August 2017

Annual Report: In-system Wet Weather Stormwater Monitoring Program

Introduction

In order to characterize nutrient and sediment concentrations related to urban stormwater, the six Phase I MS4 localities within Hampton Roads, in partnership with the U.S. Geological Survey (USGS) and the Hampton Roads Sanitation District (HRSD), created a regional stormwater monitoring network. This network is dual-purposed, simultaneously addressing local water quality issues and fulfilling MS4 permit requirements, while providing useful data to support Chesapeake Bay Program modeling efforts. The Chesapeake Bay Program's watershed model is responsible for estimating loads of total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) throughout the Bay watershed. However, there are no calibration stations within the Coastal Plain, and therefore no verifiable loading rates of these compounds. By providing high frequency and high quality data through the USGS quality control and quality assurance framework, the Hampton Roads region will be well-represented with accurate estimates of loading rates for future phases of the model. This report was developed to fulfill the requirements stated in the Phase I localities' MS4 permits.

Monitoring Network

The six Phase I MS4 localities (Chesapeake, Hampton, Newport News, Norfolk, Portsmouth, and Virginia Beach) participate in the Hampton Roads Regional Water Quality Monitoring Program (RWQMP). Each locality has two monitoring sites, draining land between 3 and 30 acres with no tidal water influence, that represent a range of urban land uses including high-density residential, single-family residential, and commercial/industrial (Fig. 1; Table 1). Site selection was also based on the goal of having very few, if any, best management practices (BMPs) upstream of the sampling

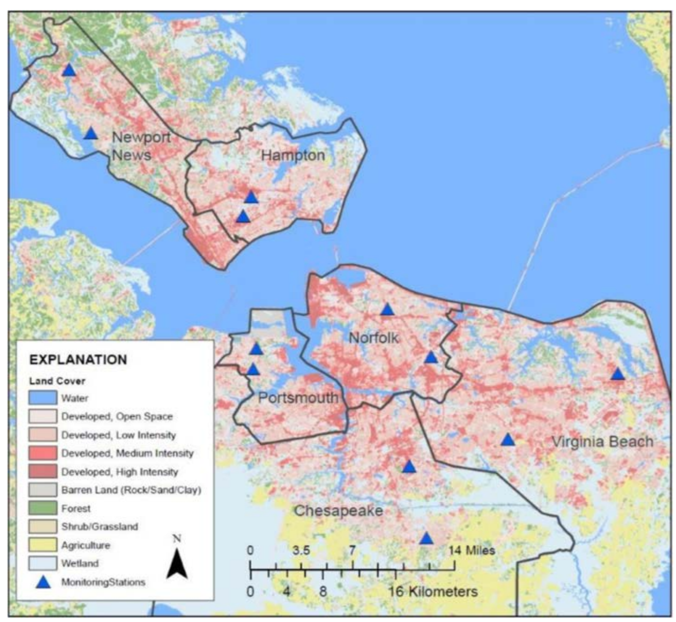

Figure 1. Locations of the 12 water quality monitoring stations, overlaid on land cover, in Hampton Roads, VA.

area. By characterizing the range in loadings that are typical of a given land-use type that do not yet have BMPs implemented, variability can be assessed within land use types, and meaningful comparisons can be developed between the three dominant land use types in the region. This should significantly enhance the understanding of how management activities can be directed efficiently.

Table 1. Locality names, station names, and land use types for all localities participating in the monitoring program.

Locality	Station Name	Land Use Type
Chesapeake	Professional Place	Commercial
Chesapeake	Ramsgate Lane	Single-family Residential
Hampton	Coliseum Drive	Commercial
Hampton	Garrett Drive	Single-family Residential
Newport News	Lakewood Park Drive	Single-family Residential
Newport News	Rivers Ridge Circle	High Density Residential
Norfolk	Sheppard Avenue	Single-family Residential
Norfolk	USAA Drive	Commercial
Portsmouth	Craneybrook Lane	High Density Residential
Portsmouth	Daisy Drive	Single-family Residential
Virginia Beach	Lindsley Drive	High Density Residential
Virginia Beach	Ludlow Drive	Single-family Residential

Operation of the monitoring network is the joint responsibility of USGS and HRSD. Data collection is supervised by the USGS Virginia Water Science Center to ensure that data quality meets the requirements established by USGS. Discrete sample collection and analysis plus system maintenance are conducted by HRSD’s Central Environmental Laboratory (CEL) while data analysis, interpretation, and reporting are conducted by USGS. All 12 stations collect real-time, high frequency data including flow (stage, velocity, and discharge), turbidity, specific conductance, and water temperature. Discrete samples for nutrients and sediments are taken during storm events over a range of flows and for quarterly baseflow sampling. Nutrient concentrations consist of measurements of TN, total Kjeldahl nitrogen (TKN), organic nitrogen, nitrate + nitrite, ammonia + ammonium, TP, and orthophosphate. Sediments are measured as TSS.

