TECHNICAL MEMORANDUM

Chesapeake Bay Program
A Watershed Partnership

To: Chesapeake Bay Program Modeling Team

From: Center for Watershed Protection, Inc.
Sediment Reduction and Stream Restoration Coordinator

Date: March 24, 2014

Re: Analysis of Stream Sediment Monitoring in Support of Objective 1 of the Sediment Reduction and Stream Corridor Restoration Analysis, Evaluation and Implementation Support to the Chesapeake Bay Program Partnership

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This analysis of stream sediment monitoring data was conducted as a continuation of the Center for Watershed Protection's work described in the technical memorandum dated September 10, 2013, "Analysis of Stream Sediment Studies in Support of Objective 1 of the Sediment Reduction and Stream Corridor Restoration Analysis, Evaluation and Implementation Support to the Chesapeake Bay Program Partnership" (CWP, 2013). The purpose of this analysis was to further investigate, using monitoring data sources, the contribution of sediment from in-stream and upland sources within a watershed. This analysis is part of Chesapeake Bay Program's (CBP) initial efforts to improve how sediment is modeled in the Chesapeake Bay Watershed Model (CBWM) and to inform Phase 6 of its development. The analysis is guided by the following research question:

> *What is the percentage of sediment and nutrients from bank and channel sources of streams compared to upland watershed load? What is the variability in these values and what are the key sources of variation?*

1.0 Introduction

The technical memorandum (CWP, 2013) provided an exploratory review of the available published research and data in the Mid-Atlantic Region on stream sediment loadings. This review suggested a total watershed sediment yield between 200 lbs/ac/yr and 1500 lbs/ac/yr and that sediment from stream bed/bank sources tend to be 300 lbs/ac/yr or less. These estimates of watershed and stream sediment yields are consistent with the trend in sediment with increasing impervious cover shown by Langland and Cronin (2003).

The purpose of this memo is to provide supplementary analysis on watershed and stream sediment loading based on available stream monitoring data in the Chesapeake Bay watershed. Stream monitoring data gathered for the analysis was based on a broad inquiry of agency staff from Bay States and the District of Columbia, municipal separate storm sewer system (MS4) regulated jurisdictions, and national databases for watersheds with an area less than sixty square miles in urban areas. The inquiry resulted in data for urban areas and included data from Maryland Department of the Environment (MDE), several counties and cities in Maryland, the National Stormwater Quality Database (NSQD) (Pitt, Maestre, & Morquecho, 2004), and United States Geological Survey (USGS) WaterWatch (USGS, 2013).

2.0 Methods

The primary dataset was provided by MDE from Municipal Separate Storm Sewer System (MS4) communities as part of state reporting requirements covering a period from 1994 to 2011. The dataset includes event mean concentration (EMC) at outfalls and the watershed[1] as a whole for stormflow and baseflow for four different land uses. The data were screened to identify sites with matching water quality samples at the outfall and watershed samples. Water quality samples collected at an outfall were assumed to represent sediment from upland land uses, while watershed samples represented total sediment contributions from all sources (upland and in-stream). Any samples taken at outfalls during baseflow conditions were disregarded in this analysis, as these flows were not represented by the modeled flow provided by the CBP modeling team and they are not likely to represent watershed background conditions. Data sets where no direct comparison was available between outfall and watershed samples were excluded in this analysis. Excluded data included the NSQD as these were only representative of outfall conditions and USGS data as these tend to only have watershed information.

The MS4 dataset was combined with hourly modeled flow for each county (or city) provided by the CBP for the period of record between 1984 and 2005. The EMCs were binned into four land use categories by MDE and included residential, commercial, industrial, and highway land uses. The average EMC value for each land use, MS4 and location was used for the entire period of flow provided by the CBP modeling team. The modeled flow data consisted of surface runoff (storm flow), baseflow, and interflow for both *regulated impervious developed land* and *regulated pervious developed land*. Land use reported with EMC data was used to assign a percent impervious and pervious cover, which was then used to proportionally add flows from regulated impervious developed land and regulated pervious developed land. Impervious percentages were based on values used in the Chesapeake Bay Watershed Model (USEPA, 2010). Residential, commercial, industrial, and highway land uses were assigned 25%, 80%, 90%, and 50% imperviousness, respectively.

Total flow is based on the sum of storm flow, baseflow, and interflow from both pervious and impervious regulated land cover. It was assumed that flow from outfalls only occurred during storm events, or when there was a corresponding stormflow EMC included in the MS4 dataset. Watershed sampling locations were assumed to have interflow, baseflow, and storm flow meaning EMC values reported for baseflow were used when estimating load during baseflow conditions. As no EMC values were available for interflow conditions, the average of storm flow EMC and Baseflow EMC was used, where baseflow EMC values were available. In instances where baseflow EMC values were not available, interflow EMC values were set equal to half stormflow EMC values. Load estimates calculated by combining hourly flow and EMC as follows.

$$Outfall = EMC_{Storm} * Surface\ Runoff$$

[1] The MS4 data refers to the watershed samples as in-stream samples that includes both stormflow and baseflow.

$$Total_{Watershed} = Outfall + EMC_{Baseflow}{}^{*} * Baseflow + EMC_{Interflow}{}^{**} * Interflow$$

* Baseflow EMCs were not available for all land use and MS4 combinations

** Interflow EMCs were not available so Interflow EMCs were set to the average of Baseflow EMC and Surface Runoff EMC, where Baseflow EMC was available or Surface Runoff EMC divided by 2, where Baseflow EMC was not available

Where:

$Total_{Watershed} = sediment\ load\ from\ all\ sources\ (upland\ load\ \&\ stream\ bed/bank\ load)$

$Outfall = sediment\ load\ from\ upland\ sources$

$EMC_{Storm} = Event\ Mean\ Concentration\ associated\ with\ storm\ events$

$EMC_{Baseflow} = Event\ Mean\ Concentration\ associated\ with\ baseflow$

$EMC_{Interflow} = Event\ Mean\ Concentration\ associated\ with\ interlow$

$$= \frac{EMC_{Storm} + EMC_{Baseflow}}{2}$$

$Surface\ Runoff = CBP\ modeled\ surface\ runoff$

$Baseflow = CBP\ modeled\ baseflow$

$Interflow = CBP\ modeled\ interflow$

The load was summed for the entire flow period (1984 to 2005) and divided by 21 years to develop a long term average load per year. In addition to using the EMC mean, minimum and maximum values were also used to allow for bounds to be set for the different land uses.

