlap between the upper quartile of the reference group and the lower quartile of the impaired group. Forest land use shows the greatest difference between the reference and impaired group.



Note: B-Pass is watershed average benthic IBI significantly >3
B-Fail is watershed average benthic IBI significantly <3
where significantly is based on 90% one-side confience interval

Figure 4: Comparison of land use between watershed with B-IBI score of pass and watersheds with B-IBI score of fail.

5.0 Long-term Average Annual Sediment Load Threshold

Determination of a specific threshold indicator is the key component of identifying a watershed impairment. From the previous analysis it is suggested that the sediment loading indicator should be the watershed sediment load beyond the all-forested condition. Two approaches were used to identify a threshold. The first approach applies the reference reach methodology outlined in EPA's Nutrient Criteria Guidance Manual (US EPA, 2000). In this approach the 75th percentile of the frequency distribution of reference watersheds determines the threshold. The second approach applies a logistic regression model that predicts the likelihood of an impaired community from the sediment load beyond an all forest condition.

Using the EPA recommended approach, the threshold value is determined to be 3.6 times the all forest load, which is the 75th percentile of the reference watershed group values. To gain understanding of the variance of this value, a confidence interval was estimated assuming normality of the distribution. The 80% two-sided confidence interval is used, which is consistent with the alpha value of 0.1 (90% one-sided confidence interval) set for the MBSS analysis, assuming a one-sided test. The resulting 80% confidence interval around the 75th percentile value of 3.6, ranges from 3.4 to 4.1 times the all forest load.

Logistic regression was applied as a second approach to developing a threshold value of the sediment load beyond the all forest condition that will result in an impairment to stream aquatic health. Logistic regression predicts the likelihood of the benthic community being impaired given a specific sediment load beyond the all forest condition. Analyses of the statistical model results indicate that the normalized sediment load is significant predictor with a model agreement of 93%. The threshold was selected by determining the load beyond all forest conditions that maximized the classification of healthy versus impaired watershed groups. The resulting value was estimated as 3.7, with an 80% confidence interval of 3.3 to 4.1

In summary, both the US EPA recommended method and the logistic regression resulted in almost identical estimates of a threshold sediment load beyond an all forest condition that predicts a sediment impact to the aquatic heath of a stream system. Table 3 lists the results for both analysis.

Table 3: Summary of sediment load threshold values

	Sediment Load Beyond All Forest Condition	
Method	Threshold	80% two-sided Confidence Interval
US EPA Method	3.6	3.4 - 4.1
Logistic Regression	3.7	3.3 - 4.1

6.0 Validation

The analysis section of this report confirmed that using the normalized sediment load was an acceptable predictor for sediment impacts to aquatic health. An additional validation was to determine if there was a relationship between the normalized sediment load and the MBSS sediment related physical habitat parameters. A total of 31 watersheds met the criteria of having at least 10 MBSS samples, for watersheds in the non-coastal plain..

The two physical habitat parameters that appear to be most directly related to sediment impacts are embeddedness and epifaunal substrate. Embeddedness is the fraction of surface area of larger particles surrounded by finer sediments and epifaunal substrate is the amount and variety of hard, stable substrates used by benthic macroinvertebrates. Spearman Rank-Order correlation coefficients were computed between the watershed normalized sediment load and the watershed averages for embeddedness and epifaunal substrate. (See Table 4 for details). Both embeddedness and epifaunal substrate average watershed values were significantly correlated with the watershed sediment load. Embeddedness had a positive correlation (R=0.36) and epifuanal substrate had a negative correlation (R=0.45)

Table 4: Spearman rank correlation of normalized sediment load with embeddedness and epifaunal substrate.

	Embed	Epifaunal Substrate
p-value	0.026	0.006
Correlation Coefficient	0.36	-0.44

This additional validation step supports that the normalized sediment load captures the effects of deposition (embeddedness) and possibly the effect of channel erosion (stable substrates). Most importantly, the sediment load captures the overall impact of sediment on the stream aquatic health.

7.0 Summary and Conclusion

The 2006 Maryland 303(d) list currently identifies 29 non-tidal Maryland 8-digit watersheds as impaired by sediment. Currently, in Maryland, there are no available numeric thresholds to identify if a watershed is impairment by elevated sediment. However, the current solids listing methodology broadly defines a sediment impairment as characterized by erosional impacts, depositional impacts and degradation of water clarity.

It is suggested that the narrative standard of aquatic health, as defined by the fish and benthic IBI, be defined as the endpoint. The target pollutant, defined as sediment, is expected to have a negative impact on the aquatic health (fish and benthic community) of the stream system at increasing levels. Because the sediment impacts to aquatic health and resulting degradation of the stream physical habitat tend to be cumulative, it is proposed that the long-term average annual sediment load be applied as the appropriate target indicator for determining a sediment impairment.

Maryland 8-digit watersheds were separated into groups either supporting benthic aquatic health or having an impaired benthic community. The groups were determined by the statistical analysis methodology applied in Maryland's biocriteria. This resulted in a total of 24 watersheds, with 12 watersheds in each group. Long-term average annual sediment loads were estimated for these watersheds using the CBP P5 watershed model EOS loads. Sediment loading distributions for the two watershed groups were compared using the sediment yield and the normalized sediment load (the load beyond the all-forested condition.) The normalized sediment load was determined to be the more robust indicator of a sediment impact to aquatic health, and showed a significant difference in reference versus impaired watersheds.

Additional validation steps were performed to support the use of the sediment load beyond the all-forested condition as the target indicator for determining a sediment impairment. The first validation identified a clear difference in the normalized sediment loads between reference and impaired watersheds. The second validation step supported that there was a significant correlation between the normalized sediment load and the watershed average embeddedness and epifaunal substrate scores.

A threshold value for the normalized sediment load was determined using an EPA proposed methodology and logistic regression analysis. Results of the analysis indicated a target value of approximately 3.6 – 3.7 times the all-forested watershed sediment load with an 80% confidence interval of between 3.3 and 4.1. It is recommended that when selecting the final threshold value, the more environmentally conservative (lower) confidence limit be used.

8.0 References

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