2016 Masonville Cove – Patapsco River Shallow Water Monitoring Data Report

21 June 2017

2016 Masonville Cove – Patapsco River
Shallow Water Monitoring Data Report

Prepared by:
Brian Smith, Diana Domotor, T. Mark Trice, and Bruce Michael
Resource Assessment Service/Tidewater Ecosystem Assessment
Maryland Department of Natural Resources
Tawes Building, D-2
580 Taylor Avenue
Annapolis, MD 21401

Website Address:
http://www.dnr.maryland.gov

Toll Free in Maryland:
1-877-620-8DNR, ext: 8630
Out of state call: 410-260-8630
TTY users call via the MD Relay: 711 (within MD)
Out of state call: 1-800-735-2258

TABLE OF CONTENTS

List of Tables………………………………………………………………………... ii
List of Figures……………………………………………………………………… iii
Executive summary………………………………………………………………… iv
Introduction………………………………………………………………………… 1
Description of continuous monitoring…………………………………………….. 1
Continuous monitoring parameters……………………………………………… 3
Calibration of continuous monitors and collection of laboratory water samples…….. 4
Masonville Cove continuous monitor deployment……………………………… 4
2016 Precipitation and Discharge Events…..…………………………………………. 4
2016 Continuous Monitoring Data…..…………………...…………………………… 6
Water Temperature………………………………………………………………… 6
Salinity……………………………………………………………………………. 7
Dissolved Oxygen………………………………………………………………… 8
Chlorophyll………………………………………………………………………... 11
pH……………………………………………………………………………….... 13
Turbidity…………………………………………………………………………... 14
Submerged Aquatic Vegetation (SAV) in the Patapsco River…..…………………… 16
Pigments, Suspended solids, and Secchi Data…..…………………………………….. 18
Conclusion…………………………………………………………………………….. 19
References……………………………………………………………………………… 20
Appendix A……………………………………………………………………………. 21

LIST OF TABLES

Table 1: Dissolved oxygen criteria failure……………………………………………. 10
Table 2: Chlorophyll threshold failure………………………………………………… 12
Table 3: Turbidity threshold failure…………………………………………………… 15
Table 4: Deployment and calibration record………………………………………….. 19
Table A1: Pigments, suspended solids, and Secchi data for 2016 calibration samples.. 24
Table A2: D.O., pH, salinity, and temperature data for 2016 calibration samples……. 25

LIST OF FIGURES

Figure 1: Map of Patapsco River and Masonville Cove……………………………… 2
Figure 2: Sonde diagram………………………………………………………… 3
Figure 3: 2016 precipitation at BWI airport………………………………………….. 5
Figure 4: 2016 daily discharge from Gwynns Falls USGS gage…..…………………. 6
Figure 5: Water temperature at Masonville Cove continuous monitor 2016………… 7
Figure 6: Salinity at Masonville Cove continuous monitor 2016…………………….. 8
Figure 7: Dissolved oxygen levels at Masonville Cove continuous monitor 2016……10
Figure 8: Total chlorophyll at Masonville Cove continuous monitor 2016…….…… 12
Figure 9: pH at Masonville Cove continuous monitor 2016………………………… 13
Figure 10: Turbidity at Masonville Cove continuous monitor 2016…………………. 15
Figure 11: Total area and density of SAV in the Patapsco River…………………….. 17
Figure A1: Chlorophyll *a* calibration data………………………..………………... 22
Figure A2: Pheophytin calibration data……………………..……………..…… 22
Figure A3: Total suspended solids calibration data…………….…………….…... 22
Figure A4: Secchi depth calibration data……………………………………..… 22
Figure A5: Salinity calibration data……………………….……………………... 22
Figure A6: Dissolved oxygen calibration data…………….…………………..….. 22
Figure A7: Water temperature calibration data…….…………………………….….. 23
Figure A8: pH calibration data……………………………..........………………….. 23

Executive summary

Masonville Cove, a small inlet of the upper tidal Patapsco River, figures in local Baltimore lore as a natural respite from the rigors of early twentieth century city life. However, as the Patapsco River was heavily impacted by pollution from centuries of being a center of commerce and population, so too was Masonville Cove. In 2007, the Maryland Port Administration received a permit to build a dredged material containment facility at the Masonville Marine Terminal, adjacent to Masonville Cove. As part of the mitigation agreement for this project, the Maryland Department of Natural Resources (DNR) deployed a continuous water quality monitor in the summer of 2009, ahead of the construction of the dredged material containment facility. Since 2009, DNR has continued to deploy a monitor during most of the year, although it has been removed in the winter in prior years due to icing conditions. In continuation of this project, a water quality monitor was deployed off the Masonville Cove pier during the entirety of 2016.

Water quality conditions in Masonville Cove during 2016, as in the rest of the Chesapeake Bay watershed, were influenced by meteorological events. Heavy rains and several associated sanitary sewer overflows in February and late July led to massive discharge events that affected salinity and turbidity. Rains in early February were also associated with reduced water clarity and the highest levels of total suspended solids (TSS) measured in 2016. Dissolved oxygen concentrations degraded for the third straight year. Chlorophyll concentrations improved from the prior year, but data indicate that significant to severe algal blooms were a frequent occurrence throughout 2016. Also, potentially harmful *Microcystis* blooms were recorded within the Dredged Material Containment Facility (DMCF) in September and November. However, turbidity measurements indicated the best water clarity, in terms of reduced threshold failure rates, since monitoring began in Masonville Cove in2009. This follows a trend of increased water clarity throughout Maryland over the past few years. All 2016 continuous monitoring data, as well as data from previous years, are available on the DNR "Eyes on the Bay" website (http://eyesonthebay.dnr.maryland.gov/contmon/ContMon.cfm). Data from grab samples are available through the Chesapeake Bay Program's Data Hub (www.chesapeakebay.net/data).

Introduction

In 2007, the Maryland Port Administration (MPA) submitted plans to the United States Army Corps of Engineers (USACE) to construct a Dredged Material Containment Facility (DMCF) in the vicinity of the Masonville Marine Terminal (Figure 1). The terminal, located on the upper Patapsco River in Baltimore, is a major port for the automotive industry. The design for the DMCF uses sand and clay dikes to contain material dredged from the navigation channels in Baltimore Harbor. The same year, an environmental impact study submitted to USACE suggested mitigation for the project. Mitigation was deemed necessary as the DMCF was to fill 130 acres of tidal open water, cover ten acres of upland habitat, and disturb one acre of vegetated wetland and 0.38 acres of submerged aquatic vegetation (SAV).

In 2016, as continuation of the mitigation plan implemented in 2009, the Resource Assessment Service of the Maryland Department of Natural Resources (DNR) monitored water quality in Masonville Cove adjacent to the DMCF site. DNR deployed a continuous water quality monitor that collected data every 15 minutes on a suite of water quality parameters, including dissolved oxygen, salinity, temperature, turbidity, pH, and chlorophyll. Data from this monitor were telemetered to the DNR website "Eyes on the Bay" (www.eyesonthebay.net) and displayed in near real-time. DNR personnel visited the station every two to four weeks to replace the meters, and to collect water samples for analyses of total suspended solids, chlorophyll *a*, and pheophytin concentrations. The continuous monitoring site at Masonville Cove was one of three continuous monitoring stations located in the upper Patapsco in 2016. The other two sites were deployed adjacent to the National Aquarium in the Baltimore Harbor.

Description of continuous monitoring

For the entirety of 2016, a data collection device known as a sonde was attached to a piling on the Masonville Cove pier (39.2447°, -76.5972°) with its instrumentation deployed one meter below the water surface (see Figure 1 for station location). This location is approximately one-tenth of a mile west of the deployment location used prior to 2013 (Figure 1). The location change was made so that DNR field personnel would be able to access the site during winter months, which allows the monitor to be deployed year-round. Prior to 2013, the site was only accessible by boat so the monitor needed to be removed during the winter months when icing at the boat ramp precluded access. The data sonde deployed in Masonville Cove was a YSI™ 6600 V2 (Yellow Springs Instruments, Yellow Springs, OH), which housed several water quality sensors (Figure 2). The water quality indicator data collected by each sensor are explained in greater detail in the following section. The sonde collected a reading from each sensor simultaneously every 15 minutes for the duration of its deployment. These readings were stored in the sonde's data memory and sent, by attached cellular telemetry equipment, to DNR headquarters in Annapolis. There, the data were posted on DNR's "Eyes on the Bay" website (www.eyesonthebay.net) for easy public access. This website enables the public to access near real-time water quality data for numerous locations throughout Maryland. The data are called "near real-time" because there is a lag of approximately 30-minutes to one hour between the time that the sonde collects the data and the time that the data are posted on the website.

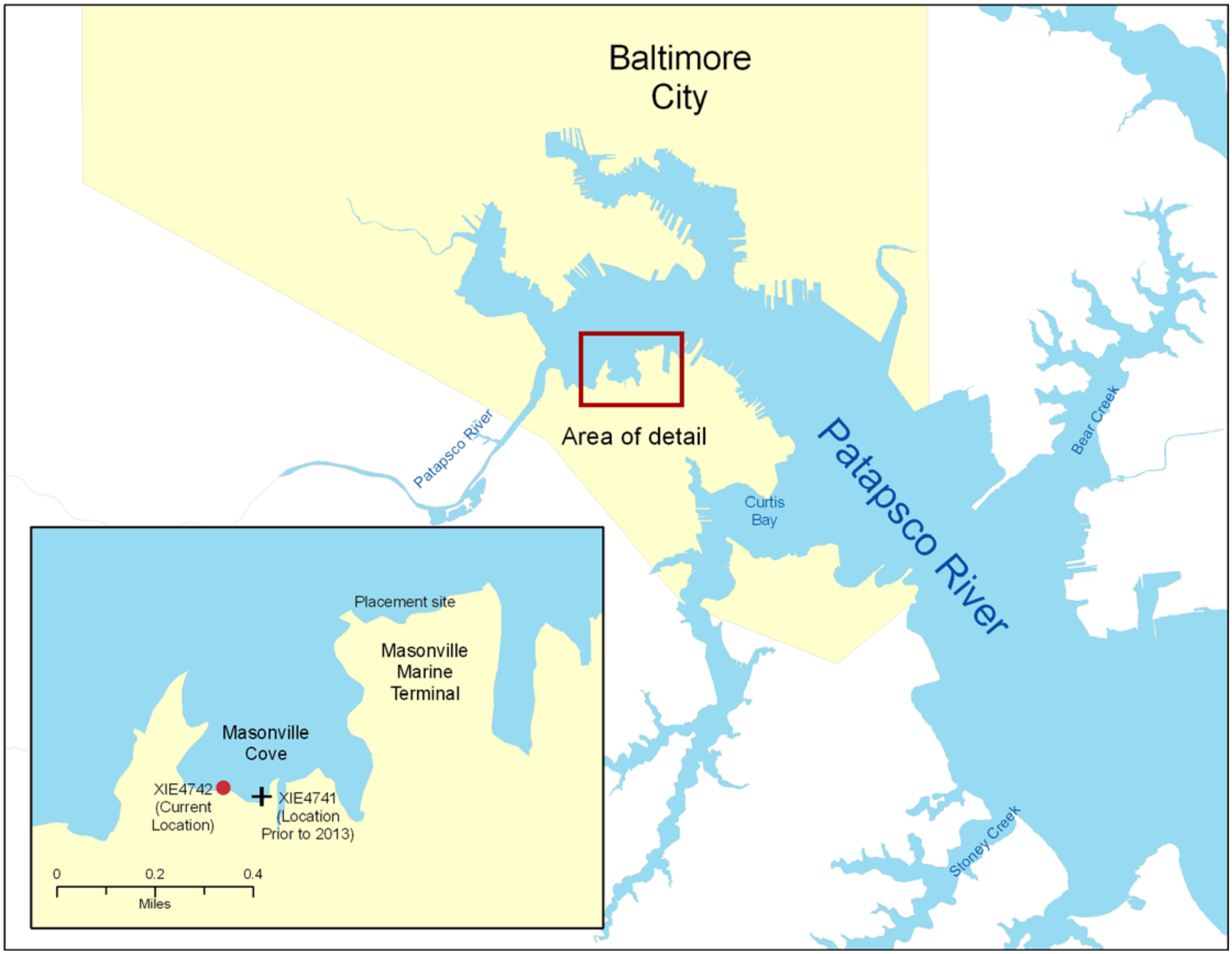

Figure 1. Map of the Patapsco River and Masonville Cove. The inset shows the 2016 continuous monitor location within the cove, the location of the monitor prior to 2013, and the approximate site for dredged material placement.