Monitoring Protocols

Each station is equipped with a continuous flow meter, a water quality sonde for continuous water quality monitoring, a refrigerated automated sampler for the collection of stormwater water quality samples, an internal data logger for recording and storing all measured values, a satellite telemetry unit to transmit data hourly, a power system supporting all components (AC power with battery backup), and a ruggedized housing that protects all equipment (Fig. 2). Continuous flow is measured at 5 minute intervals and flow meters are connected to the data logger and satellite telemetry system to provide data in near real time. Instruments are operated in accordance to manufacturer guidance, and USGS guidance (see http://water.usgs.gov/osw/pubs.html). Continuous water quality monitors measure water temperature, specific conductance, and turbidity and are operated in accordance to standard protocol (Wagner et al. 2006).

Figure 2. Ruggedized housing and components present at each stormwater monitoring station.

Discrete sampling for nutrients and sediment are triggered by the datalogger when stormflow conditions exist (as indicated by flow and water quality conditions). Samples are retained in the refrigerated sampler (≤ 6°C) until retrieved by HRSD field staff. Samples are retrieved within 24 hours of collection, transported in coolers (≤ 6°C), and delivered to the laboratory for preservation and analysis. The analytes measured have defined laboratory methods within 40 CFR Part 136 and TN is calculated as the sum of TKN and nitrate + nitrite. Detailed standard operating procedures for nutrient and sediment analysis are maintained at HRSD's CEL and available upon request.

All data collected for this monitoring program, including continuous time series data and discrete sample data, is retained in the USGS National Water Information System (NWIS) and made publicly available online via NWISweb (http://waterdata.usgs.gov/HRStormwater). Continuous data from the flow meter and water quality monitors are transmitted via GOES satellite hourly and uploaded directly into NWIS via automated processes. These data are made publicly available on NWISweb within minutes of the hourly transmission. Discrete sample data is entered into the Laboratory Information Management System (LIMS) at HRSD. These data are electronically transferred monthly to USGS for entry into NWIS, at which time they are publicly accessible via NWISweb.

Results

Monitoring station installation began in April 2015 with all stations on-line and collecting data by December 2016. Between July 1, 2016 and June 30, 2017, a total of 547 discrete sampling events were logged, inclusive of baseline and event-triggered sampling and thousands of continuous monitoring data points have been collected and evaluated. In addition, meteorological data was collected from the Norfolk International Airport and from rain gauges throughout the region. Annual precipitation in 2016 was greater than years previous (Fig. 3), thus results interpreted from this snapshot in time will have higher than normal discharges and loads.

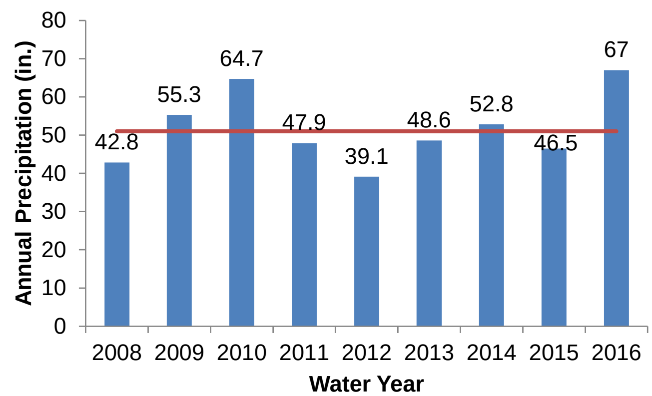

Figure 3. Total annual precipitation from Norfolk International Airport (NOAA) for water years 2008-2016 (blue bars) and the 10 year mean (red line).

