Hybrid Permitting Advantages for Residential

Construction Best Management Practices

By
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ABSTRACT

Lundquist, David. Masters of Environmental Assessment. Hybrid Permitting Advantages for Residential Construction Best Management Practices. During the past several decades Coastal North Carolina, particularly in the Wilmington area, has experienced rapid growth in residential and commercial development. The development is largely due to an expanding population of families, retirees, and sun searchers that desire to live on or near North Carolina's abundant recreational waters. The increase of inhabitants drives development, and in turn poses many risks to recreational water quality. The risks are related to rainwater runoff that occurs from roofs, driveways and other impervious surfaces. When runoff is not managed effectively it can carry pollutants such as nitrates, petroleum products, fecal chloroforms and sediments directly to receiving waters. In order to help mitigate pollutants, state officials and developers are mandated to treat the runoff from development with the use of Best Management Practices (BMP's), Low Impact Development (LID) and responsible land use planning.

Currently, developers and state regulators are divided on finding the right balance between effective treatment and cost effective designs for high density development. This study presents an example where both goals can be achieved through the use of a hybrid construction permit that allows for conventional curb and gutter conveyance to engineered BMP's as well as direct discharge from grass swale discharge in high density developed areas.

BIOGRAPHY

During high school I became fond of classes that allowed me to create with the skillful use of my hands. Upon graduation I pursued a technical degree Building Construction, from North Hennepin Technical College in Brooklyn Park Minnesota. Over the next eight years I immersed myself in the construction of single family residential homes working with my hands and heart to become a master carpenter. I had the opportunity to become familiar with many trades that would ultimately shape me personally as well as advance my career.

During this time I met my future wife Susan who would accompany me to Colorado in order to pursue her Master's of Science at Colorado State University, with the ultimate goal to volunteer for the Peace Corps. Susan completed her degree while I worked in the commercial construction industry building schools. After three years, and Susan's graduation from Colorado State University, we left for San Marcos De Colon, Choluteca in the far south of Honduras to serve in the Peace Corps. There we would have experiences that would change us forever. I worked with small villages in the design and construction of potable water systems, while Susan developed a natural resources management plan for an area that would later become protected by the Honduran forest agency. This was the first time I had been introduced to the engineering world as it related to construction. I asserted on return to the states that I enter a university program for civil engineering.

Upon return we landed in Fairfax, VA where I enrolled, and attended courses related to civil engineering before transferring to North Carolina State University. NCSU would not only pose as a challenge it also opened many doors to me that I had not previously realized were out there. After eight long years of working full time and attending engineering courses, I graduated with a Bachelors of Science in Civil Engineering. Immediately upon graduation I committed to completing a Masters degree.

With my background in construction, civil engineering, nature and the physical sciences a master's degree in environmental assessment seemed to be a natural choice. Participating in the Master of Environmental Assessment program at North Carolina State University has pushed me to further understand our environment from a different perspective, while permitting me to use the skills I have already gained.

ACKNOWLEDGEMENTS

First and foremost I would like to thank my wife Susan Lundquist for her undying support. Words cannot describe the commitment, patience, and support she has given me over this thirteen-year process while I accomplish this goal of completing a master's degree. Her early words, and stern advice, still ring true when I desired to abandon my studies during the first semester of my undergraduate degree. Her advice was simple; *"You are not going to quit just because it's difficult, and you don't understand, you are going to pick yourself up by your boot straps and finish"*. I applaud her dedication, and exuberance that will not be forgotten.

I also want to thank my close friends John Herrera, Brandon and Susan Hill, and Andrew Lipetsky, who have always encouraged me to continue, work hard and always reach for more. Andrew has continually reminded me of my inner intensity and drive to succeed.

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Stormwater Runoff

A growing population and subsequent explosion of development near the land-water interface of North Carolina coastal communities has the potential to negatively impact recreational water quality and put humans, and the environment at risk (NOAA, 2014). Negative impacts come from the introduction of pollutants into waterways resulting from untreated or undertreated stormwater runoff from urban areas (Natural Resources Defense Council, 2011). Runoff occurs when rainfall comes into contact with impervious surfaces such as roofs, sidewalks, streets, and driveways. Stormwater runoff has the ability to capture, and transport pollutants from impervious surfaces discharging them into receiving waters (i.e. lakes, rivers, streams and estuaries). Common pollutants include petroleum, oil, and lubricants (POLs), fertilizers, toxic metals, bacteria, and heat that can adversely affect plants, animals, and the aquatic ecosystems. (Hunt, 2006).

Humans that participate in water based activities are at greater risk of illness due to the effects of pollutants from direct contact, and or involuntary ingestion of polluted water. (North Carolina Division of Marine Fisheries, 2014). There are a number of methods that can be used to minimize harmful runoff, including engineered structures; best management practices (BMPs) and comprehensive land use planning by municipalities.