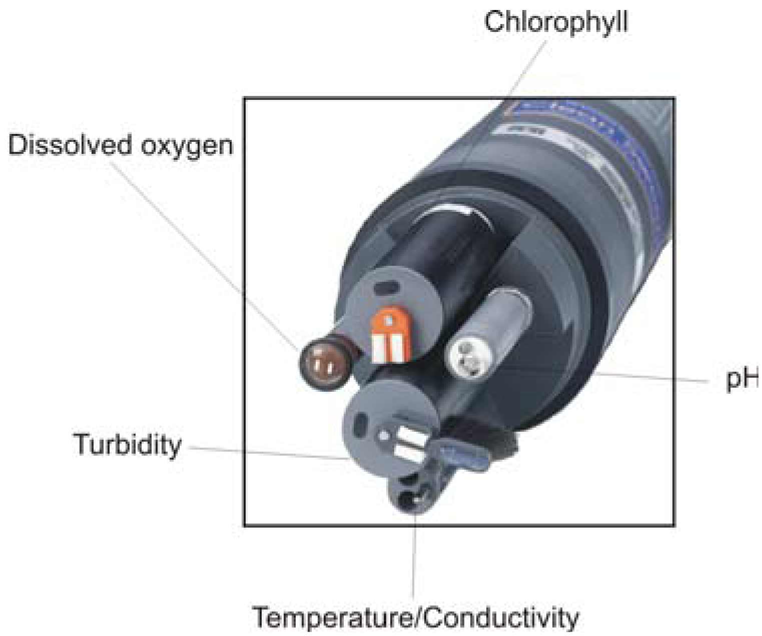

Figure 2. YSI 6600 continuous monitoring sonde showing individual sensors. Image courtesy of YSI, Inc.

Continuous monitoring parameters

The continuous monitor at Masonville Cove, like all continuous monitors in the DNR Shallow Water Monitoring Program, collected data on six water quality parameters:

1. Dissolved oxygen (DO): Fish and other aquatic life require DO to survive. Maryland state water quality criteria require a minimum DO concentration of 5 milligrams per liter (mg/L) (COMAR 1995). This threshold is necessary for the survival of many fish and shellfish species, including blue crabs (*Callinectes sapidus*) and striped bass (*Morone saxitilis*).
2. Salinity: Salinity, or salt concentration, in the Patapsco River comes from the Chesapeake Bay. Therefore, areas closer to the Bay have higher salinities, except perhaps during large freshwater releases from the Conowingo Dam on the Susquehanna River. During periods of low precipitation and river flow, salinity increases as salty water intrudes further up the river. During wetter periods, salinity decreases. Salinity also cycles in relation to tides, increasing during flood tides and decreasing during ebb tides. Salinity levels are important to aquatic organisms, as some organisms are adapted to live only in brackish or salt water, while others require fresh water.
3. Water temperature: Water temperature is another variable affecting suitability of waterways for aquatic organisms. Many aquatic organisms can tolerate gradual temperature changes associated with changing seasons, but sudden changes can cause stress. Higher water temperatures cause more dissolved oxygen to come out of solution and enter the air, decreasing the amount available to fish and other aquatic organisms.
4. pH: The acidity of water is indicated by pH. A neutral pH is 7; lower values indicate higher acidity, while higher numbers indicate more alkaline conditions. pH is affected by salinity (higher salinities tend to buffer pH in the 7-8 range) and algal blooms (large algal blooms can raise the pH over 8 in low salinity waters).

5. Turbidity: Turbidity is a measure of water clarity. Events that stir up sediment or cause runoff, such as storms, will increase turbidity. Dense algal blooms will also cause higher turbidities. Relatively clear water (low turbidity) is required for growth and survival of submerged aquatic vegetation (SAV).
6. Chlorophyll: Chlorophyll concentration is a surrogate measure of the amount of algae in the water. Chlorophyll is the main photopigment responsible for photosynthesis, the process by which sunlight is converted into food energy. Chlorophyll concentrations are calculated from fluorescence values collected by the sensors. One downside to this method is that certain species of phytoplankton, such as cyanobacteria or blue-green algae, fluoresce outside the detection range of the chlorophyll fluorescence sensor.

Calibration of continuous monitors and collection of laboratory water samples

Pigments and suspended solids data were obtained by DNR staff during deployment of continuous monitoring data sondes. Discrete whole water samples were collected to measure chlorophyll *a*, pheophytin, and total suspended solids. Data sondes were removed and replaced with freshly calibrated instruments on a biweekly basis between April and October, and once a month between November and March. At the time of each instrument replacement, Secchi disk depth was recorded for use in water clarity determination and water column profiles were taken. During profiles, an instrument was lowered into the water and collected readings for depth, water temperature, pH, specific conductance, dissolved oxygen, and salinity.

Masonville Cove continuous monitor deployment

In 2016, the continuous monitor at Masonville Cove was deployed the entire year. Data sondes collected 35,133 data records and 19 calibration samples were collected and analyzed in 2016. Automated telemetry generally operated throughout the deployment of the sonde, but there were times when telemetry did not work properly, which led to gaps in near real-time web presentation of the data. Telemetry issues did not, however, impede the sonde from collecting data. Gaps seen in the data are where questionable data were removed for quality assurance purposes.

2016 Precipitation and Discharge Events

Precipitation increases runoff into waterways, which can lead to a higher input of nutrients that fuel algal blooms, decrease water clarity, and suppress SAV growth. Although beyond the scope of sampling for this report, precipitation has also been tied to increased loads of contaminants from urban and industrial centers in and around Baltimore (Leffler and Greer 2001).

After two wetter than normal years in 2014 and 2015, annual precipitation for 2016 at Baltimore Washington International (BWI) Thurgood Marshall Airport was slightly below the 30-year average (Figure 3). Almost 30% of the total precipitation in 2016 fell in two months, February and July, and total precipitation was more than 10% above average through September. However, October through December were much drier than normal with total rainfall 50% below the long-term average.

Daily mean discharge at the USGS gaging station in the Gwynns Falls reflected the pattern of precipitation seen in 2016 (Figure 4). Gage data show numerous spikes throughout 2016, which are indicative of the precipitation events that affected the region during the year. The largest spikes occurred during heavy rains in February, as well as late July when over 6-inches of rain fell on some areas in central Maryland. Flow on July 30th was 60-times greater than the daily median measured over 51-years, reflecting high discharge levels into the Patapsco River and Chesapeake Bay. Flows during October and November were below the daily median for much of those months, reflecting the rainfall deficit.

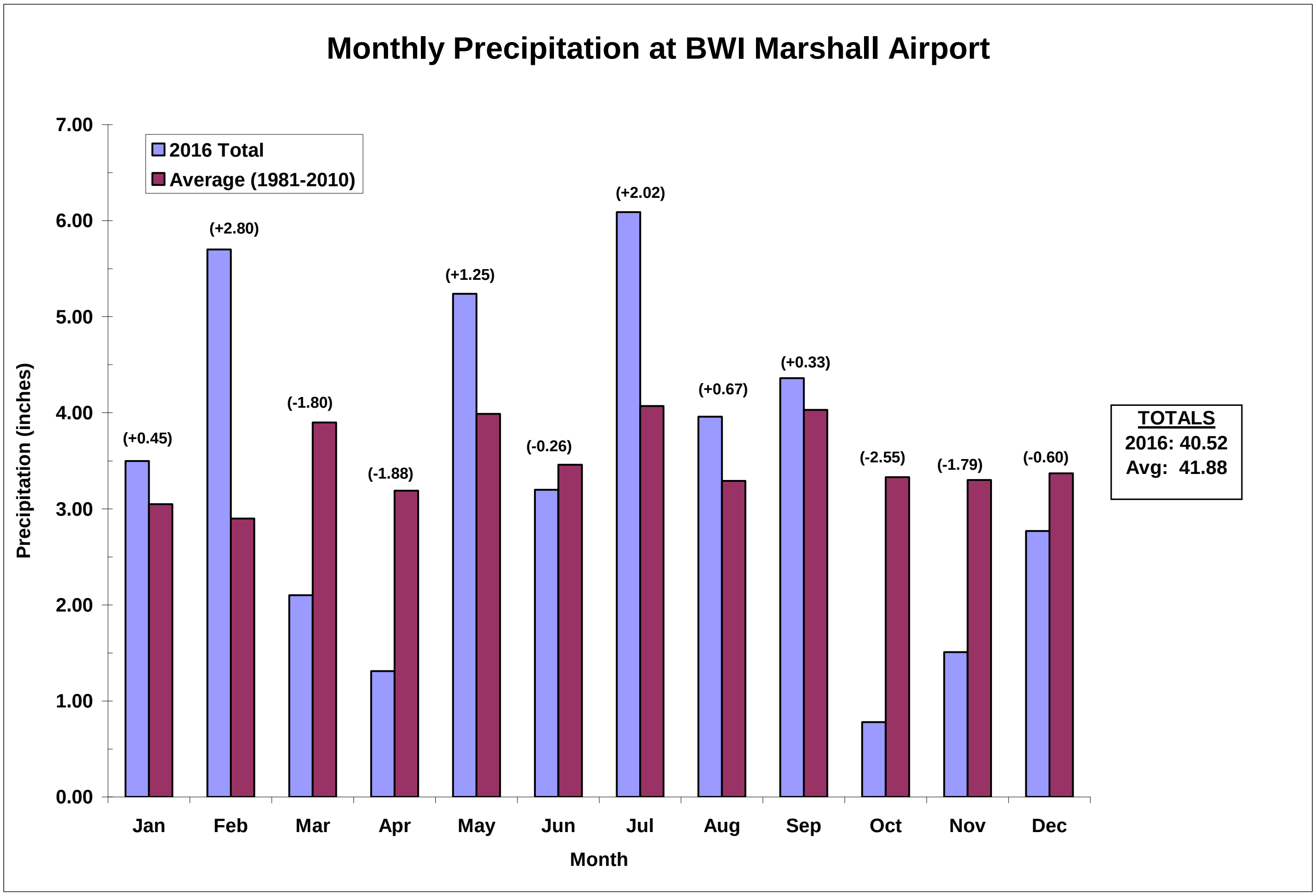

Figure 3. Total 2016 monthly precipitation at BWI Thurgood Marshall Airport compared to 30-year averages. Data source: National Weather Service (http://www.weather.gov/media/lwx/climate/bwiprecip.pdf).