Total annual discharges were highest at the commercial sites, followed by high density residential, and single family residential (Fig. 4). Commercial sites had the greatest amount of impervious surface compared to other land use types which were comprised more of turf grass and tree cover. Not unexpectedly, seasonal temperature variations were consistent between sites (Fig. 5).

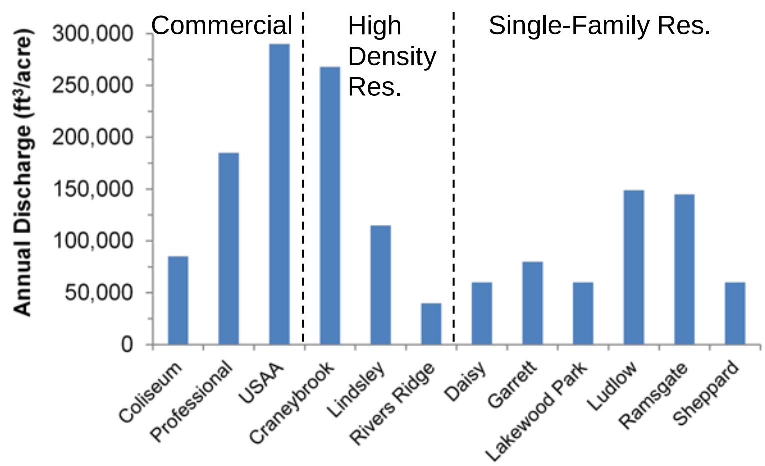

Figure 4. Total annual discharge at each site, grouped by land use.

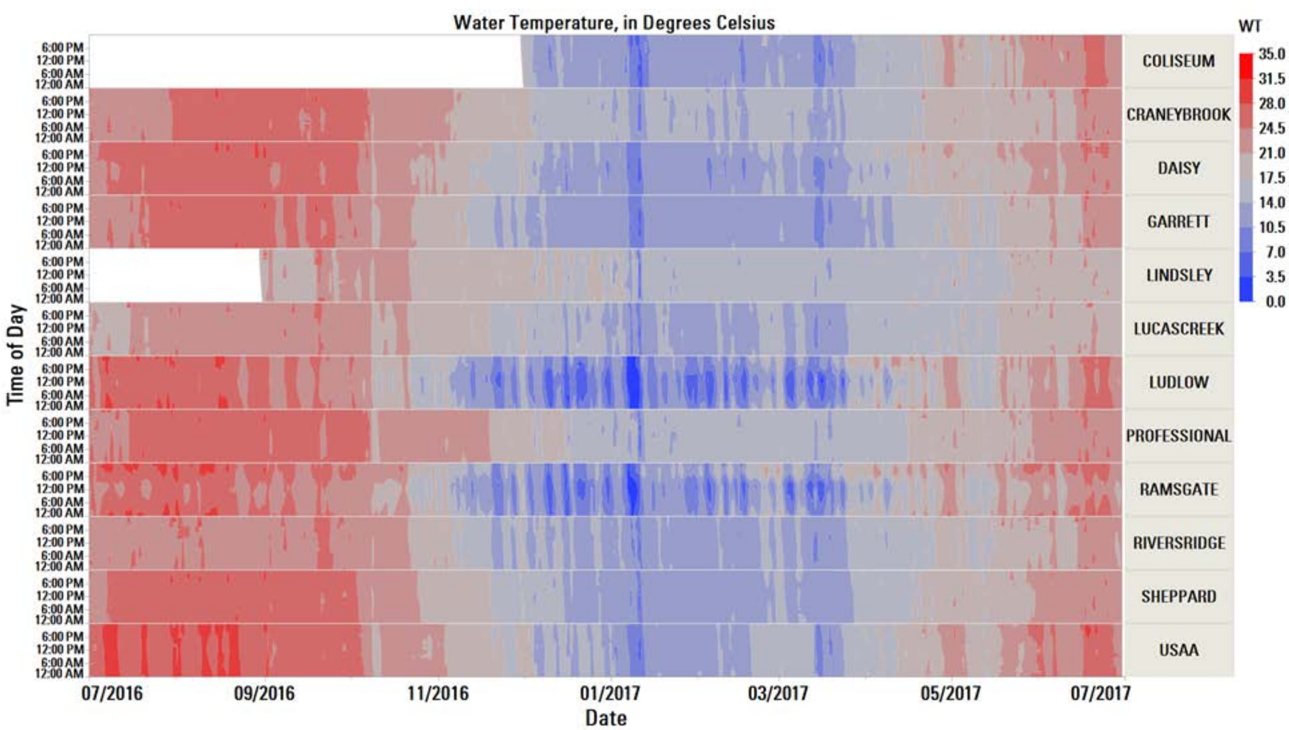

Figure 5. Daily temperature (°C) at 5 minute intervals for each site between July 1, 2016 and June 30, 2017.