The issues surrounding stormwater based pollution along the coastline can be traced directly to a population shift that has increased the number of residents along coastal areas over the past several decades. The National Oceanic and Atmospheric

Administration (NOAA) indicates that coastal areas in the United States (US), excluding Alaska, are far more densely populated than the U.S as a whole (NOAA, 2014). The agency further states, which according to the 2010 census, there has been close to a forty percent increase in population near the coast between the years of 1970 and 2010. As more people are drawn to the water for recreation and choose to move to these popular locations they influence additional development. In turn the increased numbers, signal a greater demand for amenities, conveniences and housing. As development increases the natural patterns of stormwater runoff are modified, and manipulated contributing to an increase of impervious surface (Wossink/Hunt, 2003).

Effects of Runoff and Recreational Waters

In the Wilmington North Carolina area both New Hanover, and Brunswick counties have experienced just this sort of rapid growth mentioned above (NOAA, 2014). The North Carolina Department of Environment and Natural Resources (NCDENR) is the North Carolina authority that has the primary responsibility for monitoring beaches and waterways for water quality issues. One of the ways that NCDENR does this is by utilizing a United States Environmental Protection Agency (USEPA) program known as Beaches Environmental Assessment and Coastal Health Act of 2000 (Beach Act, 2000). The BEACH Act is an amendment to the Clean Water Act (CWA), and was initiated in October of 2000. The act allows the EPA to award program development and implementation grants to eligible states with the intent to reduce the risk of illness to users of the nation's recreational waters.

The way in which NCDENR accomplishes the objectives set forth by the BEACH Act is by executing a comprehensive sampling program of beaches where recreational use is most prevalent. Each beach location is categorized by NCDENR into a Tier 1, 2 or 3 body of water. Tier 1, the most heavily used, beaches are generally in the proximity of resort areas, public access points, and ocean beaches. Tier 1 waters are sampled with the highest frequency between April and September. Tier 2 beaches constitute areas such as those along the Intracoastal Waterway, tidal creeks, and exposed shoals. Sampling in these areas generally occur on a monthly basis. The tier 3 beaches are characterized as sporadic use areas, and are tested less regularly.

Monitoring samples are analyzed for fecal bacteria called enterococci which can be found in the intestines of birds, dogs, raccoons, and people (NC Division of Marine Fisheries, 2014). There are two parameters that the recreational water quality levels must maintain, a single-sample level and a set average. When a single sample exceeds states levels advisories may be posted for public awareness. The set levels are based on usage, and cannot exceed the limits detailed below;

Tier 1. A single sample of 104 enterococci per 100 milliliter of water.

Tier 2. Area shall not exceed a single sample of 276 enterococci per 100 milliliter of water.

Tier 3. Area shall not exceed two consecutive samples of 500 enterococci per 100 milliliter of water.

The set average parameter is the mean of 5 samples taken within a 30 day window. This mean cannot exceed 35 enterococci per 100 milliliters of water. When the set average is not below state standards the public is advised through public broadcast, the internet, and the posting of signs at the impaired water body. In the event that there is an eminent public health risk, county health directors have the authority to close any body of water. According to the Natural Resources Defense Council seventy percent of the closings and advisories in 2010 were due to stormwater runoff (Natural Resources Defense Council, 2011).

North Carolina also monitors for *Karenia brevis* (G. Hansen et Moestru) more commonly known as red tide. Karenia brevis is the dominant toxic red tide algal species found in the Gulf of Mexico. It produces potent neurotoxins (brevetoxins [PbTxs]), which can negatively impact human health, and the environment, local economies, and ecosystem function Natural Resources Defense Council, 2011). Shellfish that ingest K. Brevis build up toxins that can lead to neurotoxin shellfish poisoning in humans and marine mammals. It is theorized that nutrient loading and elevated phosphate levels from point source runoff may contribute to the prevalence of red tides. Testing for K. Brevis begins when the Gulf Stream comes near the Carolina coast. If near shore levels are detected, beach advisories can be issued (NC Division of Marine Fisheries, 2014).

Construction and Water Quality Permitting

It is the goal of this paper to illustrate how BMPs can be incorporated into a planned subdivision successfully, both during the pre and post development phases. It also serves as a way to identify the economic impact engineered structures have on development under current NCDENR regulation, and introduce a hybrid method of water conveyance that would perform effectively (regarding level of treatment) while minimizing construction expenses, and long term maintenance cost. As mentioned previously, municipalities frequently require that developers install measures that minimize pollution from leaving the construction site as well as a long term solution for mitigating stormwater runoff pollution.