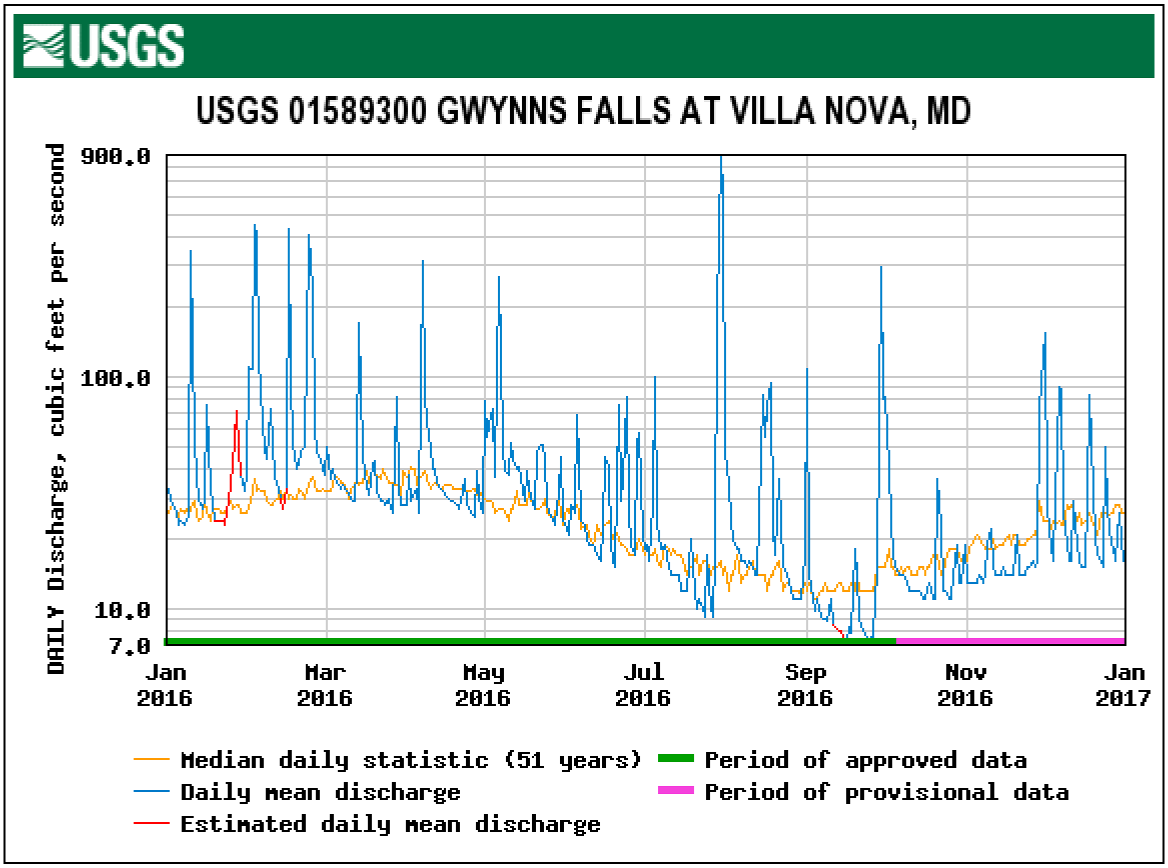

Figure 4. 2016 daily discharge in cubic feet per second measured at a USGS gaging station west of Masonville Cove. The y-axis is in logarithmic scale. Graph courtesy of the United States Geological Survey (http://waterdata.usgs.gov/nwis/dv/?site_no=01589300).

2016 Continuous Monitoring Data

Water Temperature

Water temperature at Masonville Cove rose predictably as air temperatures increased during the summer months (Figure 5). Water temperature peaked at approximately 32°C (89º F) on August 14th, remained generally above 25-26°C (77-79º F) through mid-September, before gradually declining with air temperatures through much of the rest of the year. Variability in the plots in Figure 5 was most likely a result of diel variation in temperature (warming temperatures during the day and cooling temperatures during the night).

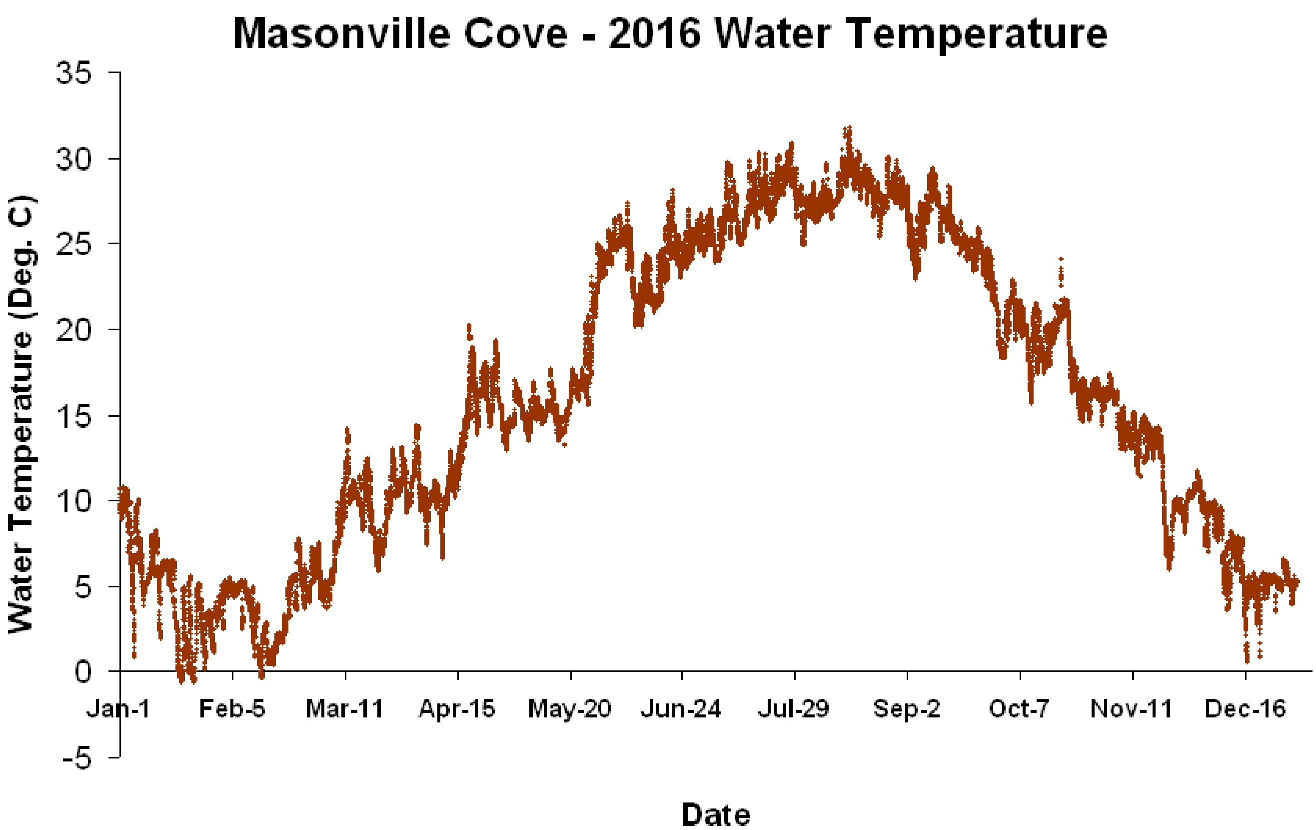

Figure 5. Water temperature at Masonville Cove Continuous Monitor during 2016.

Salinity

Salinity tends to vary with precipitation and stream flow. The overall salinity trend in 2016 (Figure 6) began with generally higher salinities in late winter. A very wet February (Figure 3) coincided with a drop in salinity values and the lowest value of the year (0.69 parts per thousand – ppt) on February 5th. Following a drop in mid-March that coincided with heavy rain, salinity in Masonville Cove generally increased for much of the rest of the year to a high of 15.8 ppt on October 11th. This increasing trend was punctuated by precipitous declines coinciding with rain events that impacted the region. In particular, a heavy rain event impacted the region on July 30th, which led to an eightfold drop in salinity in just a few hours. Over four inches of rain fell on the region over a four day period in late September and early October, which led to a steep drop in salinity.

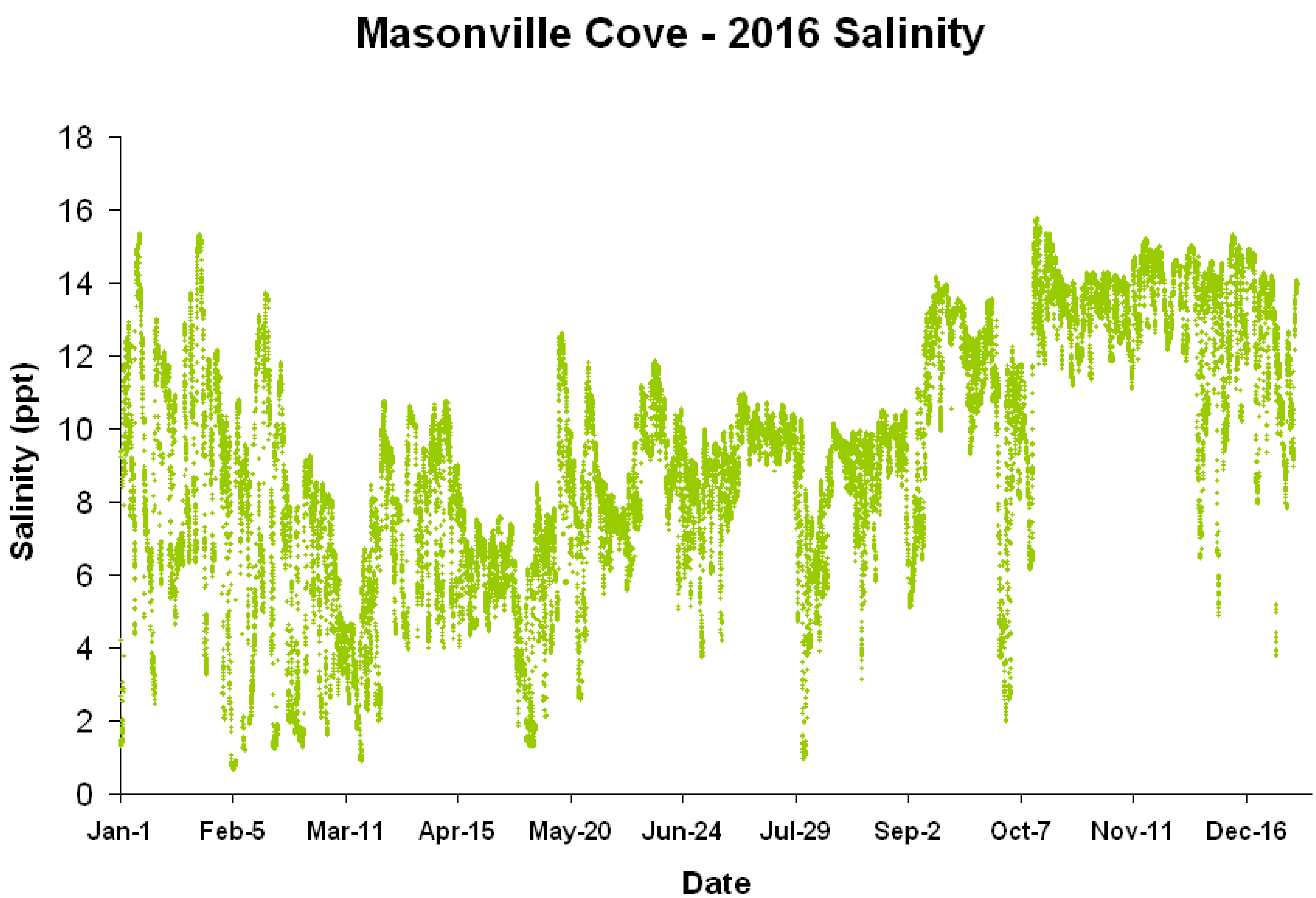

Figure 6. Salinity levels at Masonville Cove Continuous Monitor during 2016.

