Building a Stormwater Toolbox: Learning What to Expect from Your Stormwater BMPs

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ABSTRACT. The May River in Bluffton, SC is designated an Outstanding Resource Water by the SC Department of Health and Environmental Control (SCDHEC, 2012) for its valued natural resources, particularly for its oyster production and aesthetic views. However, due to the rapid development within the watershed, rising fecal coliform levels in the river's headwaters resulted in closing portions of the river to shellfish harvesting. Rising fecal coliform levels are a clear indicator of the deterioration of the health of a watershed.

Research, studies and countless staff-hours have been used to identify where and why increased pollutant loading occurs within the watershed. The indications from those efforts are that increased stormwater runoff volume from development is a key contributor to pollutant loading downstream. This knowledge resulted in the Town of Bluffton adopting a volume-based stormwater ordinance in 2010 and the May River Watershed Action Plan (AMEC, 2011) in 2011. These two documents provide preventative and restorative measures aimed at improving water quality within the May River.

The May River Watershed Action Plan (Action Plan) lists multiple project recommendations at fecal coliform "hot spots," which were identified through the Town's water quality monitoring program. The Town's priority is implementing those projects and refining our understanding of what can be expected. Recently completing an EPA 319 Grant-funded New Riverside Stormwater Lagoon at one of the hot spots represents the start of on-the-ground solutions, demonstrating real action toward restoring the health of the May River. Equally important is the knowledge gained by comparing post-construction water quality monitoring data of the lagoon to pre-development monitoring data to determine its efficacy.

Using the Action Plan for guidance the Town applied for, and was awarded, a second 319 Grant for a stormwater Best Management Practice (BMP) project. The project will retrofit an existing stormwater system, permitted before the current volume-based ordinance, with volume control through stormwater reuse for irrigation. This is the most common volume reduction technique used by the development community to meet the Town's ordinance. Currently there are no design guidelines for these systems. One of the expected outcomes of the project is creating a design strategy that optimizes the amount of runoff infiltrated by the system. Flow monitoring for both pre- and post-project conditions will help determine its efficacy. In addition to the water quality benefits, valuable information will be gained from this BMP that will aid the Town in offering design guidance to the public that will maximize this particular type of BMP's volume control potential.

Both projects contribute to a better understanding of the true impact of a particular BMP to improve water quality. The Town expects to continue this methodology for different BMP technologies in the future. Thus, every project will help the Town build a stormwater toolbox tailored to its specific needs and conditions and provide a template for use by other communities or watershed managers.

INTRODUCTION

The success of watershed management is difficult to track without a strategic water quality monitoring program. The purpose of this study is to document and examine a water quality monitoring protocol that will track the effectiveness of individual stormwater BMP projects, resulting in a more comprehensive and complete stormwater toolbox. Initial results of the New Riverside project will then be analyzed to determine its efficacy, both at the site and watershed level. Knowing what to expect, based on localized results, from different types of stormwater BMPs will help watershed and stormwater managers better plan a strategy to achieve or maintain their desired water quality standards.

BACKGROUND

The May River (HUC 3060110-03) is a tidal embayment located in southern Beaufort County, South Carolina. The Town of Bluffton, sitting alongside the May River, has had strong ties to the river since the Town's incorporation in 1852. Commercial shellfish harvesting has historically been, and still remains, a significant component of the economy, tradition and community character of the Town. Additionally, the aesthetics and views of the May River increase the popularity of Bluffton for residential, commercial, and tourist visitation growth, tying the Town's economic conditions directly and indirectly to the river.

Rising popularity of the area resulted in the Town's incorporated limits expanding from one square mile in 1987 to over 54 square miles today. Between 2000 and 2010 the Town's population increased by 883% from 1,275 to 12,530. The number of housing units rose from 501 to 5,393 during the same time, an increase of 976% (U.S. Census Bureau, 2000 and, 2010). However, with the rapid increase in population and development came rising fecal coliform levels in the May River, resulting in portions of the river being closed to shellfish harvesting.

