Memorandum

To:	James Davis-Martin (Virginia Department of Conservation & Recreation)
From:	Steve McLaughlin (City of Virginia Beach)
CC:	John Paine (URS)
Date:	June 20, 2013
Subject:	Sanctuary Oyster Reefs as a BMP

Purpose

Chesapeake Bay TMDL requirements have municipalities in Virginia viewing the role of traditional stormwater BMPs in a new light. Amended local ordinances requiring stormwater BMPs to treat runoff to higher and higher standards for both new development and redevelopment may help localities meet their Watershed Implementation Plans (WIPs), however the construction of traditional BMPs alone, such as wet ponds, will not meet the reduction requirements set forth by the Chesapeake Bay TMDL. Many localities within the Chesapeake Bay watershed contain stormwater systems that are currently not treated by any type of BMP. In older built-out urban areas, public land may not be available for the construction of BMPs, or available public land is located in an area where treatment of stormwater is not possible, such as the high points of a watershed, far from any stormwater outfalls. Some BMPs, such as manufactured filtering devices, or bio-retention areas are designed to treat runoff from relatively small areas of a few acres at most. Heavily developed localities, trying to reduce their nutrient runoff, often need to treat stormwater from large areas of a watershed to make a significant impact to their pollution reduction goal, especially when using BMPs with limited efficiencies, such as wet ponds. In order meet their TMDL reduction goals, some localities are looking towards innovative BMPs to help achieve TMDL compliance in a cost-effective manner.

The City of Virginia Beach would like to propose the creation of “Sanctuary Oyster Reefs” to be included as a nutrient reducing water quality BMP and an acceptable method for nitrogen removal from a watershed, in order to comply with the Chesapeake Bay TMDL. These sanctuary oyster reefs would be created within the Lynnhaven River by placing oyster shells on the river bottom for a reef base, and then placing spat-on-shell on top. Once created, these reefs would then be off-limits to harvesting. The City would be responsible for maintenance and replacement of oysters as necessary to maintain the reef, and would measure denitrification rates at initial reef sites to calculate annual nitrogen removal rates more accurately.

Background

Executive order 13508, signed by President Barack Obama in May of 2009 declared the Chesapeake Bay a national treasure and called for federal agencies, and state and local governments to work together to clean up the Chesapeake Bay. The order calls for improving the water quality of the Bay, habitat restoration, land conservation, and the sustainability of fish and wildlife. Due to its significance ecologically and commercially, oyster restoration within the Bay has become a priority within the Chesapeake Bay program. The Oyster has long been associated with the Bay and the decline of the native oyster population has been a sign of the overall health of the Bay. For that reason, the oyster population, along with the populations of brook trout, black ducks and blue crabs, will be used to track progress in achieving the goals of the Chesapeake Bay executive order.

The ecological importance of oysters to the Chesapeake Bay cannot be overstated. As filter feeders, their role in improving water quality in the Bay is vitally important. A single adult eastern oyster, (*Crassostrea virginica*) also referred to as the Atlantic oyster or Virginia oyster, can filter approximately 50 gallons of water per day. When the colonists first explored the Chesapeake Bay, oyster reefs were so vast that they defined the deep water channels of the Bay and its tributaries, and posed threats to navigation. At that time, water in the Bay was clear enough to see 20 to 30 feet down into the water column, and it is estimated that the oyster population could filter the entire volume of water within the Chesapeake Bay within a week or less. Today, oyster numbers in the Bay are approximately 1% of what they once were. There are many reasons for the decimation of the oyster population: overharvesting, disease and an abundance of silt and sediment as well as pollutants in runoff to the Bay.

The U.S. Army Corps of Engineers (USACE) and the National Oceanic and Atmospheric Administration (NOAA) had the task of developing a plan to meet the goal of restoring the oyster population within the Chesapeake Bay and its tributaries. The USACE and NOAA, together with the Commonwealth of Virginia and the State of Maryland, and other state and federal agencies published the plan—*Chesapeake Bay Oyster Recovery; Native Oyster Restoration Master Plan*—in September of 2012. The master plan calls for the restoration of native oyster populations to 20 of 35 to 40 candidate tributaries within the Chesapeake Bay. Candidate tributaries were classified as “Tier 1” or “Tier 2,” with Tier 1 tributaries given the highest priority for demonstrating “the historical, physical, and biological attributes necessary to provide the highest potential to develop self-sustaining populations of oysters.” The Lynnhaven River within the City of Virginia Beach is listed in the master plan as a Tier 1 tributary with a restoration target of 40 – 150 acres of oyster reefs to be restored by the year 2025.