Dissolved Oxygen

Dissolved oxygen (DO) values remained high through most of the spring in 2016. Levels then dropped in the late spring and early summer and exhibited a large number of extremely low readings (< 3.2 mg/L) for much of the summer and early fall before gradually increasing again in the fall (Figure 7). The summer decrease and fall increase were expected since warmer water carries less dissolved oxygen, while cooler water can hold more. DO also generally fluctuated on a daily (diel) basis, possibly due to photosynthetic activity and tidal influence. However, the large daily swings seen in DO levels between late May and early October are indicative of algal bloom conditions that were present in Masonville Cove during this time period (Figure 8). During such blooms, DO levels peak during the day when algal cells are photosynthesizing and producing large amounts of oxygen. However, DO drops to very low levels at night when photosynthesis ceases and oxygen is consumed through cellular respiration. Prolonged periods of low DO concentrations can stress and be detrimental to the survival of juvenile fish and other aquatic animals (US EPA, 2003). The lowest DO reading of 2016 was 0.18 mg/L on July 18th.

Decreases in chlorophyll levels signal the death and decomposition of algal blooms and are often accompanied by a drop in DO levels. The decomposition process can consume significant amounts of oxygen in the water and can lead to conditions harmful to aquatic organisms. For example, decreases in DO levels to extremely low concentrations at the Masonville Cove water quality monitor coincided with drops in chlorophyll levels (Figure 8) on June 23rd (0.47 mg/L) and August 1st (0.55 mg/L).

As part of the 1987 Chesapeake Bay Agreement, the signatories agreed “to provide for the restoration and protection of living resources, their habitats and ecological relationships.” Further, the Chesapeake Executive Council (CEC) committed to “develop and adopt guidelines for the protection of water quality and habitat conditions necessary to support the living resources found in the Chesapeake Bay system, and to use these guidelines in the implementation of water quality and habitat protection programs.” A document was produced by the Chesapeake Bay Program outlining dissolved oxygen thresholds for various living resources (Jordan et al. 1992). The State of Maryland adopted these dissolved oxygen thresholds as standards in 1995 (COMAR 1995). For shallow water habitats, the DO criteria are a 30-day average of 5 mg/L and an instantaneous minimum of 3.2 mg/L. Table 1 shows the percentage of time the Masonville Cove DO data fell below these criteria values between April and September, which is generally the time of year that DO values are the lowest due to warmer waters. In 2016, DO failure rates increased for the third straight year, and were the highest since monitoring began in Masonville Cove in 2009 (Table 1). Both the 3.2 mg/L and 5 mg/L failure rates were markedly higher than the average failure rate over the prior 7-years of monitoring (10.7% for 3.2 mg/L; 24.3% for 5 mg/L). Most of these low DO readings in 2016 occurred between June and September, which were the four warmest months of the year. Chlorophyll data (Figure 8) also indicate that several algal blooms occurred during this time period.

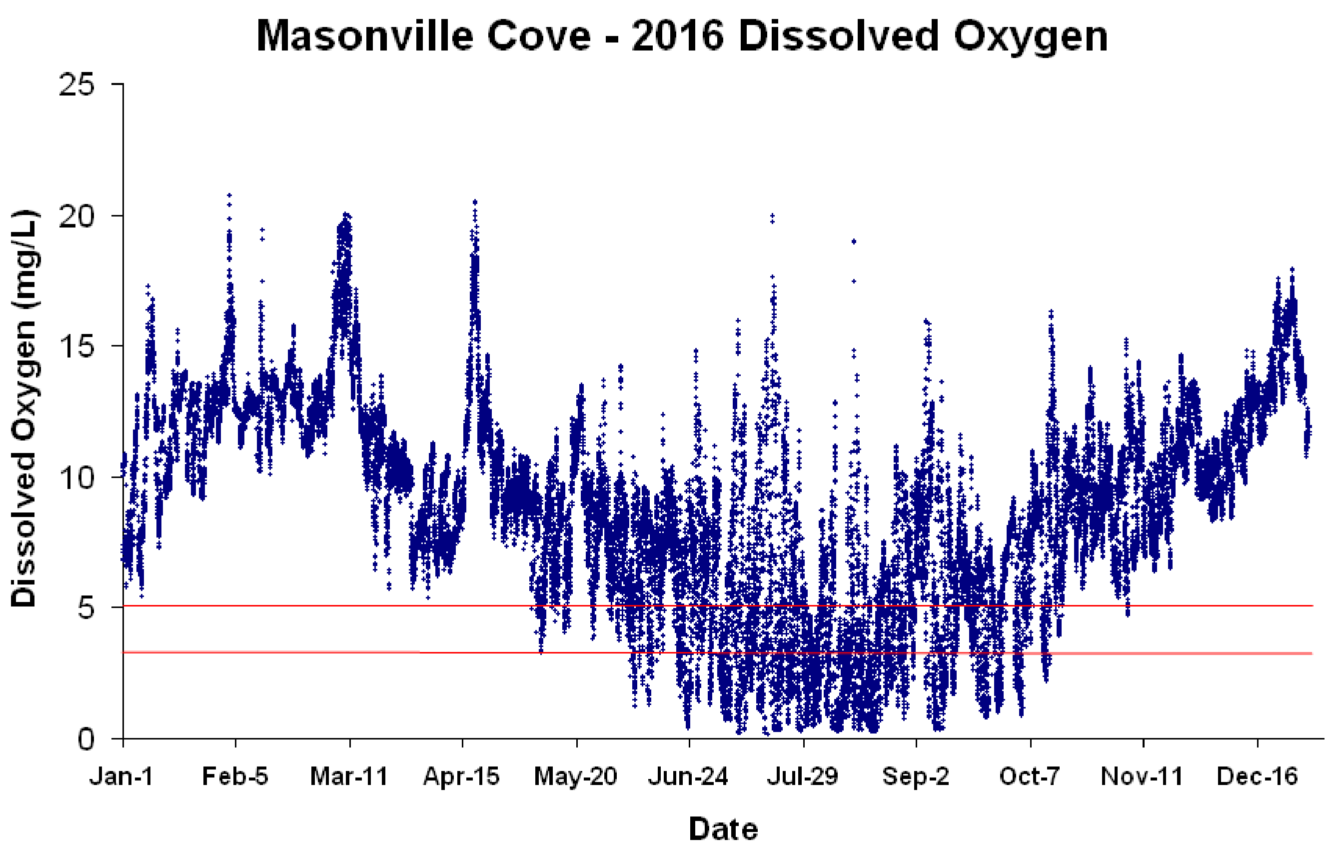

Figure 7. Dissolved oxygen levels at Masonville Cove Continuous Monitor during 2016. (*Red lines indicate 5 mg/L and 3.2 mg/L criteria.)*

Table 1. Dissolved oxygen criteria failure at Masonville Cove Continuous Monitor during June through November, 2009, March through October, 2010, and April through September, 2011 to 2016.

Continuous Monitor	2009	2010	2011	2012	2013	2014	2015	**2016**
Surface								
Dissolved Oxygen less than 5 mg/L	28.29%	20.02%	14.32%	30.59%	26.01%	24.88%	26.38%	**32.97%**
Dissolved Oxygen less than 3.2 mg/L	9.89%	8.61%	8.17%	14.20%	11.73%	8.81%	13.49%	**18.97%**

Chlorophyll

Chlorophyll values tend to vary with, and are an indicator of, algal (phytoplankton) levels. Spikes above 15 micrograms per liter (µg/L) represent algal blooms that can negatively affect living resources. Chlorophyll concentrations greater than 50 µg/L represent significant algal blooms, and concentrations above 100 µg/L represent severe blooms. At Masonville Cove, measured chlorophyll values indicate that significant or severe algal blooms occurred in every month of 2016 except April (Figure 8). The highest chlorophyll value of the year (458 µg/L) occurred in early February during a severe bloom.

Water samples collected by Maryland Environmental Service (MES) on September 9th were used to measure the concentration of a *Microcystis* bloom within the Dredged Material Containment Facility (DMCF) adjacent to Masonville Cove. The samples, which were analyzed by DNR biologists, were found to contain high concentrations (1.9 x 10^8 cells/L) of the potentially harmful algal species *M. aeruginosa*. Another *Microcystis* bloom was observed within the DMCF during the first three weeks of November. Three samples collected by MES on November 2nd, November 9th, and November 16th and analyzed by DNR biologists all contained elevated concentrations (120,000 cells/mL; 16,688 cells/mL; 20,328 cells/mL, respectively) of *Microcystis*.

As stated previously, chlorophyll readings greater than 15 µg/L and 50 µg/L indicate blooms with potential ecosystem effects and significant blooms, respectively. Table 2 lists the percentage of data readings that violated these thresholds for Masonville Cove during the portion of the 2016 deployment that coincided with SAV growing season (March – October). Algal blooms during this period may impede the ability of SAV to grow and reproduce. Chlorophyll levels exceeded the 15 µg/L threshold during 40% of the readings in 2016 (Table 2), which was a slight decrease from 43% in 2015 and just below the average (46%) over the prior 7-years. Chlorophyll levels exceeded the 50 µg/L during 4% of the readings (Table 2), which was the lowest rate in Masonville Cove since 2011, and below the average (7%) over the prior 7-years.