Due to the correlation between increased development and increased fecal coliform levels, the Town of Bluffton attributes the deterioration in the health of the watershed primarily to the volume of stormwater runoff resulting from the impervious area added by development. This degradation occurred even though the additional runoff volume typically has been routed through lagoons that were designed for peak rate control and water quality treatment.

The Town has since implemented a volume-based stormwater ordinance (Town of Bluffton, 2011) that requires new development to control and infiltrate the first one inch of stormwater runoff over the entire development, or maintain the pre-development hydrology for the 95th percentile storm event, depending on soil conditions. Several different technologies can be used to achieve this standard. As the Town moves forward with its own water quality modeling, it seeks to quantify the expected water quantity and quality benefits of multiple technologies, while gaining a better understanding of what, if any, downstream benefits are offered by a traditional stormwater detention pond.

Building the Toolbox: New Riverside Stormwater BMP

Several years of weekly sampling and studies by the Town and its partners indicate that stormwater lagoons have low effluent fecal coliform levels that recharge by a factor of 10 or more just a short distance downstream in a wetland ditch system (Ahern, et. al., 2012). While the Town regularly collected effluent samples at several lagoons, limited or no sampling was occurring for fecal coliform concentrations in stormwater runoff as it entered into the same lagoons. Therefore, their actual efficacy for reducing fecal coliform concentrations was unknown. Any benefits attributed to lagoons for water quality modeling was based on recommended efficiencies, and not local knowledge.

To get a better understanding of how detention ponds affect fecal coliform concentrations, the Town used EPA Section 319 Non-Point Source Pollution Grant funds to implement a pilot project. Working with New Riverside LLC, the Town constructed the New Riverside Stormwater BMP, a wet detention pond. As the contributing drainage area is primarily undeveloped, stormwater volume reduction is not a concern. However, the naturally high incoming fecal coliform concentrations provide the Town with an opportunity to determine the efficacy of a detention only BMP both immediate to, and downstream of, its location within the watershed.

Building the Toolbox: Pine Ridge Lagoon Retrofit

The Town was awarded a second EPA 319 Grant in 2012, also aimed at reducing the amount of fecal coliform reaching the May River. However, a different methodology will be used to achieve the reduction. The lagoon network of an existing community, Pine Ridge Subdivision, will be retrofitted with a reuse irrigation system that will irrigate nearby open space around the community. Scheduled pumping from the lagoons will draw down the water surface elevation, creating available runoff storage for future rain events. This should result in a reduction in the volume of stormwater runoff that leaves the community during future rain events. Reducing the volume of runoff will reduce the overall fecal coliform loading to the May River.

Stormwater reuse for irrigation is a popular option that the design development community uses to meet the Town's water quality volume requirements. However, little guidance has been provided that specifies an ideal irrigation schedule. The typical submittal specifies an irrigation rate of 1 inch per week for the available open space area. The assumed daily irrigation rate is then approximately 0.14 inch. Using the 95th percentile storm event, or 1.95 inches of rainfall over a 24-hour period, as the standard, it would take two weeks to draw down the water surface of the lagoon to the desired elevation needed to achieve the required volume. If a rain event occurs during the drawdown cycle, the required storage capacity may not be available.

The Pine Ridge Lagoon retrofit project gives the Town an opportunity to create a design strategy that will maximize the water quality storage potential in stormwater lagoons used for irrigation. Pre-retrofit and post-retrofit monitoring will be used to help determine

the efficacy of stormwater reuse for irrigation as a stormwater volume reduction technology.

METHODS

Detention-only Water Quality BMP Sampling

The location of the New Riverside BMP project is ideal due to its close proximity upstream of two of the Town's ongoing weekly grab sampling sites, BECY 1.5 and PBR 9. These sites are sampled every week provided that there is an adequate amount of outgoing flow. Additionally, the BMP only has two primary locations for incoming flow. This simplifies inflow sampling.

Adding four sampling locations for the BMP (NRP-IN-N and NRP-IN-S for incoming flow, NRP in the lagoon, and NRP-OUT at the lagoon's outfall) gives the Town an opportunity to measure the impact of the lagoon on water quality within the overall drainage basin at several points (see Figure 1). Construction of the lagoon began in Spring 2013 and was substantially complete in Summer 2013. The four locations were added to the Town's weekly grab samples at that time. Approximately twelve months of post-BMP installation sampling has occurred.