Summary metrics and statistics for EMC for each land use were calculated. F-statistics and T-Tests assuming equal and unequal variances were used to determine significant differences in EMCs between land uses. In general, these data were generally positively skewed and the median tended to be a better predictor of central tendency. However, the average EMC for each land use was used in the analysis to estimate sediment loads as the majority of the sediment is typically transported during high flow conditions, thus making the average values more suitable for overall load estimation. No out of range values were included in the averages (i.e. a “ND” or “NA” or any other anomaly was excluded).

A mass balanced approach was used to estimate the in-stream sediment contributions given available monitoring data. This method estimates the sediment loads originating from the upland areas and the loads being contributed by the stream channel using stormwater outfall and in-stream monitoring data for TSS concentrations and modeled flow data provided by the CBP.

$$Stream_{Bed/Bank} = Total_{Watershed} - Outfall$$

Where:

$Stream_{Bed/Bank} = sediment\ load\ contributed\ from\ stream\ channel\ bed\ and\ bank\ material$

$Total_{Watershed} = sediment\ load\ from\ all\ sources\ (upland\ \&\ stream\ bed/bank\ load)$

$Outfall = sediment\ load\ from\ overland\ sources$

The percent of total load attributed to the in-stream (channel bed and banks) sediment contributions was determined by:

$$Stream\ \% = \frac{Total_{Watershed} - Outfall}{Total_{Watershed}} * 100$$

Given the assumptions used to estimate the percent stream sediment load, the results were compared to before and after bed and bank erosion data for Spring Branch watershed provided by Department of Environmental Protection and Sustainability, Baltimore County, MD to evaluate the efficacy of the results.

3.0 Results

Results are based on the analysis of EMC data provided by MDE for ten MS4 communities along with modeled flow provided by the CBP modeling team. The number of samples and period record for the data provided is summarized in Tables 1 and 2. The data provided over 2,500 outfall and watershed stormflow EMC data points for the four land uses and an additional 567 baseflow EMCs.

Table 1: Number of TSS Event Mean Concentration samples collected during storm flow for each MS4 and years between which collection occurred. Data are presented as number of samples taken followed by the date range [i.e. # (Date Range)].

	Residential		Commercial		Industrial		Highway	
County	Outfall	Watershed	Outfall	Watershed	Outfall	Watershed	Outfall	Watershed
Anne Arundel	nd	nd	132 (1999 - 2011)	129 (1999 - 2011)	nd	nd	nd	nd
Baltimore City	131 (1995 - 2010)	153 (1995 - 2010)	nd	nd	nd	nd	nd	nd
Baltimore	79 (1995 - 2010)	98 (1995 - 2010)	18 (1996 - 1998)	18 (1996 - 1998)	nd	nd	32 (1999 - 2003)	31 (1999 - 2003)
Carroll	nd	nd	nd	nd	53 (2000 - 2011)	51 (2000 - 2011)	nd	nd

Table 1: Number of TSS Event Mean Concentration samples collected during storm flow for each MS4 and years between which collection occurred. Data are presented as number of samples taken followed by the date range [i.e. # (Date Range)].								
Charles	156 (1999 - 2010)	149 (1999 - 2010)	nd	nd	nd	nd	nd	nd
Frederick	95 (2003 - 2011)	118 (1999 - 2011)	nd	nd	nd	nd	nd	nd
Harford	90 (1999 - 2008)	94 (1999 - 2008)	nd	nd	nd	nd	nd	nd
Howard	74 (2000 - 2004)	59 (2000 - 2011)	nd	nd	nd	nd	nd	nd
Montgomery	88 (2002 - 2010)	87 (2002 - 2010)	nd	nd	40 (1996 - 2001)	48 (1996 - 2001)	nd	nd
Prince George's	115 (1994 - 2006)	172 (1994 - 2010)	23 (1994 - 1997)	17 (1994 - 1997)	28 (1994 - 1997)	24 (1994 - 1997)	51 (2002 - 2004)	nd

nd = no data. No information was reported or useable from the MS4 about the land use.

Table 2: Number of TSS Event Mean Concentration samples collected during baseflow for each MS4 and years between which collection occured. Data are presented as number of samples taken followed by the date range [i.e. # (Date Range)].

County	Residential	Commercial	Industrial	Highway
Anne Arundel	nd	11 (2006 - 2009)	nd	nd
Baltimore City	112 (1999 - 2009)	nd	nd	nd
Baltimore	35 (1995 - 1998)	34 (1994 - 1998)	nd	44 (1999 - 2008)
Carroll	nd	nd	37 (2000 - 2007)	nd
Charles	9 (2001 - 2009)	nd	nd	nd
Frederick	104 (1999 - 2009)	nd	nd	nd
Harford	83 (2000 - 2008)	nd	nd	nd
Howard	30 (2003 - 2009)	nd	nd	nd

Table 2: Number of TSS Event Mean Concentration samples collected during baseflow for each MS4 and years between which collection occured. Data are presented as number of samples taken followed by the date range [i.e. # (Date Range)].

Montgomery	42 (2002 - 2005)	nd	62 (1996 - 2001)	nd
Prince George's	45 (1994 - 2009)	nd	nd	nd

nd = no data. No information was reported or useable from the MS4 about the land use.