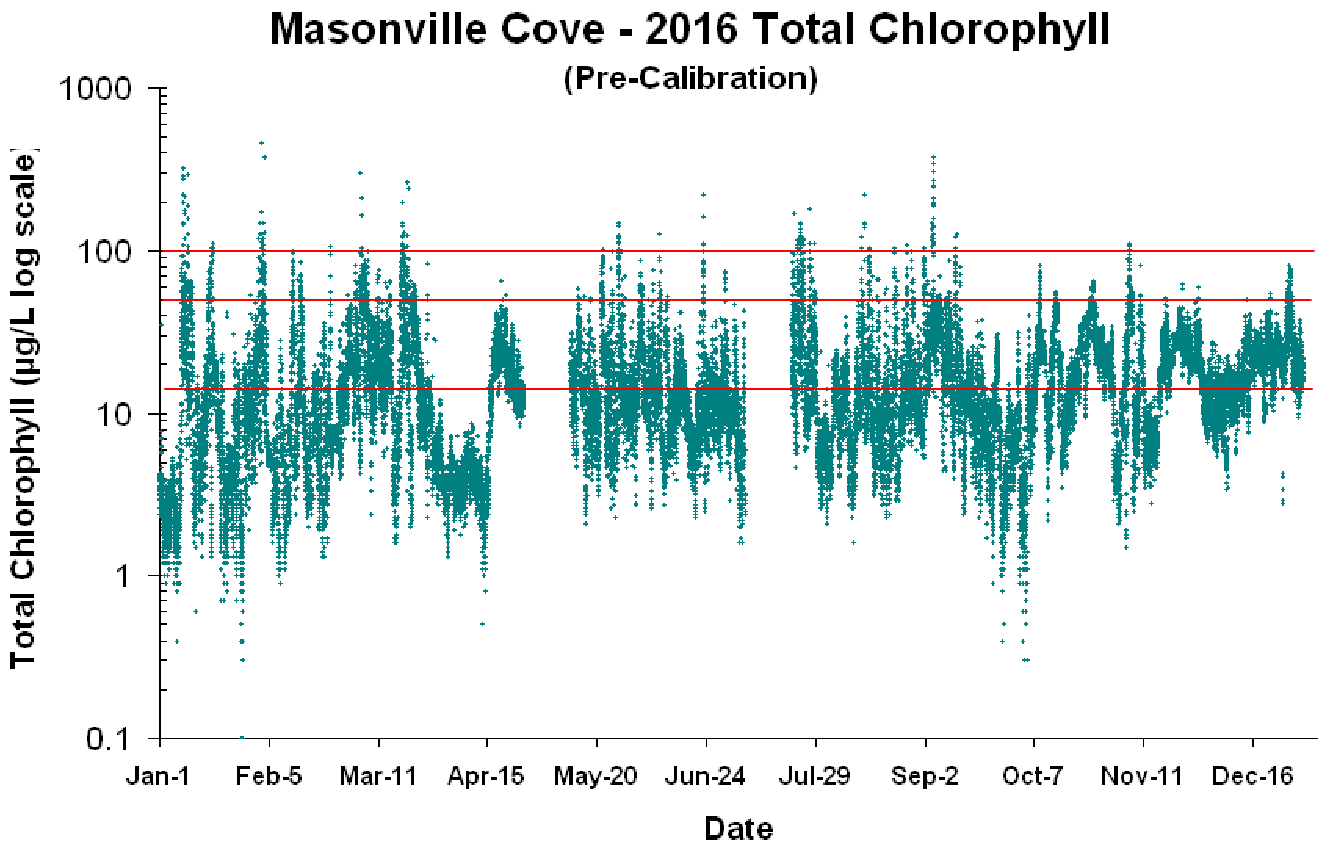

Figure 8. Total chlorophyll levels at Masonville Cove Continuous Monitor during 2016. *(Red lines indicate thresholds above which levels may have harmful effects on aquatic ecosystems—15 mg/L—are considered significant blooms—50 mg/L—or are considered severe blooms—100 mg/L.)*

Table 2. Chlorophyll threshold failure at Masonville Cove Continuous Monitor during June through November, 2009, and March through October, 2010 to 2016.

Continuous Monitor	2009	2010	2011	2012	2013	2014	2015	**2016**
Surface								
Readings greater than 15 µg/L	37.37%	58.99%	38.78%	55.63%	52.12%	36.24%	43.11%	**40.14%**
Readings greater than 50 µg/L	3.28%	6.58%	0.87%	14.52%	10.50%	5.24%	8.89%	**3.97%**

pH

pH readings tend to fluctuate between 7 and 9 in most Chesapeake Bay tidal waters, with spikes above 9 indicating potential algal blooms. High pH in the absence of high chlorophyll can also give some indication that a blue-green algal bloom may have occurred (the chlorophyll sensors on the continuous monitors deployed at Masonville Cove are not designed to detect the wavelengths emitted by cyanobacteria). At Masonville Cove, there were only fifty-three pH values that exceeded 9 in all of 2016. Most of these occurred in late November, at approximately the time that a *Microcystis* bloom was measured in the DMCF adjacent to Masonville Cove. The highest pH value of the year (9.07) was recorded on November 22nd.

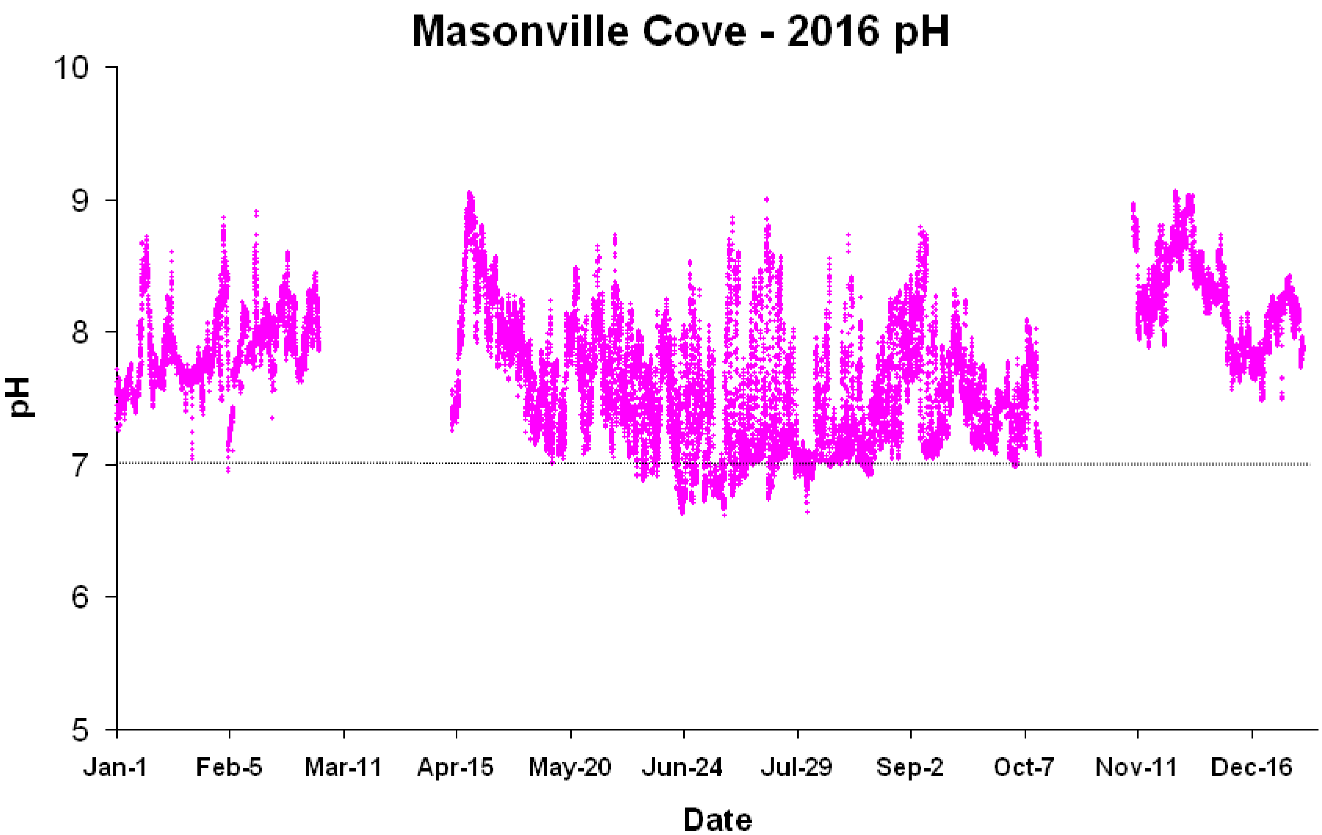

Figure 9. pH levels at Masonville Cove Continuous Monitor during 2016. *(Line indicates neutral pH.)*

Turbidity

Turbidity is quantified by measuring how much light is reflected from suspended particles in the water and is used to determine water clarity. Lower turbidity values indicate less reflection and, therefore, clearer water, while values above 7 Nephelometric Turbidity Units (NTU) are generally thought to be detrimental to SAV growth based on the effects of elevated turbidity in other systems (M. Trice, MD DNR, personal communication). During the year, there were only a couple time periods when turbidity levels spiked very high to above 100 NTU. The most significant of these occurred in late February following a heavy precipitation and discharge event. However, the majority of turbidity values throughout the year were below 7 NTU (Figure 10). Masonville Cove turbidity levels were greater than 7 NTU for 30% of all readings collected in 2016 (median value: 4.7 NTU).

On the evening of February 24th, over 2.5 inches of rain fell on Central Maryland, which led to a large discharge event (Figure 4). Due to heavy rains overwhelming sanitary lines, several sanitary sewer overflows into the Patapsco River and associated tributaries were reported by the Baltimore City and County Departments of Public Works. An estimated 922,000 gallons of untreated, diluted wastewater were spilled into the watershed during these overflows. As a result of the storm and associated discharge event, turbidity levels at Masonville Cove spiked from approximately 4 NTU on February 24th, prior to the rain, to greater than 100 NTU the morning of February 25th, and remained at those high levels until the early morning of February 27th. The highest reading of the year (166.6 NTU) was recorded on February 25th. The high turbidity readings during this event indicate that water discharged into the river brought high concentrations of particles and sediment that clouded the water.

Turbidity values again briefly spiked above 100 NTU in early April, before remaining below 7 NTU for much of the remaining spring and early summer. A few brief spikes to approximately 30 NTU, which were associated with heavy rainstorms, occurred in June and July.

On the evening of July 30th, over 6-inches of rain fell in just a couple hours on some areas in central Maryland, leading to a massive discharge event (Figure 4). Sanitary sewer overflows associated with this storm spilled over 20 million gallons of untreated, diluted wastewater in the watershed. Unfortunately, the immediate effects of this storm to Masonville Cove were not recorded. A sonde malfunction precluded measurement of accurate turbidity data between July 30th and August 3rd.

Following some brief spikes in August and September, turbidity generally remained below 7 NTU for most of October, November, and December. This may have been the result of the rainfall deficit (Figure 3) and low flows (Figure 4) during this time period.

Turbidity measurements above 7 NTU, as stated previously, are considered a threshold for detrimental effects on SAV. The water quality monitor at Masonville Cove recorded turbidity above this threshold for almost 35% of the readings (Table 3) during the 2016 SAV growing season (March through October). This annual threshold failure rate was well below the avergage of the prior 7-years (51.7%) and was the lowest since monitoring began in Masonville Cove in 2009. DNR has also measured improving water clarity in other parts of Maryland over the past few years.