Volume Reduction Retrofit Project-Selection Process

The most important aspect of selecting a site for the second 319 Grant was its ability to reduce existing stormwater volume, thereby reducing fecal coliform loading. After a review of possible project sites, the Pine Ridge community became the focus area for the project. Pine Ridge offers the advantage of being within the Rose Dhu Creek watershed, a primarily developed drainage basin to the May River. The Rose Dhu Creek drainage basin has minimal opportunity for a large scale BMP for volume reduction. The primary way to reduce stormwater volume within the basin will be through small to medium-scale community retrofits.

Pine Ridge offers several factors that make it an ideal choice for a medium-scale retrofit project. It has a medium to high-density residential development pattern that is relatively compact. It also has a significant interconnected lagoon network. This is beneficial as the larger water surface area minimizes the amount of drawdown that will be required for the volume reduction design. It will be important to maintain a similar aesthetic for the lagoon network to which the community is currently accustomed. Also, it is adjacent to a significant amount of upland open space that is available for irrigation.

Once Pine Ridge was identified as the ideal retrofit community, the subdivision needed to be evaluated to determine an ideal project location that provided the Town with the best case scenario to measure its success. The chosen location should have minimal offsite contributing drainage area. This will keep irrigation system component costs to a minimum, as it will be sized only for the community drainage area, and not additional offsite flow. The irrigation withdrawal location needed to be as close to the irrigated open space as possible, again to control system component costs. Finally, the ability to set up a data collection protocol that measures the project's success is critical. All of those factors resulted in selecting two separate project locations within Pine Ridge, each with an identifiable outfall.

Volume Reduction Retrofit Project-Data Collection Protocol

Two data collection locations have been selected, one at each project outfall. The Town will measure stormwater runoff at each location. In order to accurately reflect the amount of runoff reduction that could be attributed to the retrofit, it is necessary to determine the total amount of runoff that exits each location. This requires a frequent time-step collection routine for quantifiable results. Data collection equipment will be placed in the outfall pipe of each location, which by design are always fully submerged. A Doppler velocity sensor will register the velocity of stormwater in each pipe at fifteen minute intervals. A positive reading will indicate discharge. As the pipe size is constant, multiplying the velocity times the area will yield the discharge at the time-stamp. Using an average flow between time-stamps over the life of any registered discharge event will yield the total runoff from the system for that event.

Data collection at each of the project outfalls is expected to begin in late September 2014. The two retrofit sites will not be completed until Summer 2015. Therefore, approximately ten months of baseline, pre-retrofit data will be collected at the locations. Data collection will continue post-retrofit as well. Several rain gauges are available for rainfall monitoring in the area. The Town will review storm events that occur during both the pre-retrofit and post-retrofit data collection phases, looking for similar duration and accumulation rain events. It will then evaluate the total runoff registered from the project areas for the similar events. This method should provide a metric that can be used to measure the efficacy of the reuse systems as a volume reduction tool.

RESULTS

New Riverside Stormwater BMP Sampling

As of September 10, 2014, 43 post-BMP installation weekly grab samples have been collected at New Riverside. Twenty-six sample sets included grabs of

runoff into and out of the pond. Only two samples were collected at NRP-IN-S. Therefore, very little contributing flow comes from that area. When comparing the fecal loading at NRP-IN-N to the loading at NRP-OUT, the geomean concentrations show an overall reduction of 70%. Refer to Figure 2.

Twenty-four of the weekly grab samples not only included grabs of runoff into and out of the pond, but also included a grab approximately 550 feet downstream of the project at BECY 1.5. This additional sample provided the Town with an opportunity to determine if the fecal coliform concentration reduction is maintained beyond the project's outfall. The geomean averages of the sampling points indicate a minimal overall reduction (1%) in fecal coliform concentrations downstream of the lagoon outfall. However, the sample sets do show greater variability between the non-winter months (March through November) and winter months. Non-winter months show a 14% reduction, while the limited sampling set (5 grabs) for the winter months show a 65% increase. Refer to Figure 3.