General Sediment Concentrations between Land Uses

Storm flow EMCs for each land use category and location (outfall or watershed), regardless of MS4, were compared (Figure 1). There is large variability in TSS EMC data, although the median stormflow EMC exhibits a narrow range between 30mg/L to 60mg/L at outfalls and 40 mg/L to 80 mg/L for watershed EMC (baseflow and stormflow). As expected, the mean EMC value is higher given the sediment transport during larger storm events.

Using the mean as the measure of central tendency for this analysis, these data show the average outfall concentrations from the residential land use (69.4 mg/l) were statistically lower than all other land uses (alpha = 0.05). Mean watershed sample concentrations for industrial (219.6 mg/l) were statistically higher than residential or commercial. Mean outfall concentrations from the highway land use (145.1 mg/l) were statistically higher than residential, but not significantly higher than commercial (119.6 mg/l) or industrial (96.3 mg/l) (alpha = 0.05). Both residential and commercial land uses had significantly higher watershed EMC concentrations compared to the outfall EMCs, whereas there were no significant differences between EMC watershed and outfall samples for industrial and highway land uses.

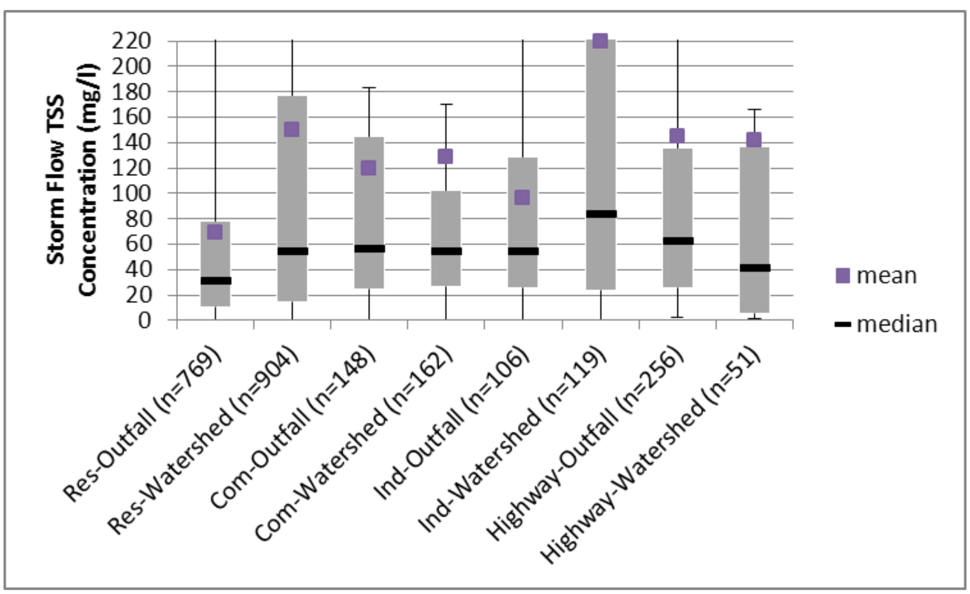

Figure 1. Event mean concentrations for total suspended sediment (TSS) during storm flow from outfall and watershed water quality sampling associated with urban land uses.

The NSQD EMCs from outfalls around the country were lower than observed from the MS4s in Maryland. The outfall water quality samples were compared to NSQD from Chesapeake Bay states to put initial results into the Bay watershed context (Figure 2). The average TSS stormflow EMC from MS4s in Maryland are larger than from the NSQD for all land use categories. However, the Maryland values are not outside the range of observations in the NSQD.

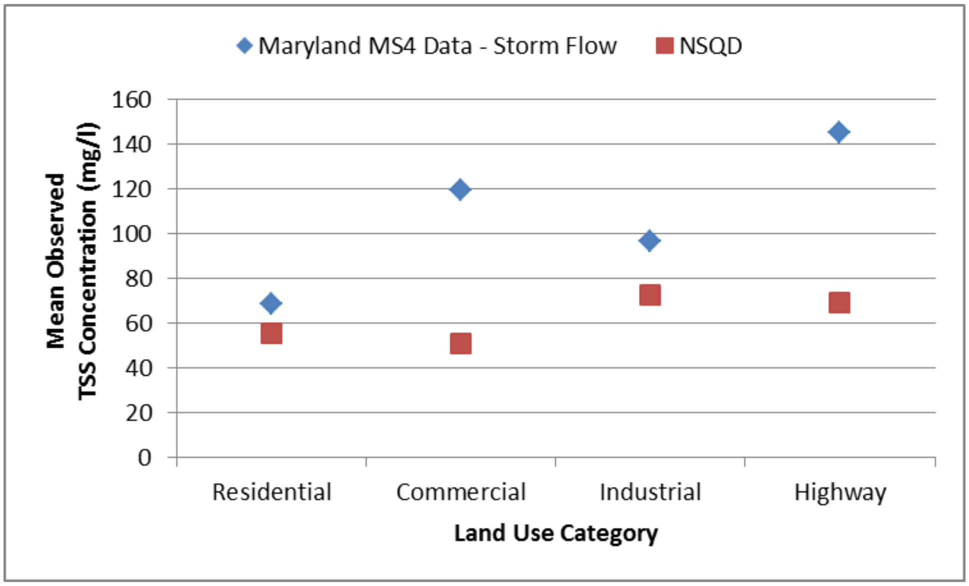

Figure 2. Average event mean concentrations (EMCs) from the National Stormwater Quality Database compared to average EMCs from Maryland during storm flow. These data are for outfalls only (NSQD does not report total watershed water quality information).