Details of the sanitary sewer overflows described in this section can be found through the Maryland Reported Sewer Overflow Database:
http://www.mde.state.md.us/programs/water/Compliance/Pages/ReportedSewerOverflow.aspx#.

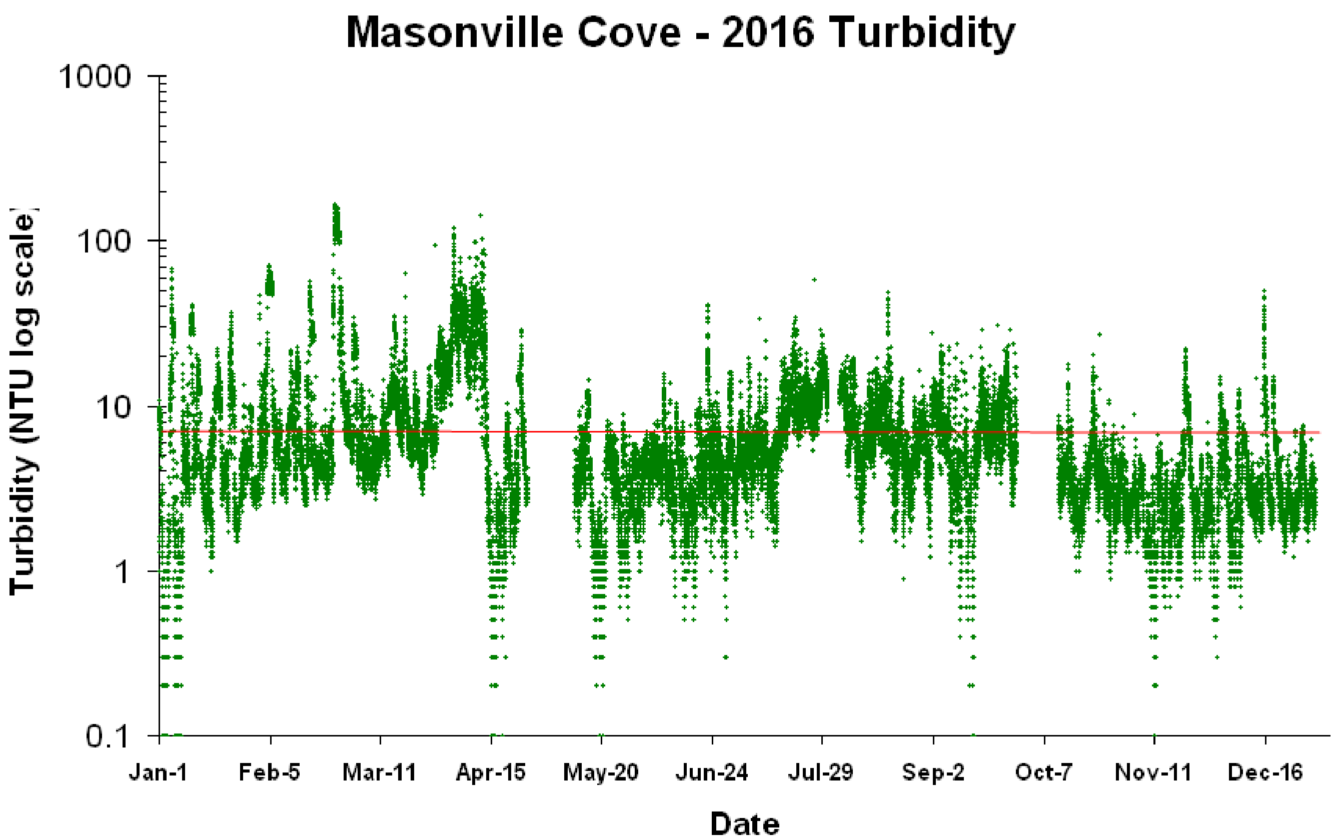

Figure 10. Turbidity levels at Masonville Cove Continuous Monitor during 2016. *(Red line indicates threshold above which levels are considered detrimental to bay grass growth.)*

Table 3. Turbidity threshold failure at Masonville Cove Continuous Monitor during June through December, 2009, and March through October, 2010 to 2016.

Continuous Monitor	2009	2010	2011	2012	2013	2014	2015	**2016**
Surface								
Readings greater than 7 NTU	54.58%	60.09%	51.58%	35.0%	53.91%	52.92%	53.82%	**34.91%**

Submerged Aquatic Vegetation (SAV) in the Patapsco River

SAV, or underwater grasses, are an important component of estuarine ecosystems. SAV provides habitat for juvenile fish and shellfish, supplies food for waterfowl, oxygenates the water, and helps stabilize bottom sediments. Since 1984, SAV within the Chesapeake Bay and associated tributaries has been assessed annually (with the exception of 1988) by the Virginia Institute of Marine Science (VIMS). Figure 11 shows total area and density of SAV within the Patapsco beginning in 1994 (the first year SAV was found in the river) through 2016.

Total area of SAV within the Patapsco River remains well below the restoration goal of 389 acres. 2005 was the single best year with 72% of the restoration goal achieved, including SAV beds within Masonville Cove. 2004 and 2005 were generally very good years for SAV throughout the Chesapeake Bay region and the increases in coverage have been attributed to an accompanying population explosion and range expansion of dark false mussels (*Mytilopsis leucophaeata*). These filter feeders may have increased water clarity and allowed SAV coverage to significantly expand (L. Karrh, MD DNR, personal communication). In 2006, the mussels died back, SAV beds disappeared in Masonville Cove, and total area of SAV within the Patapsco decreased 83%. In 2010, there was no SAV in the entire Patapsco River. As of 2016, approximately 3.4 acres of SAV were observed in the Patapsco River, and no SAV was found within Masonville Cove. This total area represents a 91% decrease from 2015, and is less than 1% of the river's restoration goal.

The lack of SAV in Masonville Cove, and in the Patapsco River as a whole, is in contrast to other areas of the Chesapeake Bay. Many Bay tributaries have seen record expansions of SAV beds over the past few years. Poor water clarity and lack of viable seed banks within the Patapsco River are likely explanations for the lack of SAV coverage.

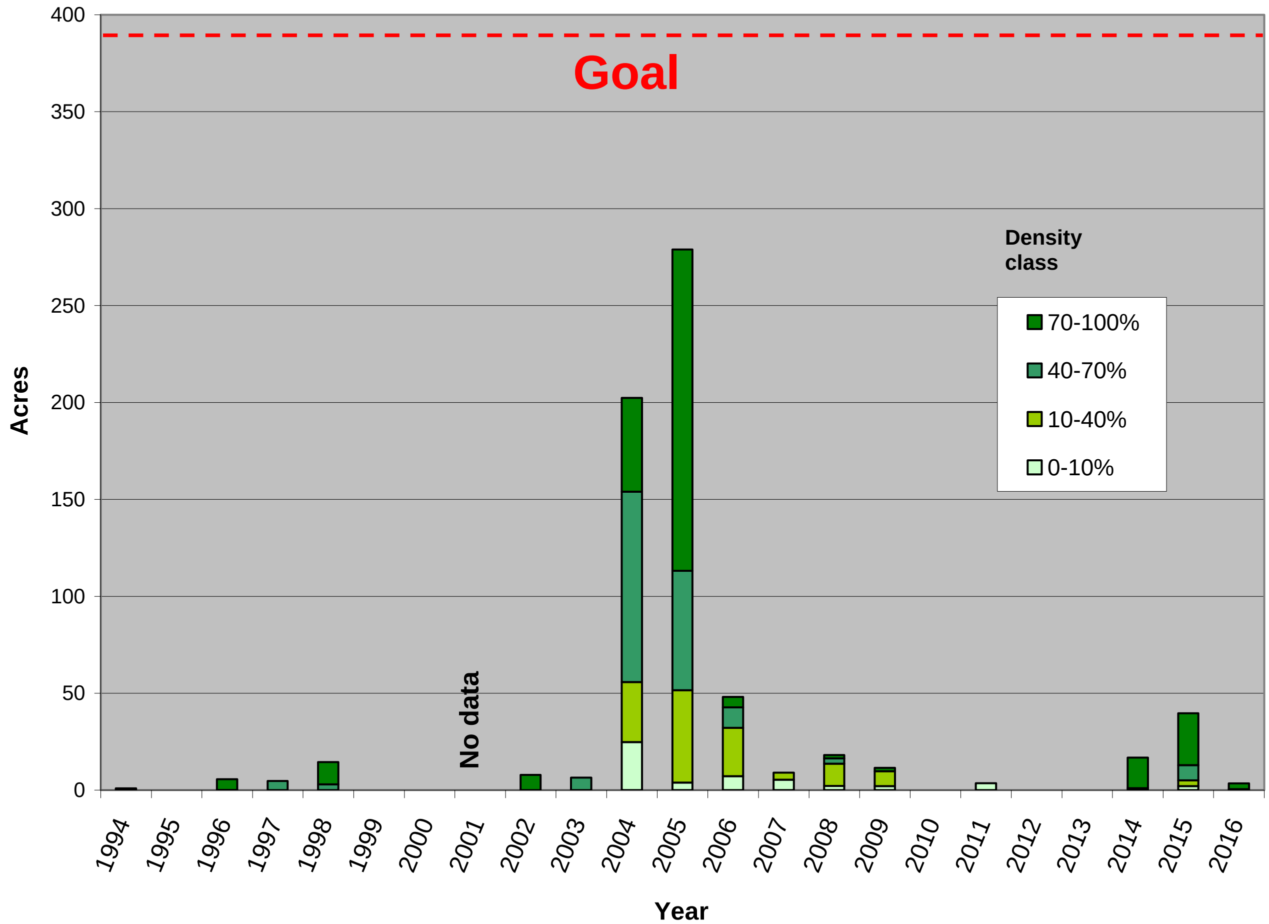

Figure 11. Total area and density of SAV in the Patapsco River between 1994 and 2016. (*Restoration goal is 389 acres)*

Pigments, Suspended Solids, and Secchi Data

Bi-weekly grab samples of water were taken at the Masonville Cove station when the YSI meters were exchanged during continuous monitoring service visits. Samples collected during November through March were collected monthly instead of bi-weekly (Table 4). Secchi depth, a measure of water clarity, was also recorded at the Masonville Cove station each time a grab sample was collected.

For the grab samples, the water was processed in the field using vacuum filtration, and the resulting particulate samples were delivered to the laboratory for analysis. Samples collected during continuous monitoring service visits were analyzed for pigments and suspended solids. All analyses were performed by the University of Maryland Center for Environmental Science's Chesapeake Biological Laboratory (CBL) Nutrient Analytical Services Laboratory (NASL). For details on methods, procedures, analysis and detection limits, refer to the Quality Assurance Project Plan (QAPP) for the Shallow Water Monitoring Program. This document can be found at: http://eyesonthebay.dnr.maryland.gov/eyesonthebay/documents/SWM_QAPP_2016_2017_Draft_v5.pdf. Results of the laboratory analyses are presented graphically in Appendix A (Figures A-1 through A-3). Secchi depth measurements are presented in Figure A-4. The suspended sediments, pigments, and secchi depth data are also presented in Table A-1 of Appendix A.