Pre- and post-project sampling results have also been compared at BECY 1.5 and the next downstream sample location, PBR 9. For this exercise, all post-project samples collected at BECY 1.5 and PBR 9 were used. Thirty-eight and 23 post-project samples have been collected at BECY 1.5 and PBR 9, respectively. One-hundred and eight samples at BECY 1.5 and 110 samples at PBR 9 were analyzed for the pre-project conditions.

Overall, both BECY 1.5 and PBR 9 show a reduction in fecal coliform levels for the post-project conditions. BECY 1.5 shows a 49% reduction, while PBR 9 shows a 9% reduction. A decrease in concentrations for the non-winter months and an increase in concentrations for the winter months show in this data set as well. While the overall reduction is encouraging, the post-project data set is small, particularly for the winter months. Refer to Figures 4 and 5.

The Town will continue to monitor the trends at BECY 1.5 and PBR 9 in the coming seasons. Although fecal coliform concentrations at BECY 1.5 recharge back to levels consistent with those in the upland runoff prior to entering the lagoon, if both BECY 1.5 and PBR 9 continue to trend downward it would indicate that the wet-detention BMP has an overall positive impact downstream of its actual location.

It is very important to note that the post-project data set is limited. Samples have been collected for only one winter season and a portion of two non-winter seasons. Additionally, some minor erosion along the pond embankments could have resulted in elevated fecal coliform concentrations during rain events. These eroded areas have been repaired and re-seeded. As samples continue to be collected, the findings will be verified.