A similar analysis of baseflow monitoring data from MDE is provided in Figure 3. Average values present a wide range in values within each land use. For example, TSS concentrations for watershed samples for industrial land use range from 2 to 10 mg/l. Statistically significant mean EMC values existed only for highway (3.42 mg/l) and industrial (8.54 mg/l) land uses. The consistency in baseflow EMCs suggests a relatively constant background conditions amongst land uses.

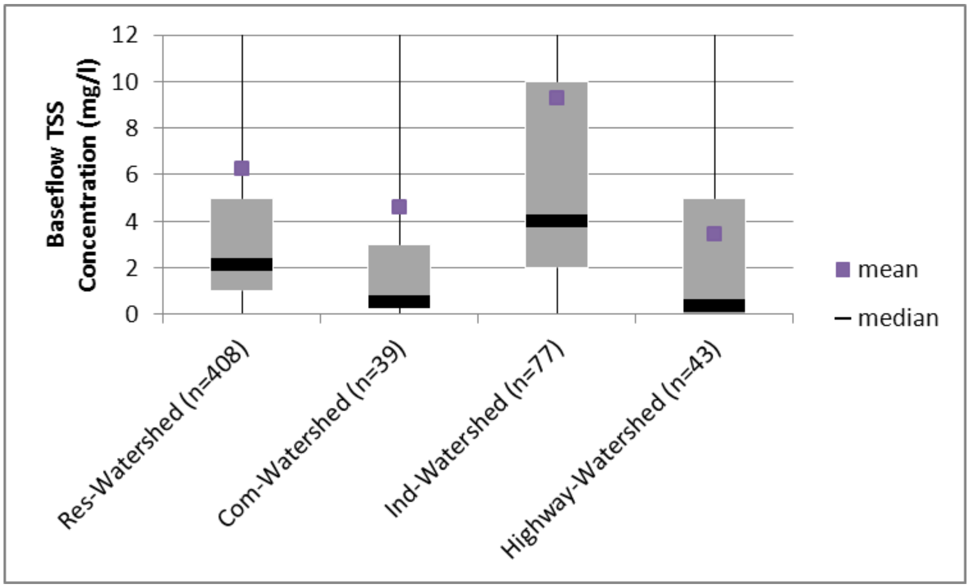

Figure 3. Event mean concentrations for total suspended sediment (TSS) during baseflow from watershed water quality sampling associated with urban land uses.

MS4 Specific TSS Concentrations

Results for storm event TSS EMCs (Figure 1) for each land use category were broken down by specific MS4 (Table 3). All of the MS4s reporting EMCs had significantly higher watershed concentrations compared to outfall concentrations (alpha = 0.05), with three exceptions. In Charles County and Anne Arundel County, the EMC was lower for the watershed compared to the outfall for residential and commercial land uses, respectively, suggesting these streams may be a sink for sediment. The outfall and watershed EMCs taken in Carroll County associated with industrial land use were not significantly different. Sample EMCs from Prince George's County were higher than any other MS4s.

Table 3. Average event mean concentration (EMC) data (mg/L) during storm events for MS4s in Maryland. Data are representative of outfall and watershed sampling locations. The sample size (n) is indicated in parentheses.

	Residential		Commercial		Industrial		Highway	
County	**Outfall**	**Watershed**	**Outfall**	**Watershed**	**Outfall**	**Watershed**	**Outfall**	**Watershed**
Anne Arundel	nd	nd	96.3 (132)	72.2 (129)	nd	nd	nd	nd
Baltimore City	88 (131)	112.3 (153)	nd	nd	nd	nd	nd	nd
Baltimore	42 (79)	66.9 (98)	39.6 (18)	96.9 (18)	nd	nd	78.1 (32)	219.3 (31)
Carroll	nd	nd	nd	nd	90.4 (53)	123 (51)	nd	nd

Table 3. Average event mean concentration (EMC) data (mg/L) during storm events for MS4s in Maryland. Data are representative of outfall and watershed sampling locations. The sample size (n) is indicated in parentheses.

Charles	59.6 (156)	34.3 (149)	nd	nd	nd	nd	nd	nd
Frederick	23.5 (95)	180.2 (118)	nd	nd	nd	nd	nd	nd
Harford	37 (90)	51 (94)	nd	nd	nd	nd	nd	nd
Howard	33.3 (74)	162.7 (59)	nd	nd	nd	nd	nd	nd
Montgomery	64.5 (88)	170.6 (87)	nd	nd	78.4 (40)	100.7 (48)	nd	nd
Prince George's	166.5 (115)	340.2 (172)	285.6 (23)	591.8 (17)	126.3 (28)	646.6 (24)	nd	nd

nd = no data. No information was reported or useable from the MS4 about the land use.

Results for baseflow TSS EMCs (for each land use category was broken down by specific MS4 (Table 4). The range in observed values was lower with baseflow conditions, although Prince George's County residential EMC was, again, higher than other MS4s. No baseflow EMCs were reported for Prince George's County for commercial or industrial land uses. Where baseflow samples were not provided, only storm EMCs from Table 3 were used with all flow to estimate loads.

Table 4. Average event mean concentration (EMC) data for watershed only, during baseflow for MS4 communities in Maryland.

County	Residential	Commercial	Industrial	Highway
Anne Arundel	nd	nd	nd	nd
Baltimore City	4.1 (112)	nd	nd	nd
Baltimore	4 (35)	0.5 (1)	nd	3.5 (44)
Carroll	nd	nd	7.1 (37)	nd
Charles	9.9 (9)	nd	nd	nd
Frederick	4.5 (104)	nd	nd	nd
Harford	2.4 (83)	nd	nd	nd

Table 4. Average event mean concentration (EMC) data for watershed only, during baseflow for MS4 communities in Maryland.				
Howard	12.9 (30)	nd	nd	nd
Montgomery	5.9 (42)	nd	11.4 (62)	nd
Prince George's	19.5 (45)	nd	nd	nd

nd = no data. No information was reported or useable from the MS4 about the land use.