In North Carolina the NCDENR has adopted the National Pollutant Discharge Elimination System (NPDES) stormwater permitting program which requires all construction activities that disturb more than one acre of land to acquire a general erosion, and sediment control permit, NCG 01000 (NCDENR/DWQ, 2011). The permit requires owners and operators to regulate point source discharges from the site due to any clearing, grading, excavation or related construction activities. This allows the permittee to discharge stormwater in accordance to the terms and conditions of the permit, and in accordance with an approved Erosion and Sediment Control (S&EC) plan approved by the Division of Land Resources (DLR). The S&EC plan is designed to ensure compliance with the NPDES and the requirements of the Clean Water Act (CWA). In other words the permit allows for controlled point source discharge to rivers, lakes and streams following treatment. Any other means of discharge, weather unintentional or deliberate is strictly prohibited, and is subject to penalties, fines or imprisonment as outlined by NCDENR.

This paper will consider a planned subdivision located in Brunswick County, which provides an excellent example of a successful development project that incorporates the use of BMPs to achieve the intended stormwater pollution control measures set forth by NCDENR.

The engineering team has collected data both during the construction, as well as over a two year period after construction, and completion of Phase 1A that has proven the effectiveness of the BMP design. The intended outcome is to ensure that the BMPs function as expected, and that the water quality regarding turbidity and nitrates remained below state regulated limits. The result was that the BMPs met or exceeded state levels during the entire study period (interview with design engineer, 2014).

Brunswick, as well as the remainder of North Carolina counties, is governed by well-defined state regulations regarding stormwater runoff. When describing stormwater requirements for subdivisions the NCDENR Stormwater BMP manual provides options that allows for a low density versus high density classification for a site. These classifications are dependent on whether the site drains to class SA or Non-SA waters. SA waters are high quality salt waters that promote shell fish harvesting. Non-SA waters are lower class salt waters, and all freshwater bodies. The BMP manual indicates that in Non-SA waters a project may be permitted as low density if it has no more than two dwelling units per acre or less than 24% built-upon area. In the case of the Brunswick County subdivision it has both single and multifamily dwellings that are concentrated at approximately one home per 0.25 acres. Therefore, by direction of the BMP manual, the project is classified as high density development (HDD). NCDENR's constraints on HDD related to stormwater controls are as follows;

- Stormwater control measures must control and treat the difference between the pre-development and post-development conditions for the 1-year 24-hour storm;
- Runoff volume drawdown time must be a minimum of 24 hours, but not more than 120 hours;
- All structural stormwater treatment systems must be designed to achieve 85% average annual removal of total suspended solids;

- Stormwater management measures must comply with the General Engineering Design Criteria For All Projects requirements listed in 15A NCAC 2H .1008(c);
- All built-upon areas are at least 30 feet landward of perennial and intermittent surface waters.

Best Management Practices

Despite the success of NCDENR's monitoring programs with regard to alerting the public to unsatisfactory conditions of recreational water, the fact remains that upstream treatment of stormwater is a key factor in protecting human health and the environment before the pollutants reach these waters. Engineered BMP structures, when installed and maintained correctly, are an effective means of mitigating pollutants carried by stormwater prior to entering receiving waters (Hunt, 2006).

Examples of engineered stormwater BMPs that have been installed in southeastern North Carolina include stormwater wetlands, sand filters, and wet or dry detention ponds (Coffman et al. 1993b). Best Management Practices are engineered in order to redirect, slow down and filter pollutants from stormwater in urban areas (Hunt/Wossink, 2003). The type of structure and design elements of any particular BMP is a product of its location, and intended use. One BMP may be adequate for nutrient removal while another is best for controlling stormwater flow.

The North Carolina Division of Water Quality publishes a Stormwater Best Management Manual, which provides guidance on the selection of structural BMPs (NCDENR, 2007). The manual recommends four steps for the designer to consider in making their recommendations.

1.) Take into consideration the treatment objective with relation to regulatory requirements of the particular site. For example, is the structure expected to mitigate, and to what level does the extenuation need to meet (i.e. removal of suspended solids, nutrients or phosphates).

2.) Determine which type of BMP will be effective in reaching the intended goal for the site.

3.) Define which of the chosen BMPs will fit within the physical site restrictions.

4.) Take into account long term maintenance cost, construction cost, and aesthetics. In other words, the BMP that is the most efficient at removing a particular pollutant may not be the final choice due to high cost or low community support due to safety or aesthetics (i.e. deep water level or mosquito breeding area).

Referencing a study on the cost of BMP completed by the Minnesota Pollution Control Agency (MNPCA) it is possible to gain a better understanding of what is meant by high cost (Minnesota Pollution Control Agency, 2011). The study indicates that the for a large wet detention basin (greater than 100,000 ft^3 of water quality volume) the cost per water quality volume is approximately \$2.00 dollars per water quality volume/ft^3. On the other hand, the cost of a small detention basin (less than 10,000 ft^3 water quality volume) would be upwards of \$145.00 dollars per water quality volume/ft^3.