The benefits of restoring the Bay’s oyster population and the creation of sanctuary oyster reefs within its tributaries go beyond those of simple filtration of suspended material in the water by the oysters. Oysters not only filter suspended material from the water column, but the oyster shells themselves offer a buffer to the acidification of the water in the Bay, and they also play a role in removing nutrients, especially nitrogen from the water. Recent studies have shown that nutrient removal by oysters can be significant and it is believed that sanctuary oyster reefs can play a very important role in removing excess nutrients from the Bay. *It is important to emphasize that the creation of sanctuary oyster reefs is not intended as a replacement for traditional stormwater BMPs, or in-lieu of appropriate land use planning within the Chesapeake*

Bay watershed. However, many traditional BMPs, especially those relying on infiltration, and others such as wet ponds in the coastal plain allow nutrients to reach the waters of the Bay and its tributaries via groundwater transport. The creation of sanctuary oyster reefs would help reduce pollutants such as nitrogen that reach the Bay through stormwater inadequately treated by traditional BMP practices, or stormwater that is not treated in any way.

Previous Studies

The importance of the eastern oyster in improving water quality by removing suspended material in the water column has never been in doubt. However, recent studies are also showing that oysters may play as big a role in removing excess nutrients from the Bay through the same filtration mechanisms. Inorganic nitrogen in the water column is used by phytoplankton for growth. Oysters, as well as other marine organisms, filter the phytoplankton and other suspended matter from the water column. Some of the organic nitrogen from the phytoplankton is incorporated into the living tissue of the oyster, while some is deposited on the on the bottom as sediment. Benthic microbes acting on these deposits can produce nitrogen gas through the processes of nitrification and denitrification. The nitrogen in gas form is unavailable to the phytoplankton and diffuses through the water to the atmosphere.

In 2011, The City of Virginia Beach, together with the USACE, Norfolk District, contracted with scientists from the Virginia Institute of Marine Science (VIMS) to study oyster reefs in the Lynnhaven River. The study, *Assessment of Oyster Reefs in Lynnhaven River as a Chesapeake Bay TMDL Best Management Practice* by Mac Sisson, Lisa Kellogg, Mark Luckenbach, Rom Lipcius, Allison Colden, Jeff Cornwell and Michael Owens, investigated oyster reefs with varying substrates and oyster densities at eight different locations within the Lynnhaven River. The goals were to "estimate bio-mass specific rates of filtration, bio-deposition, nutrient sequestration and denitrification associated with intertidal and shallow subtidal reefs in the Lynnhaven River, VA." The work was performed by placing the bases of special testing chambers, which essentially acted as trays to hold reef material, at the various study sites. The bases were filled with substrate and oysters and were left in the field for 33-34 days to allow the material in chamber bases to equilibrate with the surrounding reef material. The trays were collected from the field by attaching the mid-portion of the testing chamber underwater to the base. In this way water from the site was collected along with the material in the bases. The chambers were transported to VIMS Eastern Shore Laboratory within 3 hours of collection. An upper section of the testing chamber which allowed for sampling and replacement of seawater and dissolved oxygen and allowed for the water in the chamber to be stirred was then added. The chambers were then placed in a seawater bath matching salinity, temperature and dissolved oxygen conditions of the Lynnhaven at the time of retrieval, where they were incubated in light and dark conditions, and sampled for dissolved gasses, and dissolved nutrients. Nitrogen and phosphorus amounts sequestered in oysters and other organisms were determined by drying the macro-fauna contained in the reef samples. Published data by Kellogg et al. (2011) of nitrogen and phosphorus as a percentage of biomass dry weight was used to determine the amounts of those nutrients for certain species. For those species with no published nutrient concentrations, representative samples were dried and weighed. Nitrogen content was measured using a CHN analyzer and phosphorus was determined by colorimetric analysis. Total nitrogen and phosphorus amounts were calculated using the percentages measured, times the total dry weight of the biomass of that species. Specific details of the sampling and testing methodology can be found in the report.

The study showed nitrogen removal rates through denitrification at the oyster reef sites ranged from 15.1 to 20.2 pounds per acre per month (lbs/ac/month) at the time of the study and total nitrogen sequestered by oysters and other organisms on the reefs ranged from 495.8 to 656.5 pounds per acre. By comparison, nitrogen removal at a bare sediment site within the Lynnhaven River was 1 lb/ac/month from denitrification with 32.6 pounds per acre of nitrogen sequestered by oysters and other reef fauna.