Sediment Load Estimates & Stream Fraction

The estimated total watershed sediment load using mean EMC monitoring data and long term average modeled flow is approximately 400 lbs/ac/year to 2100 lbs/ac/year (Table 5). However, the envelope around the mean of a given land use, as indicated by minimum (min) and maximum (max) in Table 5, shows a much larger range. Minimum and maximum values represent the load based on minimum observed EMCs and maximum observed EMCs, respectively. This range effectively creates a lower and upper bounds of expected sediment loads from a given land use in a given year. The review done by CWP (2013) indicated total sediment yield between around 200 lbs/ac/year and 1500 lbs/ac/year.

Table 5. Annual loads based on minimum, mean, and maximum observed event mean concentrations (EMCs) for Maryland MS4 dataset.

Annual Loads (lbs/ac/year)									
	Total			Upland			Stream		
Land Use	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Residential	4	381	3208	1	149	1266	3	232	1941
Commercial	92	1659	9448	32	917	5262	60	742	4186
Industrial	103	2085	9923	48	706	3007	54	1380	6916
Highway	6	949	5190	59	323	846	-53	626	4344

A review of all MS4s for sediment load shows the variability amongst jurisdictions given the available data (Figure 4). Prince George's County had a maximum total watershed load of 4,600 lbs/ac/year. Additional data from the County and MDE is needed to identify what factors may be contributing to this higher load, given the simplifying assumptions used with the available data to estimate loads. Excluding Prince George's County, total sediment load from MS4s was below 1000 lbs/ac/year. These estimates are similar order of magnitude to the watershed load estimated by CWP (2013), ranging from 200 to 1,500 lb/acre/yr.

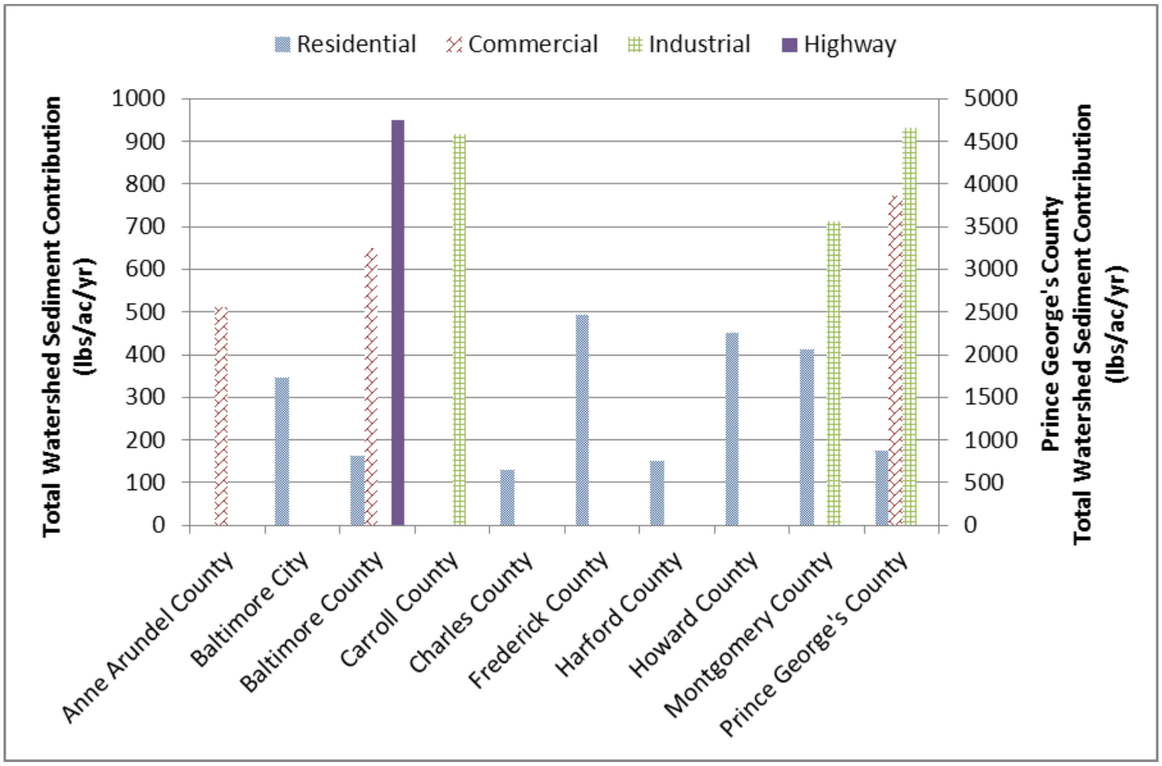

Figure 4. Estimated total watershed load for land uses reported to Maryland Department of the Environment (MDE) from municipal separate stormwater sewer system (MS4) communities.

The load estimates from Table 5 were used to calculate the fraction, or percent contribution by in-stream sources (channel bed and bank erosion). The fraction of in-stream sediment was calculated individually for each land use within an MS4, and then averaged for each land use. This attempts to address the potential bias where more weight is given to MS4s with higher loads. Results are summarized in Figure 5. There were minimal differences in calculated percent stream contributions when comparing using maximum and mean EMCs (Figure 5). This suggests that mean EMCs may be used to estimate sediment contributions even though sediment concentration may be higher during large storm events.