In considering all aspects, it is best when the designer takes both a qualitative and quantitative approach to the design. Table 1 below provides an example of the construction costs, maintenance, and community acceptance of each BMP.

Table 1: Cost and Community Issues for BMP's (NCDWQ BMP Manual, 2007)

	Construction Cost	Maintenance Level	Safety Concerns	Community Acceptance	Wildlife Habitat
Bioretention	Med-High	Med-High	N	Med-High	Med
Stormwater wetlands	Med	Med	Y	Med	High
Wet detention basin	Med	Med	Y	Med	Med

Conventional North Carolina BMP's

A May 2003 essay, "*The Economics of Structural Stormwater BMPs in North Carolina",* is a document produced by two North Carolina State University (NCSU) professors (Bill Hunt and Ada Wossink) as an effort to define the economics of BMPs relative to their effectiveness in mitigating pollution on a cost per acre basis in the state of North Carolina. The paper debates the pros, and cons of three popular types of BMP structures. The three BMP examples include wet ponds (North Carolina's BMP that has historically been utilized most frequently), stormwater wetlands, (*USEPA definition below) and sand filters. The following narrative provides a brief explanation of each as described by Wossink and Hunt.

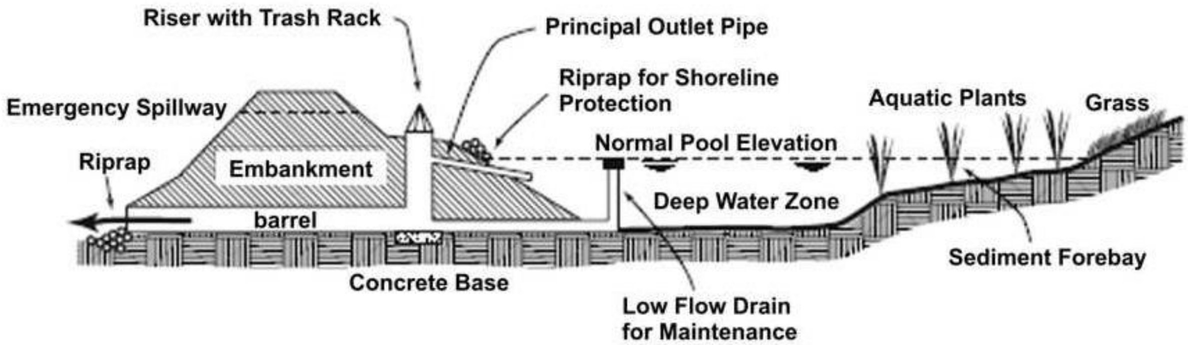
The first of the three conventional BMP's used in North Carolina is the wet pond. It has been proven to be highly versatile, and has been traditionally utilized for a wide range of watersheds. In North Carolina wet ponds have been constructed for areas as small as one acre, and up to several hundred acres (Hunt/Wossink, 2003). The structure is differentiated by an excavation which incorporates a deeper forebay that gives way to a shallower permanent wet area, termed the permanent pool. They are essentially artificial lakes encompassed by a vegetated buffer; with the purpose of collecting large volumes of water during rain events in order to reduce the velocity of the runoff, and slowly release it to adjacent water bodies (see Figure 1.). Prior to release, pollutants are allowed to settle, and become confined in the sediment of the permanent pool.

Wet ponds are low in maintenance, and provide moderately effective removal of total suspended solid (TSS), total nitrates (TN), and heavy metals when compared to sand filters, and stormwater ponds (see Table 2). One disadvantage of wet ponds is safety. Many communities view them as a risk to children due to the permanent wet pool, and the potential to fall in without being able to easily climb out.

Table 2: BMP Removal Rates (Table 4.1, NCDWQ Stormwater BMP Manual, 2007)

	Quantity Control	TSS Removal Efficiency	TN Removal Efficiency	TP Removal Efficiency	Fecal Removal Ability	High Temperature Concern
Bioretention	Possible	85%	40%	45%	High	Med
Stormwater wetlands	Yes	85%	40%	35%	Med	High
Wet detention basin	Yes	85%	25%	40%	Med	High

Figure 1: Wet Pond (Metropolitan Council of Minneapolis, 2003)



A second type of BMP detailed in the report is the constructed wetlands. A constructed wetland typifies a shallow filter into which stormwater flows at one end, is then absorbed into a substrate layer of vegetation, and finally released at a controlled rate over a weir or to receiving lakes, streams, and oceans (Hunt/Wossink, 2003). Wetlands are generally highly vegetated with plants that thrive in wet or semi wet locations (see Figures 2 and 3). The vegetation is situated in order to slow the water entering the wetland allowing pollutants to settle. The plant then removes pollutants via absorption, and the nutrient uptake process. Unlike wet ponds, wetlands do not have a permanent wet pool, and are considered to be more aesthetically pleasing as well as highly effective at absorption, and uptake of key pollutants such as nitrogen and phosphorous in areas where heavy use of fertilizers are observed.