Ambient water quality data (dissolved oxygen, pH, salinity, and water temperature) were collected concurrently with the grab samples. The data values are presented graphically in Figures A-5 to A-8 in Appendix A. These water quality parameters are measured as a profile, with readings recorded at 0.5m depth intervals at the station. In the graphs, the data range for each profile is represented by a vertical bar for each sample date. The vertical bars are connected by a line that intersects each bar at the mean value for the station on that date. All data values for dissolved oxygen, pH, salinity, and water temperature are provided in Table A-2 of Appendix A. Note that on May 11, 2016, the field crew did not collect Hydrolab readings, thus a data profile is not available for this date.

As previously noted, chlorophyll concentrations in excess of 50 µg/l may be indicative of a significant algal bloom. At Masonville Cove in 2016, chlorophyll concentrations exceeded the 50 mg/l threshold on two sampling dates: May 11th (64.5 µg/l), and July 19th (349.8 µg/l) (Figure A-1). The July 19th value was the peak measured value for chlorophyll in 2016 and is indicative of a severe algal bloom (chlorophyll concentrations greater than 100 µg/l). Chlorophyll values were below the 50 µg/l threshold for all other sample dates. Values approached the 50 µg/l threshold in January, June, September, and November. Pheophytin values remained below 10 µg/l throughout the year, with values greater than 5 µg/l occasionally observed from May through August (Figure A-2).

Elevated values of total suspended solids occurred at Masonville Cove in the months of February and June, and again in late July to early August (Figure A-3). The largest suspended solids value measured during 2016 was 41.0 mg/l on February 4th. Secchi depth (a measure of water clarity) also exhibited its lowest measured value (0.2 m) on February 4th (Figure A-4). Field remarks noted "fresh surface water due to rain and snowmelt" at the station during the February sampling. Accordingly, unusually low salinity values of less than 0.5 ppt were recorded at shallow water depths on this date, while salinity values around 9 ppt were recorded in bottom waters (Figure A-5). Later in the year, total suspended solids values peaked above 20 mg/l on several dates during June-August. The August 3rd sampling date was not long after the record rainfall on July 30th during which over six inches of rain fell in the area in just a few hours. Likewise, the June 21st sampling date coincided with more than one inch of rainfall in the region. Suspended solids values increased, and both Secchi depth and salinity values decreased on these sampling dates in response to increased turbidity and freshwater input from the storms.

Dissolved oxygen values at Masonville Cove were generally lower during the summer months, with values less than 3 mg/l measured in the bottom waters from June through mid-August (Figure A-6). An exception was on August 3rd, when bottom water oxygen measured greater than 5mg/l. It is likely that the stormy weather and excessive rainfall on July 30th helped to mix the water column and increase oxygen levels. As further evidence of vertical mixing, the values for dissolved oxygen, temperature, salinity, and pH at the surface and at the bottom of the water column differed only slightly on August 3rd.

Water temperature varied seasonally at Masonville Cove, beginning with a low measurement of 3.8 °C on January 8th, gradually rising to a peak of 28.8 °C on August 16th, and then falling slowly to around 10 °C on December 8th (Figure A-7). For 2016, pH values at Masonville Cove generally fluctuated between 7 and 8.5 throughout the year (Figure A-8).

Table 4. Deployment and calibration record for Masonville Cove continuous monitor 2016.

Scheduled calibration date	Samples collected	Comment
January 8, 2016	Yes	
February 4, 2016	Yes	
March 3, 2016	Yes	
April 13, 2016	Yes	
April 26, 2016	Yes	
May 11, 2016	Yes	
May 24, 2016	Yes	
June 7, 2016	Yes	
June 21, 2016	Yes	
July 6, 2016	Yes	
July 19, 2016	Yes	
August 3, 2016	Yes	
August 16, 2016	Yes	
August 30, 2016	Yes	
September 13, 2016	Yes	
September 28, 2016	Yes	
October 11, 2016	Yes	
October 25, 2016	No	Site not visited due to scheduling conflict.
November 9, 2016	Yes	
December 8, 2016	Yes	

Conclusion

Shallow water monitoring was conducted in Masonville Cove in the upper Patapsco River during 2016. Continuous monitoring data provide a critical function for assessing the health of Maryland's tidal waters in areas historically lacking water quality information. Shallow water data provide information about the effects of nutrient pollution and weather events on Masonville Cove and the Patapsco River as a whole. In 2016, heavy rains in February and July led to massive discharge events that affected salinity, water clarity, and TSS. Significant to severe algal bloom conditions occurred in every month of 2016 except April, and potentially harmful *Microcystis* blooms were recorded within the Dredged Material Containment Facility (DMCF) in September and November. Dissolved oxygen concentrations were low for much of the summer and early fall, but turbidity measurements indicated the highest water clarity in Masonville Cove since monitoring began in 2009. Finally, as of 2016, no submerged aquatic vegetation was found in Masonville Cove. Therefore, conditions remain relatively poor for living resources in the upper Patapsco River.

Shallow water monitoring information is not only used for characterizing the health of shallow water habitats, but it is also useful for: 1) assessing Chesapeake Bay water quality criteria for dissolved oxygen, water clarity and chlorophyll in shallow water habitats; 2) determining attainment or non-attainment of shallow water habitats for their designated uses; 3) assessing SAV habitats and identifying potential SAV restoration sites; 4) providing information to better understand ecosystem processes and the impact of extreme events (e.g. hurricanes, high flows, sanitary sewer overflows) in shallow water and open water environments; 5) providing data for calibrating the Bay Eutrophication and Watershed Model; and 6) assessing mitigation efforts in relation to the dredged material containment facility at the Masonville Marine Terminal.

References

COMAR (Code of Maryland Regulations). 1995. Code of Maryland Regulations: 26.08.02.03 – Water Quality Criteria Specific to Designated Uses. Maryland Department of the Environment. Baltimore, Maryland.

Jordan, S., C. Stegner, M. Olson, R. Batiuk, and K. Mountford. 1992. Chesapeake Bay dissolved oxygen goal for restoration of living resources habitats. Chesapeake Bay Program, Reevaluation Report #7c. CBP/TRS88/93. Annapolis, Maryland.

Leffler, M. and J. Greer. 2001. Taking on toxics in Baltimore Harbor. Maryland Marine Notes 19(2). http://www.mdsg.umd.edu/MarineNotes/Mar-Apr01/

Appendix A

Results of laboratory and ambient water quality analyses for:
Masonville Cove Pier (Station XIE4742)

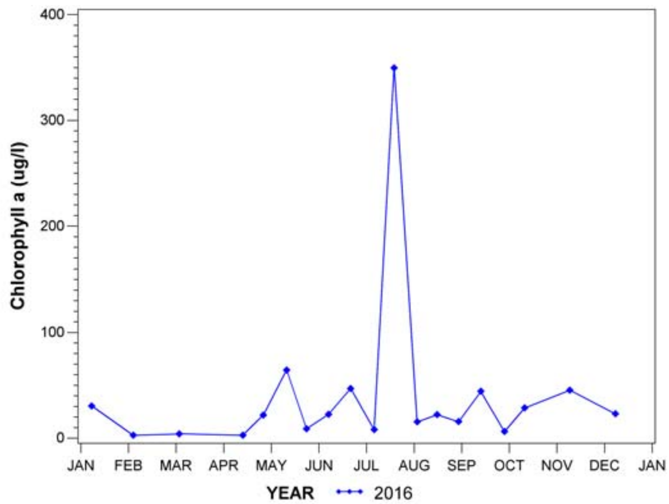

Figure A-1. Chlorophyll *a* concentrations at Masonville Cove in 2016.

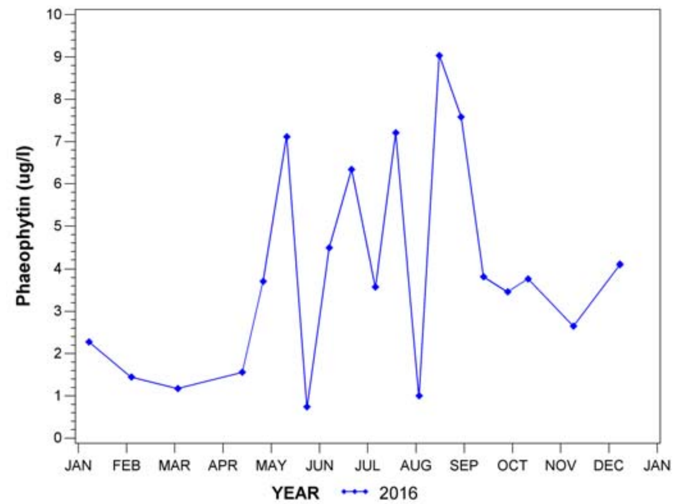

Figure A-2. Pheophytin concentrations at Masonville Cove in 2016.

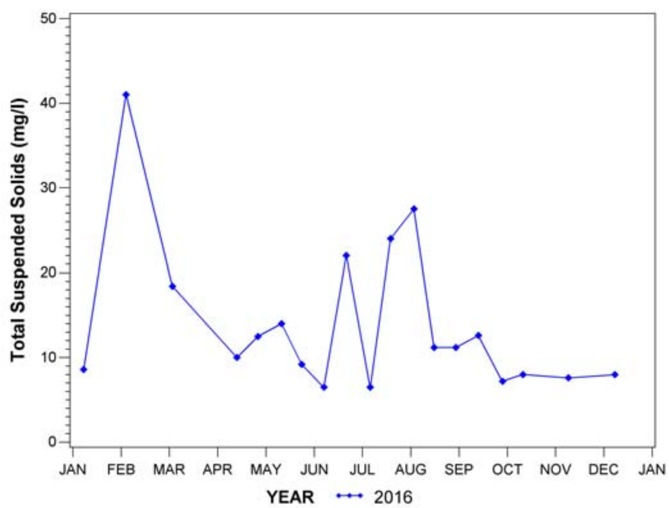

Figure A-3. Total suspended solids concentrations at Masonville Cove in 2016.

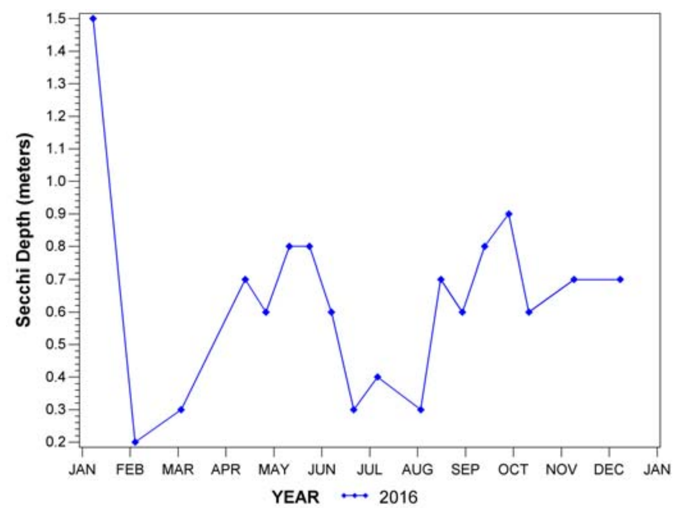

Figure A-4. Secchi depth at Masonville Cove in 2016.