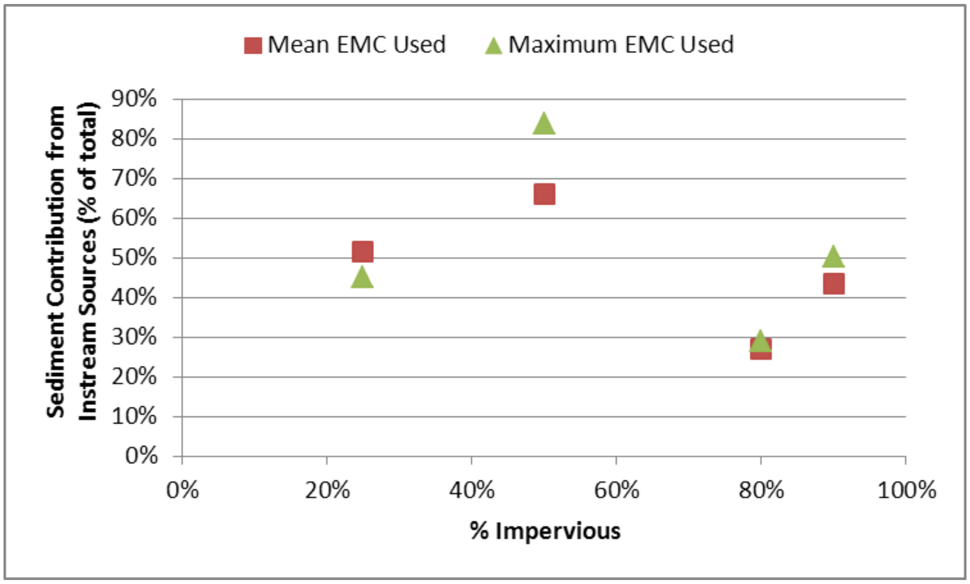

Figure 5. The estimated contribution of sediment from in-stream sources from Maryland MS4 communities.

The 300 lbs/ac/yr or less stream contribution trend found by CWP (2013) did not hold for all the MS4s in Maryland reporting data to MDE (Figure 6). Prince George's County, in particular showed loads above 500 lbs/ac/yr for all land uses monitored up to 3,750 lbs/ac/yr for industrial land uses (Figure 6). Though the sediment loads from Prince George's County were high, they are in the same range as extrapolated data from a study done in Baltimore City looking at Stony Run (Mitrus et al., 2006), which suggests a potential per acre stream contribution of over 4,000 lbs/ac/year based on per linear foot stream bank erosion. In another study by Baltimore City (Stack, 2009) sediment loading rates for several urban and rural streams varied between 500 and 1000 lbs/acre per year. All other MS4 observations were near 400 lbs/ac/yr or lower with the exception of the highway land use in Baltimore County (625 lbs/ac/yr).

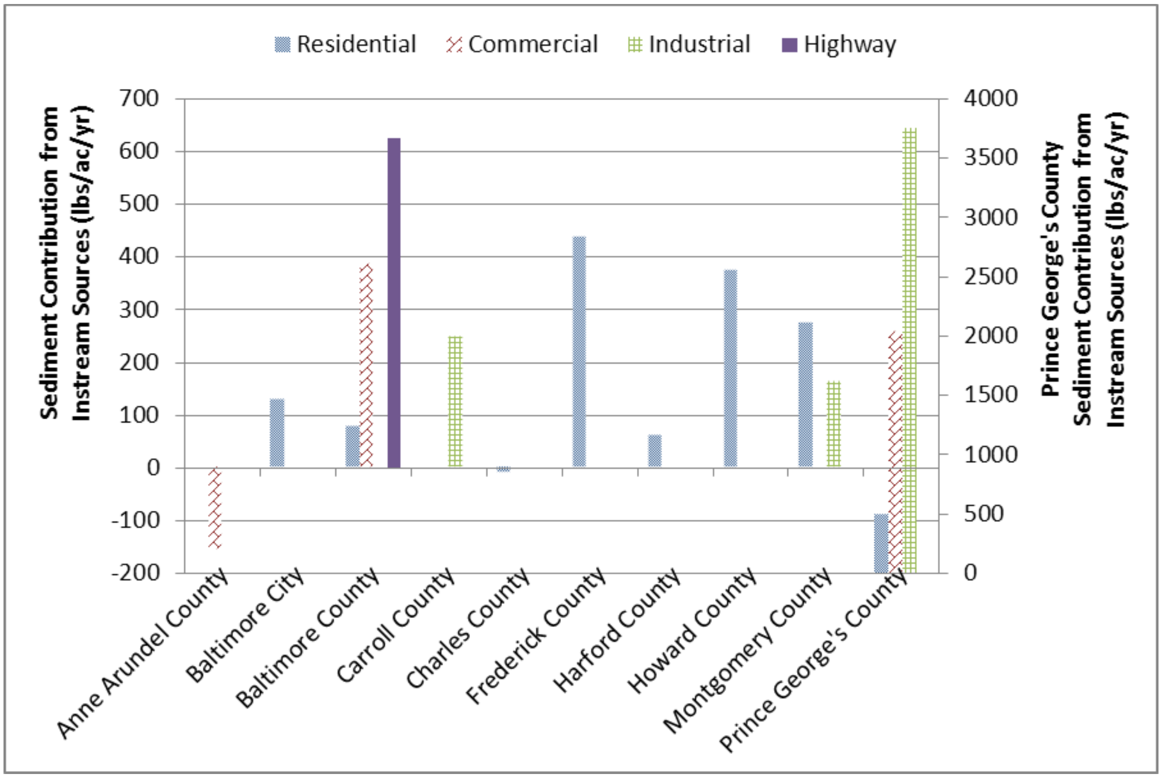

Figure 6. Estimated sediment contribution from streams for land uses reported to Maryland Department of the Environment (MDE) from municipal separate stormwater sewer system (MS4) communities.

Figure 7 displays in-stream loads as a percentage of total watershed load. Results show contributions from in-stream sources are between -30% (sediment storage in streams) and 89% (Figure 7); however, when sinks and sources are separated, the range of the two sink instances is -7% to -30% with an average of -19% while the range for the sources streams is 23% to 89% with an average of 55%.