Figure 2: Engineered Wetland (Stormwater Manager's Resources Center, 2015)

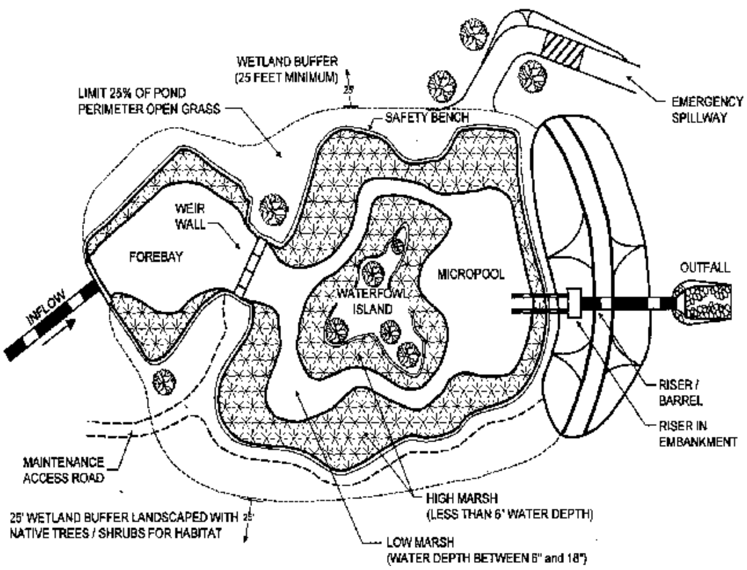
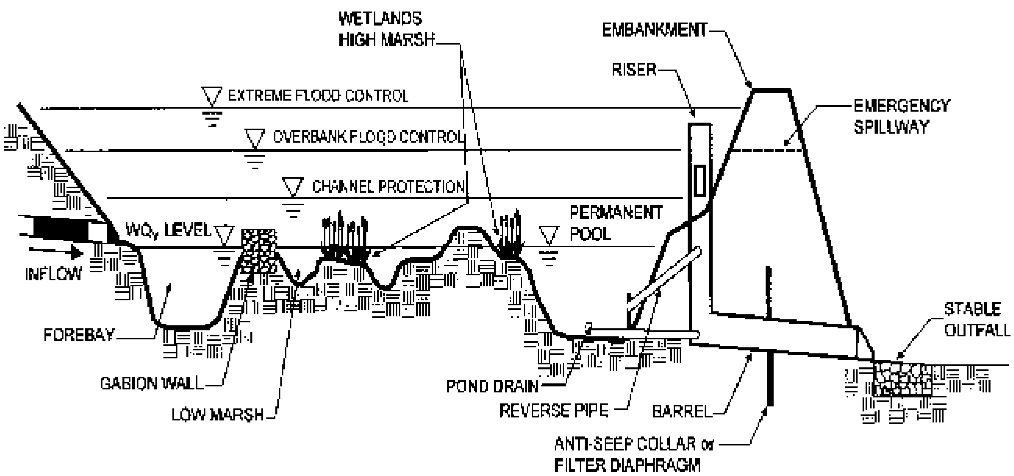
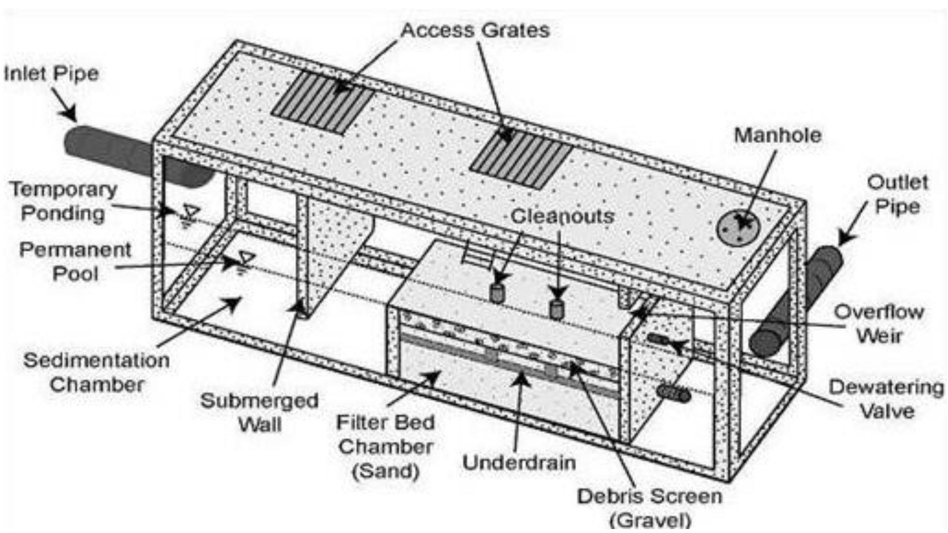