TN concentrations were significantly different between land use types on average, and were greatest for single family residential land use (Fig. 6A). Nitrate + nitrite concentrations were greatest in high density and single family residential land uses compared to commercial (Fig. 6B). Organic nitrogen tracked with TN concentrations (Fig. 6C). There were no significant differences between ammonia + ammonium concentrations and land use (Fig. 6D). The bulk of the N pool was comprised of organic N (Fig. 7).

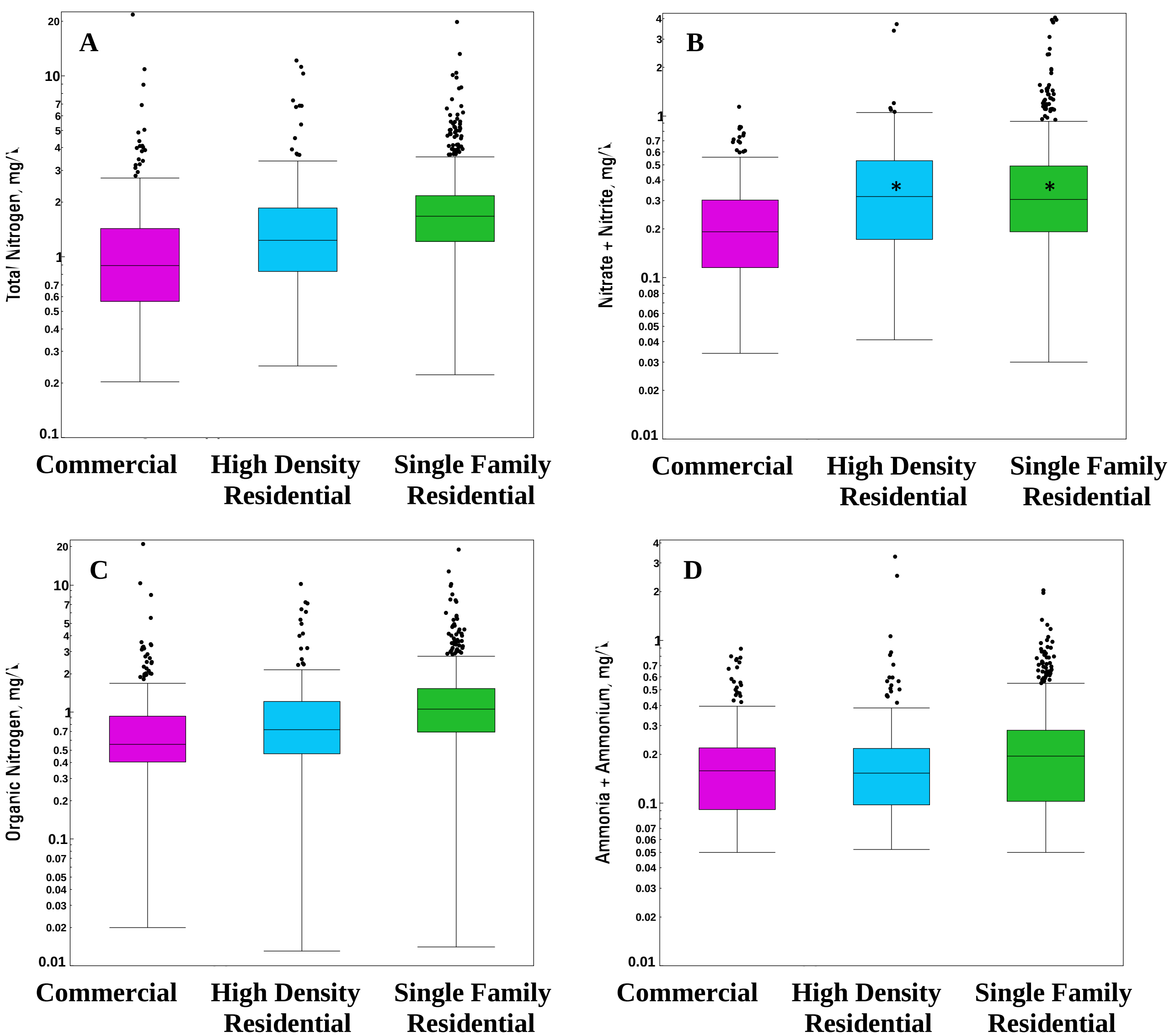

Figure 6. Box and whisker plots of concentrations (mg/L, log scale) of TN (A), nitrate + nitrite (B), organic N (C), and ammonia + ammonium (D) for the three land use types for July 1, 2016 – June 30, 2017. Outliers (black dots) denote concentrations outside error bars from higher discharge events. Median values are statistically different unless denoted with an asterisk (*).

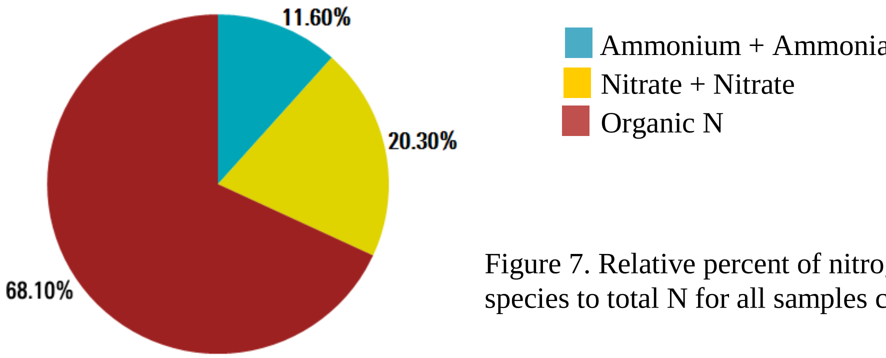

Figure 7. Relative percent of nitrogen species to total N for all samples collected.

TP and orthophosphate concentrations were also significantly greater for single family residential land uses compared to commercial and high density residential land uses (Fig. 8A & 8B). There was no significant difference in TSS concentrations among sites (Fig. 9). Outliers in all plots, denoted by black dots, are a result of higher discharge events occurring outside of the highest interquartile (> 75th percentile).