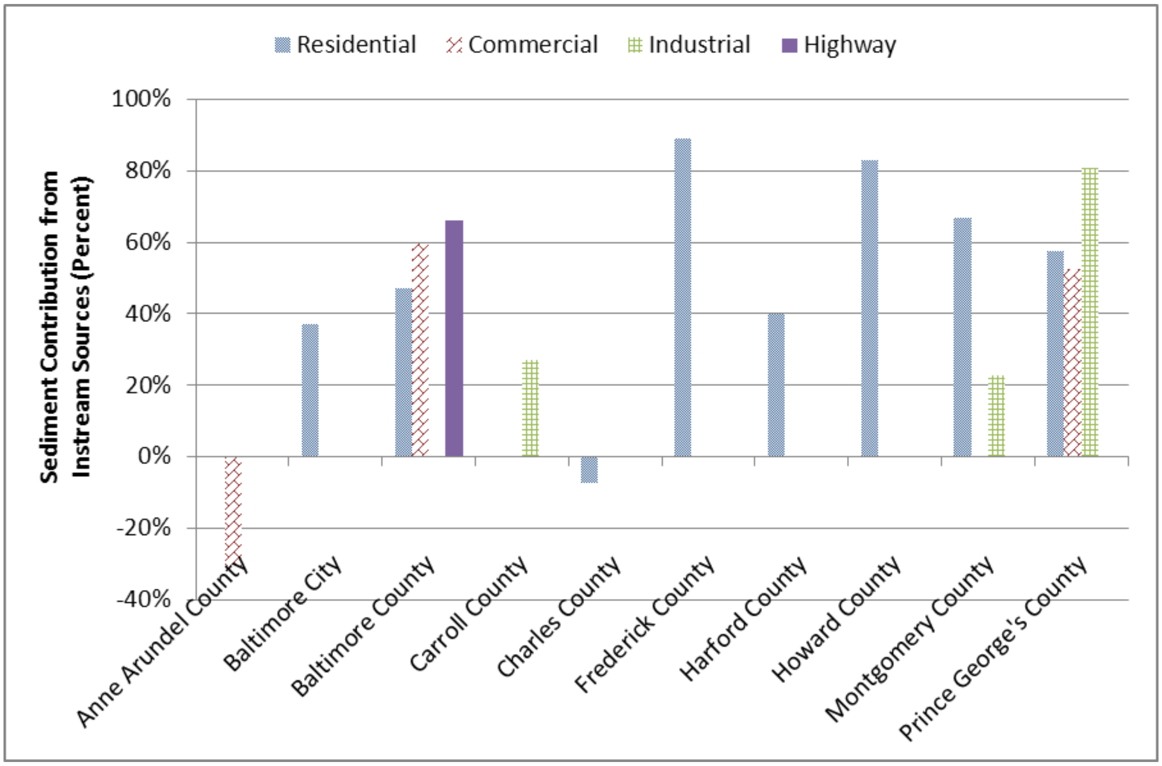

Figure 7. Estimates of relative contributions from the in-stream sources for urban land uses for MS4 communities in Maryland.

Comparison with Spring Branch

To put this work into perspective, sediment contribution from Spring Branch bed and bank erosion before and after stream restoration is compared to the estimated mean load from streams of MS4 residential communities in Maryland (Figure 8). Spring Branch is an urban stream with a drainage area of 1,005 acres in Baltimore County that has the only known data set within the Chesapeake Bay watershed of before and after stream restoration monitoring. Though the Spring Branch stream contribution estimate was higher than contribution estimates based on average EMCs in Baltimore County, results are not outside the range observed in other MS4 communities. Based on EMC data, streams in one county (Charles) are likely aggrading which means they are serving as sediment sinks rather than contributing sediment to the Bay.

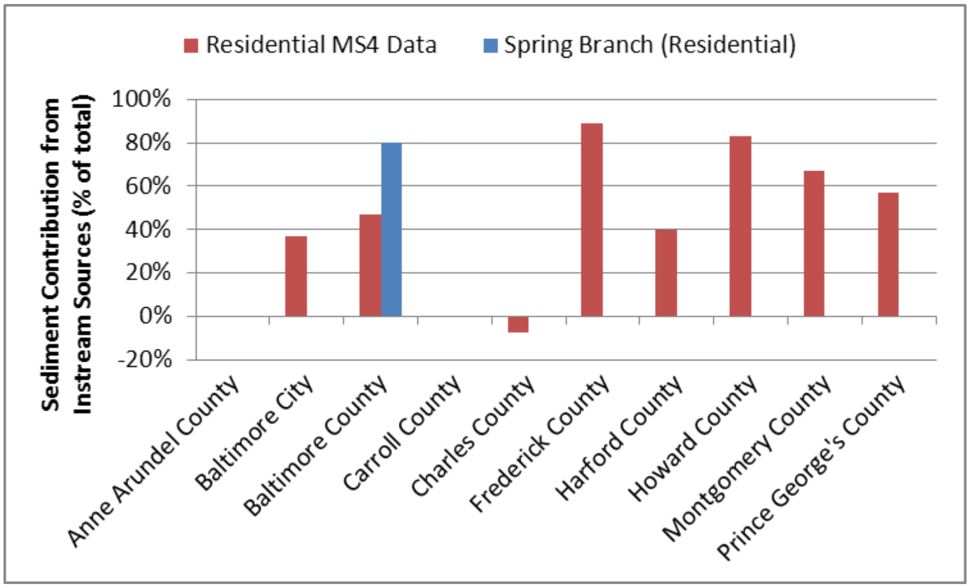

Figure 8. Estimated contributions of sediment from MS4 residential land uses in Maryland compared to Spring Branch. Data for Spring Branch provided by Baltimore County Department of Environmental Protection and Sustainability.

In terms of sediment load from in-stream sources, the highly residential Spring Branch watershed (74.5 lbs/ac) is comparable to in-stream source load estimates made in Baltimore County using MS4 residential data (76.7 lbs/ac). Baltimore City MS4 estimates for residential are slightly higher (127.7 lbs/ac). These loads were consistent with the previous sediment technical memo reviewing literature, which stated most estimates for stream contributions were at or below 300 lbs/ac (CWP, 2013).