Figure 3. Engineered Wetland (Stormwater Manager's Resources Center, 2015)



The final BMP readily found in North Carolina is the sand filter which is generally characterized by a two chamber system (See Figure 4). There are several variations of the basic sand filter design, including the surface sand filter, underground sand filter, perimeter sand filter, organic media filter, and Multi-Chamber Treatment Train. All of these designs operate in a similar manner, and are more often configured based on the site. The filter relies on the initial chamber to settle out large particles such as leaves, twigs, and debris. The second chamber is designed to capture fine particles, including sand, silt, and dust while at the same time filtering out the pollutants. Sand filters are known to be an economical method for filtering pollutants due to the fact they can be used in highly urban areas where space is limited. One drawback is their comparatively poor performance in areas where the topography is relatively flat. They are known to perform best where the topography lends sufficient relief in order to force runoff through the filter at a relatively aggressive velocity. The amount of drop required is usually between 5 to 8 feet. This type of filter is very effective at the removal of pollutants with the exception of nitrates (Brown/Schueler, 1997).

Figure 4. Sand Filter (VA Dept. of Conservation and Recreation, 2011)



BMP Maintenance

Following the construction, and implementation phase, the single most important factor in maintaining the effectiveness of a BMP system is its continued and timely maintenance (USEPA, 2003). Some of the most common maintenance items include clearing inlets, and outlets of trash, mowing, trimming, pruning, and replanting of vegetation dredging of silt as needed. The cost, and time involved for maintenance activities varies, and is dependent on the type of constructed structure (see Table 3). The operation and maintenance should be calculated into the overall cost during the design phase of the structure, as the cost will be passed onto the end user (i.e. homeowners, business owner, and municipalities). The DWQ Stormwater BMP manual indicates that with the exception of highly vegetated BMP's, structures should be inspected at a minimum on a quarterly interval, and after any large storm event.

Municipalities frequently mandate that developers install structures during the construction phase of a development (Land Use and Environmental Compliance, 2014). The developers frequently have a good understanding of how these structures perform, and recognize the need for annual inspections. However, after the development is completed, maintenance costs often fall on homeowners associations that can be less technically prepared. Even though the importance of proper operation and maintenance of BMP structures is widely published (NCDENR, 2007), the maintenance is regularly ignored. The following table illustrates the type, and frequency of maintenance that is recommended.

Table 3. BMP Maintenance and frequency (Hunt/Wossink, 2003)

BMP type	Maintenance Performed (rate/frequency)
Wet Ponds	Mowing banks (monthly, seasonal). Outlet/inlet inspection (after large rain events). Removing vegetation from outlet (varies). Forebay dredging (0-3 times over life of pond).
Stormwater Wetlands	Harvest and replanting of wetland vegetation (0-1 times over life of wetland). Outlet/inlet inspection (after large events). Removing vegetation from outlet (varies). Forebay dredging (0-3 times over life of pond).
Sand Filters	Dredging sedimentation chamber (1 time annually to 1 time every three years). Removing built up debris from sand chamber (2-3 times per year initially, 1 time per year thereafter). Outlet inspection (1 time per year) Underdrain inspection (1 time per year).

Homeowners that live in a community that is responsible for the maintenance should have significant interest in maintaining those structures. Facilities that are neglected, and don't receive regular maintenance will fail over time. Repair or replacement of a failed system can be an extremely costly undertaking; therefore, the USEPA provides guidance on how to prepare communities with an effective post construction plan for managing stormwater (USEPA, 2003).

Project Subdivision Site Details

The project site, located in Brunswick County, totals 80 residences that are situated on a 17.94 acre parcel of property. It is bordered by a NC state road to the east, and mature subdivisions to both the north, and the south. The land located directly west of Phase 1A consists of future phases within the same development, known as phases 1B and 1G. The entire tract is zoned residential with a minimum lot size of six thousand square feet denoted as R-6000. There is a mixture of twenty-three multifamily homes, and fifty-seven single family dwellings (see figure 5).