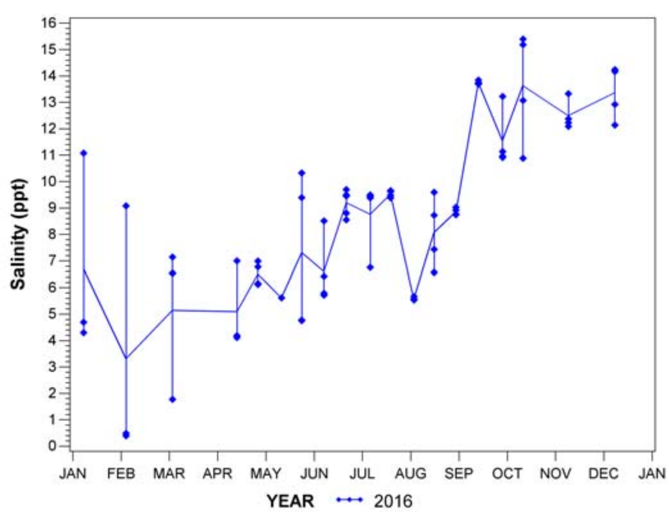

Figure A-5. Salinity concentrations at Masonville Cove in 2016.

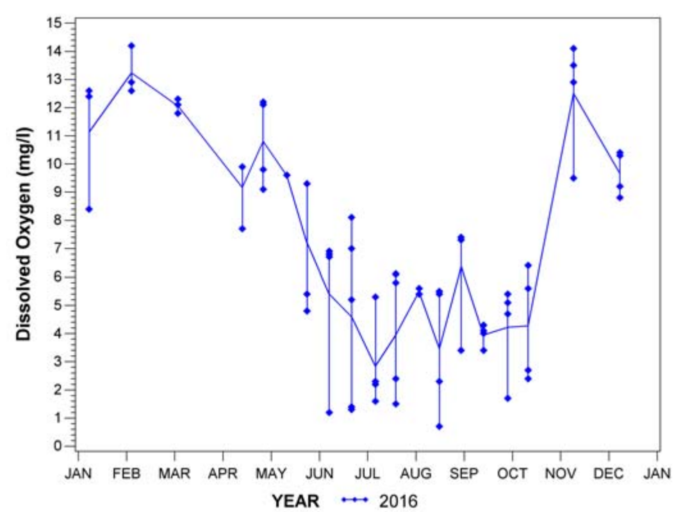

Figure A-6. Dissolved oxygen concentrations at Masonville Cove in 2016.

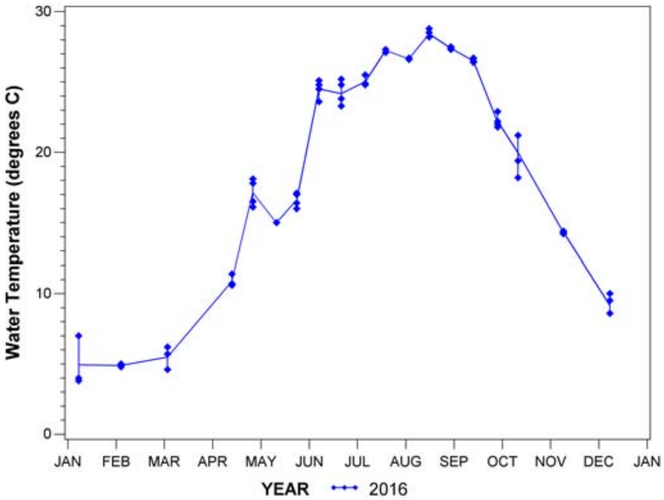

Figure A-7. Water temperature at Masonville Cove in 2016.

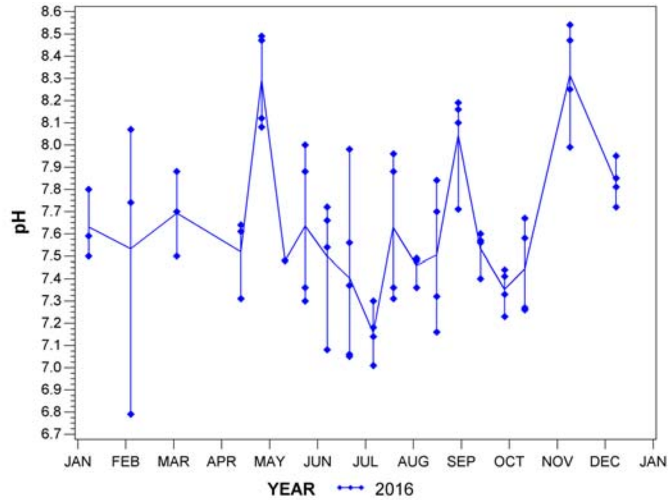

Figure A-8. Values of pH at Masonville Cove in 2016.

Vertical bars within a graph represent the data range for each profile, with readings recorded at 0.5m depth intervals, and are intersected at the mean value.

Table A-1. Discrete Continuous Monitoring Data for Chlorophyll-a, Pheophytin, Total Suspended Solids, and Secchi Disk Depth for Masonville Cove (XIE4742) in 2016.

Date	Sample Depth (m)	Chlorophyll-a (ug/L)	Pheophytin (ug/L)	Total Suspended Solids (mg/L)	Secchi Depth (m)
01/08/16	1	30.514	2.273	8.6	1.5
02/04/16	1	2.670	1.442	41.0	0.2
03/03/16	1	4.058	1.175	18.4	0.3
04/13/16	1	2.777	1.559	10.0	0.7
04/26/16	1	21.894	3.711	12.5	0.6
05/11/16	1	64.507	7.113	14.0	0.8
05/24/16	1	8.971	<0.740	9.2	0.8
06/07/16	1	22.428	4.486	6.5	0.6
06/21/16	1	46.992	6.337	22.0	0.3
07/06/16	1	8.010	3.578	6.5	0.4
07/19/16	1	349.770	7.209	24.0	No data
08/03/16	1	15.353	1.001	27.5	0.3
08/16/16	1	22.214	9.035	11.2	0.7
08/30/16	1	15.593	7.583	11.2	0.6
09/13/16	1	44.246	3.814	12.6	0.8
09/28/16	1	6.408	3.460	7.2	0.9
10/11/16	1	28.569	3.765	8.0	0.6
11/09/16	1	45.497	2.649	7.6	0.7
12/08/16	1	23.095	4.098	8.0	0.7

Table A-2. Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Masonville Cove (XIE4742) in 2016 (continued on next page).

Date	Sample Depth (m)	D. O. (mg/L)	pH	Salinity (ppt)	Water Temperature (°C)
01/08/16	0.5	12.4	7.8	4.30	4.0
01/08/16	1.0	12.6	7.6	4.70	3.8
01/08/16	1.6	8.4	7.5	11.08	7.0
02/04/16	0.5	12.9	7.7	0.39	4.9
02/04/16	1.0	12.6	6.8	0.49	4.8
02/04/16	1.7	14.2	8.1	9.08	5.0
03/03/16	0.5	12.3	7.7	1.77	4.6
03/03/16	1.0	12.1	7.9	6.54	5.7
03/03/16	1.7	11.8	7.5	7.14	6.2
04/13/16	0.5	9.9	7.6	4.12	10.7
04/13/16	1.0	9.9	7.6	4.19	10.6
04/13/16	1.7	7.7	7.3	7.00	11.4
04/26/16	0.5	12.2	8.5	6.13	18.1
04/26/16	1.0	12.1	8.5	6.16	17.8
04/26/16	1.5	9.8	8.1	6.77	16.5
04/26/16	2.1	9.1	8.1	6.99	16.1
05/11/16	1.0	9.6	7.5	5.62	15.0
05/24/16	0.5	9.3	8.0	4.76	17.1
05/24/16	1.0	9.3	7.9	4.78	17.0
05/24/16	1.5	5.4	7.4	9.39	16.4
05/24/16	2.2	4.8	7.3	10.32	16.0
06/07/16	0.5	6.9	7.7	5.72	25.1
06/07/16	1.0	6.8	7.5	5.79	24.8
06/07/16	1.5	6.7	7.7	6.43	24.5
06/07/16	2.2	1.2	7.1	8.51	23.6
06/21/16	0.5	8.1	8.0	8.55	25.2
06/21/16	1.0	7.0	7.6	9.70	23.3
06/21/16	1.5	5.2	7.4	8.80	24.8
06/21/16	2.0	1.4	7.1	9.45	23.8
06/21/16	2.3	1.3	7.1	9.49	23.8
07/06/16	0.5	5.3	7.3	6.75	25.5
07/06/16	1.0	2.3	7.0	9.44	24.9
07/06/16	1.5	1.6	7.1	9.38	24.9
07/06/16	2.1	2.2	7.2	9.49	24.8
07/19/16	0.5	6.1	8.0	9.38	27.3
07/19/16	1.0	5.8	7.9	9.66	27.1
07/19/16	1.5	2.4	7.4	9.48	27.3
07/19/16	2.0	1.5	7.3	9.62	27.3

Table A-2 (continued). Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Masonville Cove (XIE4742) in 2016.

Date	Sample Depth (m)	D. O. (mg/L)	pH	Salinity (ppt)	Water Temperature (°C)
08/03/16	0.5	5.6	7.5	5.54	26.7
08/03/16	1.0	5.6	7.4	5.67	26.6
08/03/16	1.5	5.4	7.5	5.56	26.7
08/03/16	2.0	5.4	7.5	5.57	26.7
08/03/16	2.4	5.4	7.5	5.57	26.6
08/16/16	0.5	5.4	7.7	6.57	28.2
08/16/16	1.0	5.5	7.8	7.43	28.2
08/16/16	1.5	2.3	7.3	8.72	28.5
08/16/16	2.1	0.7	7.2	9.59	28.8
08/30/16	0.5	7.4	8.2	8.74	27.4
08/30/16	1.0	7.4	8.1	8.91	27.3
08/30/16	1.5	7.3	8.2	8.76	27.4
08/30/16	1.9	3.4	7.7	9.03	27.5
09/13/16	0.5	4.0	7.6	13.74	26.7
09/13/16	1.0	3.4	7.4	13.84	26.5
09/13/16	1.5	4.3	7.6	13.72	26.4
09/13/16	2.0	4.1	7.6	13.69	26.5
09/28/16	0.5	5.1	7.4	10.91	22.0
09/28/16	1.0	5.4	7.3	10.96	21.8
09/28/16	1.5	4.7	7.4	11.14	22.2
09/28/16	1.9	1.7	7.2	13.23	22.9
10/11/16	0.5	6.4	7.7	10.88	18.2
10/11/16	1.0	5.6	7.6	13.07	19.4
10/11/16	1.5	2.7	7.3	15.18	21.2
10/11/16	2.0	2.4	7.3	15.40	21.2
11/09/16	0.5	14.1	8.5	12.09	14.2
11/09/16	1.0	12.9	8.3	12.37	14.3
11/09/16	1.5	13.5	8.5	12.23	14.4
11/09/16	2.0	9.5	8.0	13.33	14.4
12/08/16	0.5	10.3	8.0	12.14	8.6
12/08/16	1.0	10.4	7.9	12.92	8.6
12/08/16	1.5	9.2	7.8	14.17	9.5
12/08/16	1.9	8.8	7.7	14.24	10.0