4.0 Discussion of Findings and Next Steps

The purpose of this analysis was to identify and explore the use of available water quality data in the Chesapeake Bay to estimate in-stream sediment loadings for headwater streams. The results of the analysis may assist the development of phase 6 of the CBWM in support of defining headwater streams as a land cover. The data available for analysis included TSS EMC for ten MS4 communities in Maryland and modeled flow data generated from the Phase 5.3 Chesapeake Bay Watershed Model. Many simplifying assumptions were used to estimate sediment contributions given available data.

Results of the MS4 dataset suggest similar order of magnitude sediment contributions, but display a much larger range compared to estimates provided by CWP (2013) and Langland and Cronin (2003). For example, it was estimated that the average in-stream sediment contribution from the four land uses is 745 lb/acre/yr, compared to 300 lb/acre/yr or less based on the literature review analysis by CWP (2013). The results also suggest that streams may be a sink as well as a source for sediment. Although, this finding is based on a set of simplifying assumptions for the analysis, the function of streams as a sediment source and trap is an important dynamic to capture in future representation of streams as part of Phase 6 model development. To date and given available monitoring studies and water quality data, there is not a strong trend between imperviousness and stream contributions; however, the data sets in this analysis limited accurate representation of the land use land cover for the MS4 datasets.

Moving forward with this analysis, a comparison between the edge-of-field sediment loadings estimated from bank erosion rates may be compared to total in-stream sediment loadings, representing edge-of-stream loads, to better quantify the contribution of sediment from headwater streams. A review of twenty-two studies used in the development of Stream Restoration Expert Panel Report (Schueler and Stack, 2013) can provide estimates for bank erosion rates. This approach may assist characterization of sediment sources in agricultural watersheds.

Improved characterization of headwater streams is needed. There is a need to identify landscape characteristics affecting the source-sink function of headwater streams to include, for example accurate impervious and pervious land cover, bank height, floodplain connection, presence/absence of impoundments, slope, vegetated cover, stormdrain network, etc. Additional data may be available from MS4 communities, whose data was used in this analysis, specifically focusing on communities indicative of sediment transport or depositional reaches. Future work with USGS on floodplain mapping using LIDAR and other remotely sensed data may also identify key variables affecting sediment dynamics in headwater streams.

For future work, where flow (modeled or measured) data are not available, EMCs from outfall and watershed sampling locations associated with comparable land uses in a watershed can be used to apportion loading between upland and in-stream load since EMCs are normalized for flow. This approach was used by Mitrus et al. (2006) who found that the average TSS EMCs from 6 different storm drain inlets where less than 25% of the EMC in the receiving stream system. Using the mean MS4 EMC data during storm flow and assuming, for a given subwatershed with uniform land use, $Flow_{Outfall}$=$Flow_{Stream}$, an estimate of the stream contribution can be made. Differences between estimated load using the equal flow assumption (simply using EMCs) and loads using EMC and modeled flow are 10.9%, 2.6%, 0.6%, and 1.4% for residential, commercial, industrial, and highway land uses, respectfully (Figure 9). This suggests that simply using storm EMCs for outfall and watershed sampling locations would provide a conservative estimate of stream contributions, particularly in highly impervious areas, with relatively little effort.

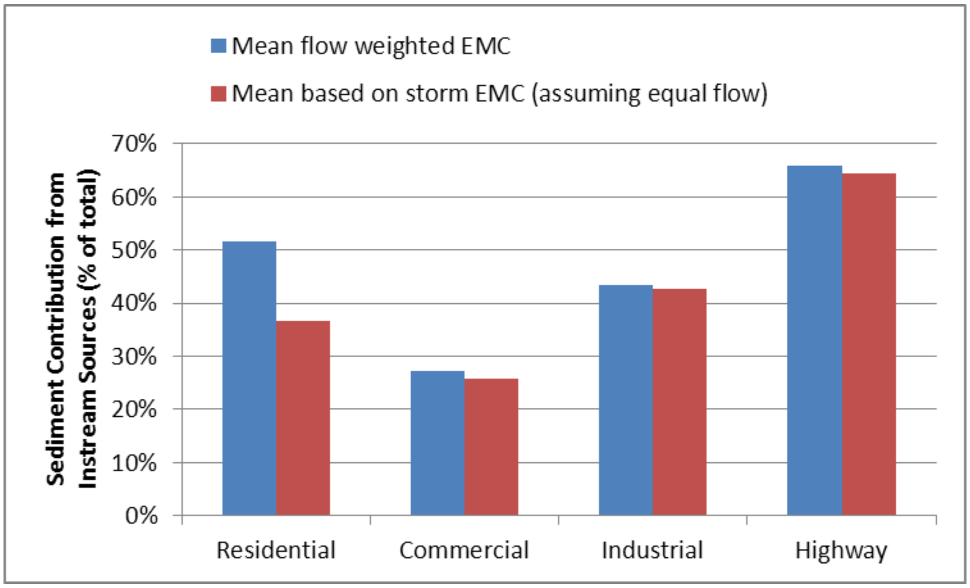

Figure 9. Estimated stream contribution based on land cover, flow-weighted sediment loads compared to loads assuming equal flow from outfalls and watershed sampling locations.

Additionally, determining the source of total phosphorus (TP) and total nitrogen (TN) loading is planned for future analysis. This will be completed once methods used for sediment are determined to be directly transferable to the nutrients.

5.0 References

CWP. (2013). Stream Sediment Studies in Support of Objective 1 of the Sediment Reduction and Stream Corridor Restoration Analysis, Evaluation and Implementation Support to the Chesapeake Bay Program Partnership (pp. 15).

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