Figure 5: Subject Subdivision

Two engineered BMPs are located within the subdivision which serves the purpose of treating construction runoff as well as future runoff from impervious surfaces upon completion of the development. There is also a constructed water feature which provides an esthetic appeal to the community. The water feature is an engineered structure, however, it is not intended for stormwater treatment, and does not appear on the NCG – 01000 permits. The upland wet detention pond collects stormwater from the greater share of single family homes located on the upland area. A second BMP (also a wet detention pond) captures runoff from the multifamily homes located lower on the property, and a small portion of the single family residences.   The multifamily section is situated in a lower lying area buffered by the BMP structure along the NC state roadway.

Prior to construction of Phase 1A the design engineer presented a water quality monitoring plan that proposed water quality sampling of the BMP structures during construction, and for a period of two years following construction. The effort was put forth to demonstrate the effectiveness of the BMP structures to moderate for turbidity, and contaminants. The subsequent report (not included here) resulted in levels that remained below state standards throughout the reporting period.

Permit Considerations

While the primary goal of this paper is to introduce the reader to the importance of BMP structures as they relate to development, and coastal water quality. It is also important to consider the economic impacts that BMP construction can have on development. There is evidence, shown above, that the options for low density versus high density development are very narrow. The possibility to broaden this scope can be mutually beneficial to both developer, and the state. More options at the development stage would present opportunity to reduce construction costs for future development. In order for this to occur, the current state regulations would need to be revised to provide for a more responsible approach.

In order to demonstrate where changes can be made it is imperative to quantify the construction, and infrastructure cost against an alternative hybrid approach if it were permitted by state regulations. The hybrid approach would allow direct discharge of stormwater, from a portion of the development, directly into wet lands by conveyance of grass swales. The remaining portion of the development would be serviced by a traditional curb and gutter collection system, and be treated by way of the existing engineered BMP (lower BMP) prior to discharge into the receiving stream (Interview design engineer, 2014). It is the belief of the author that if this approach were allowed during the construction permitting stage, there would have been opportunity to realize a considerable cost savings by the developer during the design and construction phase. Current state regulations do not allow the use of grass swales that directly discharge to wetlands from high density developments. This may be attributed to the inability of grassed swales to effectively treat large areas. In general, the current literature reports that a well-designed, well-maintained swale system can be expected to remove 70% of total suspended solids, 30% of total phosphorus, 25% of total nitrogen, and 50 to 90% of trace metals (WisDOT/CTC & Associates, 2007).

Although the development is considered to be fully successful with regard to treating, and mitigating storm water runoff, there are discussions between designers and developer that unnecessary costs have been incurred due to NCDENR regulations that may be too stringent. In this case the designer believes that a lower cost treatment may be able to be implemented. This is not an isolated occurrence, and has become a topic of conversation in other areas of North Carolina as well (EAB/SMAC, 2012). The discussion revolves around the need to revisit state regulations to allow for a hybrid approach for treating stormwater runoff in high density development. This would allow developers the option to use alternative methods in conjunction with traditional curb and gutter to convey, slow, filter, and treat stormwater in an effective manner. This is not only a greener approach than the use of curb and gutter, when designed and incorporated properly; it can be beneficial for both developers, property owners. While this is not a new concept in low impact, low density development, it is not currently supported by the NCDENR permitting system (outlined above) as an approved method of treatment in developments that are considered high density.

The incentive for developers is simply to reduce the foot print of the wet ponds on the project site, allowing for the potential of additional buildable area. By reducing the pond area, and eliminating curb and gutter there can be a reduction in the cost for infrastructure. This in turn lends to the likelihood of constructing more units within a given development. From a fiscal standpoint grass swales rather than hard piped conveyance systems present a low cost, low maintenance option that promotes removal of pollutants while promoting the natural infiltration of runoff into the water table.

The subject site is a good example of a development that would benefit from the use of a hybrid conveyance system had NCDENR allowed for it in their permitting process. The design engineer proposes a change to the construction permit that provides the developer incentive to make changes that are mutually beneficial to the development of the subdivision, and NCDENR regulations. The first change would allow for the use of grass swales in the upland single family home area, rather than curb and gutter. The design engineer proposes a system of shallow grass swales parallel to the road rite-of-way. The rite of way swales would interconnect into a series of swales located along individual lot lines between every forth home (see figure 6). This type of system would disconnect the single family discharge from the multifamily which is located lower on the property. The benefit is that upper system of swales could transport, and discharge stormwater into the perched wetlands surrounding the area rather than releasing the outflow from the pond into higher quality wetlands at the lower portion of the project. A strategy such as this would eliminate the need for the upper wet detention pond. Homes that are unable to take advantage of swales would be equipped with curb, gutter, and a hard pipe conveyance system that is treated, and discharged at the wet pond located along the state road. The benefit is that infrastructure cost would decrease for the upper residential, along with the opportunity to utilize the area for built structures.