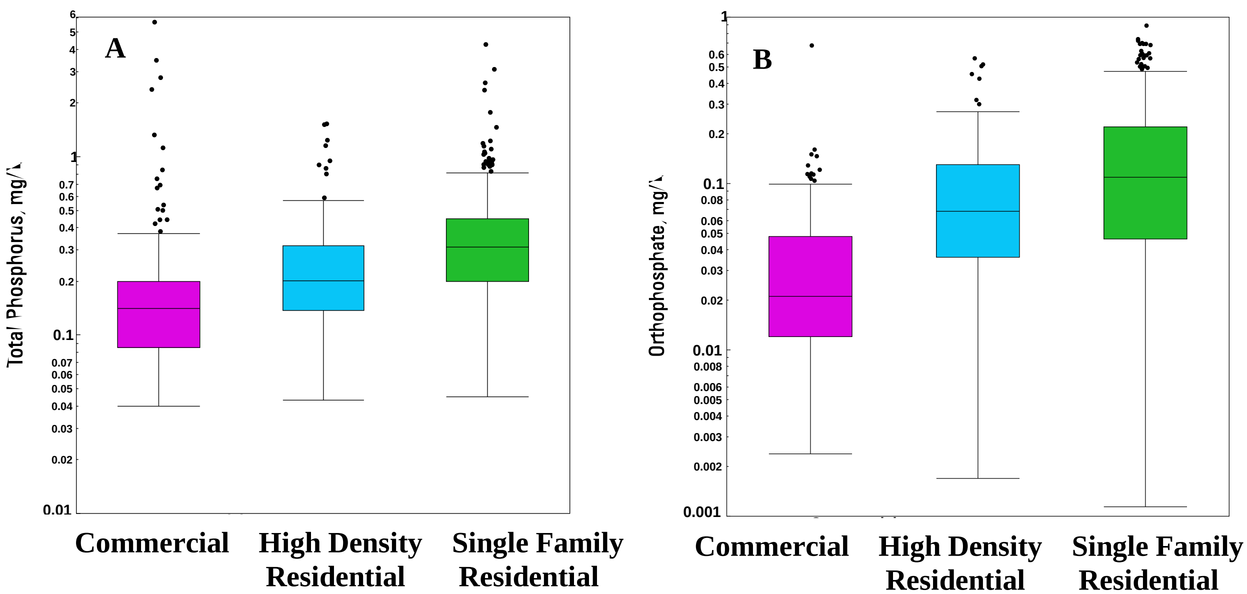

Figure 8. Box and whisker plots of concentrations (mg/L, log scale) of TP (A), and orthophosphate (B) for the three land use types for July 1, 2016 – June 30, 2017. Outliers (black dots) denote concentrations outside error bars from higher discharge events. Median values are statistically different.

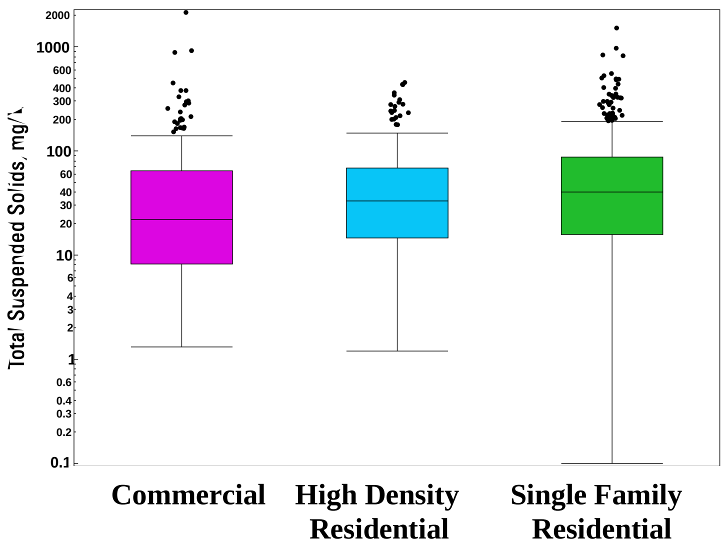

Figure 9. Box and whisker plots of TSS concentrations for the three land use types for July 1, 2016 – June 30, 2017. Outliers (black dots) denote concentrations outside error bars from higher discharge events. Median values are significantly different.

Discussion

While long term trends and loading rates cannot be established at this time, nutrient concentration variability among land use types is evident for this first year of data. Higher concentrations of nutrients from single family and high density residential land uses compared to commercial land uses suggests higher urban fertilizer usage per acre in those areas. However, other nutrient sources must be considered, as a P ban has been enacted in VA for urban fertilizer, and the bulk of TN in the samples was organic N. The presence of the high fraction of organic N is likely due to low flushing in some areas, resulting in accumulation of organic material. Conversely, TSS did not vary from site to site, and in a preliminary comparison to other monitoring programs across the state conducted by the USGS, TSS concentrations were lower in the Coastal Plain. It is important to note that there are a wide range of concentrations for all constituents at all sites, related to the flashiness of these systems in response to storm events. Additionally, higher concentrations at higher density land uses may not translate into similarly high loads, because drainage acreage and the degree of imperviousness of the land dictate the volume of water delivered to the stormwater system (Schueler, 1994, Schueler, 2009).

A variety of factors will impact the amount of nutrients or sediments in urban runoff, including antecedent rain events, rain duration and total volumes, storm frequency, time of year, and of course land use (Brezonik & Stadelmann, 2002; Sonzogni et al., 1980). Over this first year, it was evident that several individual storms can account for a large amount of annual discharge, which could translate to high loads in a short time frame. As an example at one site, three storms accounted for nearly 50% of the total annual flow, translating to 65% of the annual sediment load. In typical stream systems, and on average in this stormwater monitoring program, 90% of the time flow is equal to or less than 1 ft^3/s. Flows greater than that only occur 10% of the time and are mostly related to larger storm events. It is the goal of this monitoring program to factor in storm variability, base flow, and land use type over an extended period of time to establish demonstrable loading rates in the Coastal Plain. This will provide valuable data to a future version of the Chesapeake Bay watershed model (Phase 7) and contribute to current calibrations of the Phase 6 model. Over the course of the next few years, localities will continue to collaborate with USGS and HRSD to collect data and evaluate loading rates over the long term.

References

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