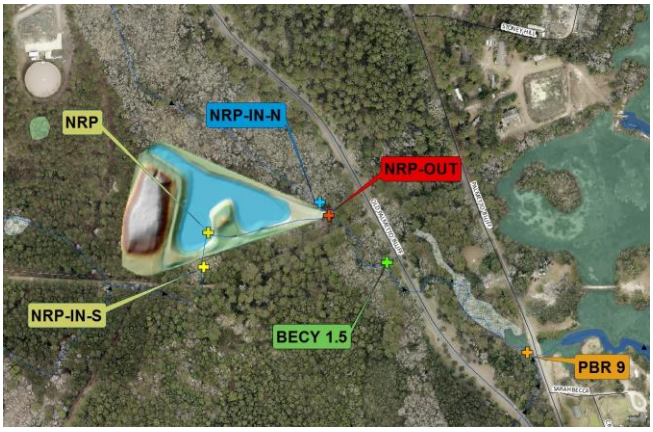

Figure 1 - New Riverside BMP Sampling Locations

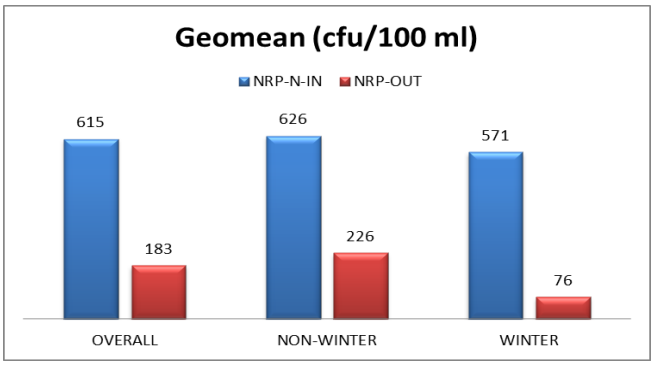

Figure 2 - New Riverside BMP In/Out Fecal Loading

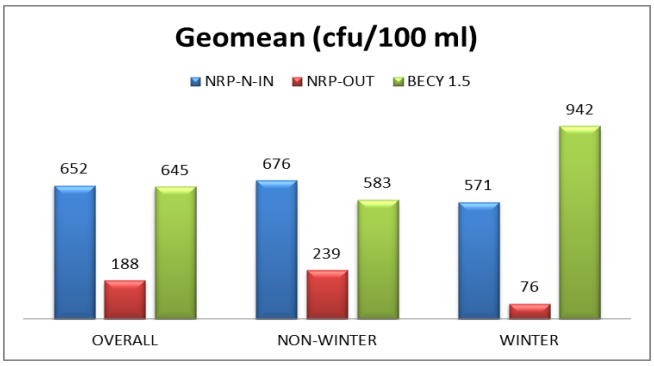

Figure 3 - Fecal Coliform Concentrations from NRP-IN-N downstream to BECY 1.5

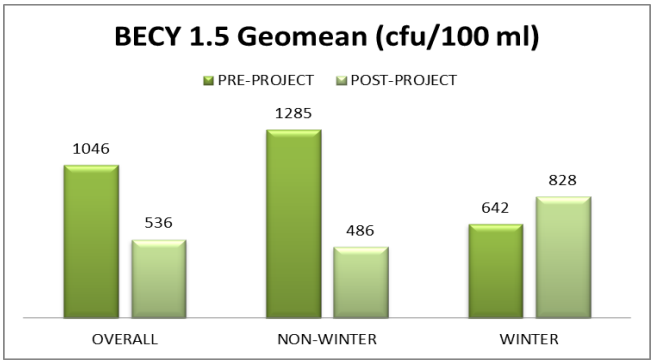

Figure 4 - BECY 1.5 Pre- and Post-Project Comparisons

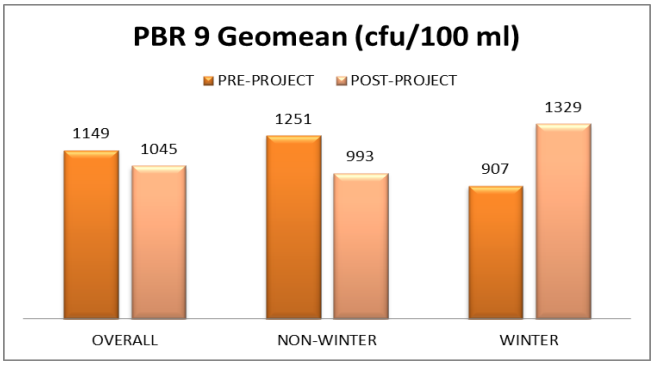

Figure 5 - PBR 9 Pre- and Post-Project Comparisons

Pine Ridge Lagoon Retrofit

Sampling is expected to begin in September 2014 for the pre-retrofit runoff volumes. The Town will continue sampling for post-retrofit conditions until an adequate amount of similar storm events exist for pre- and post-retrofit comparisons. The Town will report on those findings once the data has been analyzed.

DISCUSSION

With the implementation of extensive pre- and post-construction sampling data, the Town is building a stormwater toolbox that will provide more comprehensive information for current, and future, watershed planning. Base line data collection is a critical component of any water quality project, as is post-project data collection. Comparing the two can offer confirmation or a contradiction of the presumed benefits of a BMP technology. The New Riverside Stormwater BMP is an excellent example of how comprehensive data collection may provide greater insight of the true effectiveness of a water quality BMP.

Preliminary sampling for the New Riverside wet-detention pond indicates that, while a wet-detention pond can be effective in reducing fecal coliform concentrations at the outfall, those levels will recharge as the runoff travels through the downstream ditch system. This data supports earlier sampling results from the Town's weekly grab sampling protocol (Ahern, et. al., 2012). However, what has yet to be determined is if the downstream fecal coliform levels lower due to an unexpected, and at this point, unknown benefit of the pond. If an ancillary benefit of a wet-detention pond can be determined that positively affects downstream water quality, its viability as a BMP in certain situations will be enhanced. Continued sampling of the pond and the downstream area, as well as a detailed statistical analysis of the data, should provide that clarification.

The Town will perform a similarly comprehensive data collection protocol and analysis for the Pine Ridge Lagoon Retrofit. As the water quality project type changes from reducing fecal coliform concentrations to reducing the volume of stormwater runoff, so do the monitoring parameters. While the parameters may change, the level of planning for the monitoring protocol to measure the project's success remains the same. The Town will maintain this mindset as it plans for, and implements, future BMPs to protect and restore water quality within the May River watershed.

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