A study published in 2013 by M. Lisa Kellogg, Jeffrey C. Cornwell, Michael S. Owens, and Kennedy T. Paynter entitled *Denitrification and Nutrient Assimilation on a Restored Oyster Reef*, compared the rates of nutrient removal from the water column at a restored reef site with a nearby control site in the Choptank River in Maryland. The restored reef site used for sampling had oyster shells placed on the bottom in 2003, with hatchery-raised juvenile oysters on adult shells placed over the shell bottom in 2003, 2006 and 2007. The control site was located approximately 600 feet from the restored reef and showed similar characteristics such as depth, except for a lack of live oysters or shell material on the bottom. Seasonal nutrient fluxes within the water column were measured, with sampling occurring in October and November of 2009, and again in April, June and August of 2010. The study showed significantly more nitrogen removed from the water column through denitrification over the restored reef site in comparison to the control site. Denitrification rates over the restored reef ranged from 22.6 lbs/ac/month to a high of 143.2 lbs/ac/month in August. By comparison, the control site showed denitrification rates of only 3.5 to 9.4 lbs/ac/month. When the rate of denitrification by the control site is subtracted from that of the restored reef, Kellogg et al. estimate that the annual nitrogen removal through denitrification over the restored reef is approximately 496 lbs/ac.

Another study by M. F. Piehler and A.R. Smyth published in 2011, *Habitat-Specific Distinctions in Estuarine Denitrification Affect Both Ecosystem Function and Services*, also showed higher denitrification rates for sediment from intertidal oyster reefs than from intertidal and subtidal flats. Sediment from the oyster reefs showed denitrification rates from 2.8 lbs/ac/month in the winter to 16.7 lbs/ac/month in summer as opposed to winter rates of 1.2 and 0.1 lbs/ac/month and summer rates of 8.2 and 2.6 lbs/ac/month for intertidal and subtidal flats respectively. It should be noted that the denitrification rates in this study are lower than the previously mentioned studies. However, the oyster densities at the natural reef sites were not reported and may be much lower than those of created sanctuary oyster reefs. In addition, this study sampled only the sediment material from the oyster reef sites and not the oysters and shell material as well. In addition, samples were constantly submerged during denitrification measurements, and the incubations of the cores were conducted in the dark. The authors noted that, "Conducting flux experiments from intertidal sediment in which the tides are not replicated likely results in an under-estimation of sediment denitrification by excluding low-tide DNF." Nevertheless, the study shows that denitrification rates are significantly higher for sediment from oyster reefs than from intertidal or subtidal mud flats.

Oysters have also been shown to provide an additional water quality benefit, beyond nutrient removal. A recent study by George Waldbusser, Eric N. Powell, and Roger Mann published in 2013, shows that oyster shells help buffer acidity in seawater. Calcium carbonate in the shells helps buffer carbonic acid which forms when carbon dioxide is added to water. As carbon dioxide inputs to the atmosphere have increased through the burning of fossil fuels, so has the acidity of the Chesapeake Bay. This can have detrimental effects to marine organisms of all types. The study estimates that oysters in the Bay could buffer approximately 70% of the acidity in the Bay in 1870, while that ability is only about 4% today.

Creation of Sanctuary Oyster Reefs for Nutrient Credit

The City of Virginia Beach is committed to improving water quality and meeting its Chesapeake Bay TMDL goals. City officials recognize the importance of oyster reefs in improving water quality, and benthic habitat in its tidal waters. The City has partnered with groups such as Lynnhaven River Now to help restore oyster reefs to the Lynnhaven. In addition, the City has helped study the benefits provided by oyster reefs through research by working with the USACE, NOAA, and VIMS. The research that has been performed to date has increased the public's awareness as to the importance of oyster reefs, and can be used by the City and other localities when choosing locations for new reefs to help ensure survivability of the native oysters and provide the greatest water quality benefits.