Figure 6: Swale vs. Curb and Gutter Location

In order for a change like this to occur it is conceivable that NCDENR would require additional measures and/or more stringent regulations on remaining structures at the same site. There are several reasonable changes NCDENR could initiate with the current BMP requirements that could provide for hybrid construction. 1.) Allow for a more stringent rainfall intensity when designing the lower wet pond. The current regulation states that wet ponds are required for a 1-inch 24 hour rain intensity event. In this case the state could increase the requirement to a 2-inch 24 hour storm. This would result in a greater pond volume coupled, and correlates to the ability to treat runoff more efficiently.

A second condition NCDENR could impose is to ensure that the drawdown time runoff is maintained in the BMP is lengthened. The drawdown time is a function of basin volume, and outlet orifice size. Therefore by decreasing the diameter of the orifice or outlet the time it takes a pond to drain is lengthened. As seen above, the current drawdown is a minimum of 24 hours, and not more than 120 hours. Adjusting the minimum drawdown to 48 hours would allow more time for the pollutants to fall out, and settle prior to discharge. This in turn results in cleaner water entering the water ways.

Associated Costs

In general, vegetated swales are considered relatively low cost control measures. Moreover, experience has shown that Vegetated Swales provide a cost-effective alternative to traditional piping and/or curbs and gutters. Generally speaking, vegetated swales cost between $4.50 dollars, and $8.50 dollars per linear foot when vegetated from seed, and $15 dollars to $20 dollars per linear foot when vegetated from sod (Malvern, 2015).

On the other hand, a report generated by the Illinois Conservation institute indicates that the installation of a structural conveyance systems which includes curb and gutter, storm drain inlet and piping, ranges between $40.00 dollars $50.00 dollars per foot.

When compared to the relatively low cost for grass swales, it seems obvious that state regulations should allow for the use of both types when issuing construction permits. Table 5: below attempts to demonstrate the potential cost savings that a developer could expect to realize by implementing a combined system. Taking in into account the elimination of curb and gutter with a grass swale conveyance system per Figure 6, and assuming the prices above reflect the general costs for each type of system. An additional assumption is that the soils on-site are of good quality, and suitable for the intended purpose of grading without the additional cost of using off-site soils.

Table 5: Conveyance Cost Difference (Town of Malvern, 2015)

Curb and Gutter Only

Cost (LF)	Total (LF)	Total Cost
$50.00	5400	$297,000.00

Vegetative Swale and Curb and Gutter

Cost C&G (LF)	Cost Swale (LF)	Total C&G (LF)	Total Swale (LF)	Total Cost C&G	Total Cost Swale	Combined Cost
$20.00	$20.00	$3400	$2700	$68,000.00	$54,000.00	$132,800.00

Engineering design Costs

Cost C&G	Cost Combined
$27,000.00	$10,800.00

Taking into account there is approximately 5400 linear feet of right of way within Phase 1, and that engineering cost are approximately ten percent, table 5 illustrates that the use of curb and gutter has an associated cost of $270,000 dollars. This cost has the potential to be reduced to $132,800 dollars by the use of a combined system. The combined system eliminates approximately 2000 linear feet of curb and gutter, and replaces it with 2700 linear feet of vegetated swale. The discount between the two systems is about 55 percent (based on a sod swale price), and could be further reduced by placing seed rather than sod to stabilize the swale. One additional benefit to the environment that isn't quantified here is that there is less land disturbance related to forming a swale versus heavy excavation necessary to install piping. In general the less land disturbance that is disturbed should equate to less silt washing off -site.

Conclusion

As populations increase in the coastal North Carolina counties, and the change in land uses continue along the land/water interface, it is important that human health, and the environment. One way that this is accomplished is through a state program initiated by NCDENR. This program requires the monitoring of recreational water quality according to the frequency of their use.

It is also important that as residential developments continue to be established, and services requested that Best Management Practices for stormwater runoff be observes. BMP's are put into place in order to mimic the normal runoff patterns that nature has provided. They are crucial in redirecting, slowing down, and filtering pollutants from stormwater in urban areas.

In keeping the protection of human health, and the environment in mind, developers, and state officials often disagree on how to accomplish their mutual goals. Developers insist that changes could, and should be made to state policy. The changes requested would allow them to use alternative methods of stormwater treatment when constructing high density developments. They contend that the modifications would be mutually beneficial to both developers, and the state. The example subdivision demonstrates that if point source discharge through a vegetative swale, in combination with traditional curb and gutter conveyance, were permitted not only would there be a great cost savings from a construction stand point, the state's level of treatment required of stormwater runoff could also be achieved. The take away from this example is that state regulators, design engineers, and developers have the potential to revisit the North Carolina water quality regulations to ensure that all parties are represented fairly. For that to happen further studies need to be produced that take into account a hybrid system. In a well maintained setting there may be evidence that pollutant removal rates are similar. If that is the case, it may leave room to make policy changes.

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