The City's collaborative research as well as research performed by others on nutrient removal by oysters and the associated reef is the basis for the City's request that "Sanctuary Oyster Reefs" be included as a nutrient-reducing water quality BMP and an acceptable method for nitrogen removal from a watershed, in order to comply with the Chesapeake Bay TMDL. While recent studies have shown that oyster reefs and the associated macro fauna contain significant amounts of nitrogen sequestered in shell material and living tissue, the oysters must be harvested to remove the sequestered nitrogen from the environment. Oyster harvesting would not be allowed on sanctuary oyster reefs and therefore this request is based only upon the ability of oyster reefs to remove nitrogen from the water column by the process of denitrification. (Phosphorus removal is not included in this request, as studies showed that oyster reefs had little to no effect on soluble phosphorus dynamics.) While some phosphorus is sequestered by oyster reefs, again, they would have to be harvested to remove the phosphorus from the environment.)

Sanctuary oyster reefs to be used for TMDL credit would be created by the City within the Lynnhaven River. The reefs would be subtidal, to increase the period of time that denitrification could occur. Reefs would be created by first placing oyster shells on the substrate, and then adding spat-on-shell to maximize the rate of survival. These created reefs would be declared “Sanctuary Reefs” and would be off limits to harvesting. Reefs would be monitored to ensure viability, and spat-on-shell added as required to maintain a healthy reef.

Calculating Nitrogen Removal Through Denitrification

The study performed by VIMS in 2011 for the City and the USACE on oyster reefs in the Lynnhaven River showed denitrification rates of 15 to 20 lbs/ac/month for the period between September and October. Given that the studies by Kellogg et al. (2013) and Piehler and Smyth (2011) showed the highest rates of denitrification during the summer, it is assumed that denitrification rates will be higher during the summer months for reefs within the Lynnhaven. The study by Kellogg et al. was similar to the Lynnhaven study in sample areas and methodology. When comparing denitrification rates from the Choptank River study with those from the Lynnhaven, the rates measured in the Lynnhaven do not appear to be excessively high as they are still below the lowest rates measured by Kellogg et al. of 22.6 lbs/ac/month.

Understanding that denitrification rates are highly dependent on environmental conditions such as temperature, dissolved oxygen concentration, etc., the City would like to propose that sanctuary oyster reefs be given a provisional removal rate of 20 lbs/ac/month or 240 lbs/ac/year until further measurements can be taken to refine this number. The City recognizes that denitrification may be significantly higher or lower than that rate during the summer and winter months. The City would also like to request specifically that this provisional rate be acceptable for use in planning and reporting Chesapeake Bay TMDL action plan progress, until additional data—including future samples collected in the Lynnhaven River—can be properly evaluated. In other words, the City can plan and implement these reefs and claim 240 lbs/ac/year nitrogen reduction credit for Chesapeake Bay TMDL purposes.

In addition to monitoring the sanctuary reefs for overall health and viability and replacing spat-on-shell as needed, the City proposes to measure denitrification rates at selected reef sites for a period of 15 – 18 months,. The City would then submit the results of the proposed sampling to DEQ for further evaluation, so that this additional monitoring data could be used to establish a permanent (non-provisional) nitrogen removal rate for qualifying sanctuary oyster reefs.

Once again, the intent of this proposal is not to use the creation of sanctuary oyster reefs as a replacement for traditional stormwater BMPs. However, it must be recognized that many traditional BMPs do not remove 100% of the nutrients they receive. With a nitrogen removal efficiency of only 20%, it stands to reason that wet ponds allow the remaining 80% of received nitrogen to pass downstream. The creation of sanctuary oyster reefs will help remove some of that nitrogen that is not removed by traditional BMPs located upstream in the watershed. However, the economics of the Chesapeake Bay Executive Order cannot be ignored. The City of

Virginia Beach, or any locality for that matter, cannot justify the expense for environmental restoration such as the creation of oyster reefs, no matter the benefits, without gaining some credit for the effort. With thousands of pounds of nutrients to remove from its portion of the watershed to comply with the TMDL requirements, the City is forced to look at those projects that will provide nutrient removal credit as part of a complete and comprehensive action plan. Likewise, the City has a fiduciary responsibility to find cost-effective projects to meet the goals of the Chesapeake Bay TMDL, and the economics could justify including sanctuary oyster reefs in the City's BMP toolbox.

The importance of oysters and oyster reefs to the health of the Bay is well understood and the benefits of creating sanctuary oyster reefs go way beyond simply removing nitrogen from the water column. We appreciate your consideration of sanctuary oyster reefs as a BMP for Chesapeake Bay TMDL pollutant reduction credit. Please let us know if there is any other information we can provide to facilitate the inclusion of this important BMP into the Chesapeake Bay Program.

Thank you for helping the City of Virginia Beach improve the quality of the Waters of the Commonwealth and of the United States within the City.

SGM

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