UNC Nutrient Management Study

Progress Report:
Evaluating the Long-term Nutrient Removal Performance of a Bioretention Cell in Chapel Hill, NC

Investigators:

William F. Hunt, III[1] Jeffrey P. Johnson[2]

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[1] William Neal Reynolds Distinguished University Professor and Extension Specialist, Department of Biological and Agricultural Engineering, NC State University

[2] Extension Associate, Department of Biological and Agricultural Engineering, NC State University

Background

One of the most popular stormwater practices in (sub-)urban North Carolina is bioretention. The North Carolina Department of Environmental Quality (NC DEQ) defines bioretention as, "the use of plants and soils for removal of pollutants from stormwater runoff via adsorption, filtration, sedimentation, volatilization, ion exchange, and biological decomposition". The reason bioretention cells (BRCs) are extensively used is because they are a (depressed) landscape feature; underlying the landscape is engineered filter media, and in many cases, an underdrainage system. Stormwater runoff fills the BRC bowl shaped while simultaneously infiltrating into the filter media. Runoff stored within the BRC exits through exfiltration to in-situ soils, drains downstream through an underdrainage system, or evapotranspires. BRC filter media guidance varies by state and country; however, a typical filter media consists of a mixture of predominantly sand with native soil, gravel, and an electron donor (e.g., organic matter).

While bioretention has been researched intensively to determine the most efficient design with respect to media depth, media selection, vegetative cover, drainage configuration, ponding depth, and capture volume, few long-term studies have attempted to assess the performance of older BRCs; however, previous research and design guidance for BRCs predict long-term water quality treatment. This suggests that a 15-year old BRC, such as the site being monitored in Chapel Hill, NC, could still be performing as originally designed, if not better. The purpose of the research is to see whether BRCs improve with age, which until recently had not been expected. To accomplish these goals, this study compares discharged concentrations and loads of nitrogen and phosphorus from a BRC post-construction and following 15 years of treatment.

Site Description

A bioretention cell was constructed in Chapel Hill, NC at the University Mall shopping center, located in the Jordan Lake watershed, in the Fall of 2001 to treat stormwater runoff from a 0.15-acre parking lot (Fig. 1). The BRC was designed and constructed following conventional methods including a sandy fill media and a conventional underdrain system. Following construction, the BRC was monitored for 11 months by Hunt et al. (2006) to determine nitrogen and phosphorus treatment potential. During this study, the same BRC was outfitted with monitoring equipment to calculate/measure nitrogen and phosphorus treatment after 15 years and characterize the effects of maturation on the treatment capabilities of the BRC.

Figure 1. Bioretention cell monitored in Chapel Hill, NC.

Preliminary Results

During the initial monitoring period (June 2002 – April 2003), the BRC showed promising removal of nitrogen and phosphorus species. Using event mean concentrations for runoff sampled and outflow samples, Hunt et al. (2006) were able to estimate 10-month loads for nitrogen and phosphorus species using observed runoff and outflow volumes. Estimated mass loads exported during the initial 10-month monitoring period were calculated as 0.365 kg and 0.048 kg for total nitrogen (TN) and total phosphorus (TP), respectively. From a nutrient treatment and reduction standpoint, the BRC provided a 40% reduction in TN and 65% reduction in TP. It was hypothesized at the time that low levels of carbon in the sandy fill media, a necessary constituent for nitrogen removal, would somewhat hinder the system's ability to remove nitrogen.

During the return monitoring period (February 2017 – June 2017), the BRC continued to show successful reduction of nitrogen and phosphorus species. Estimated mass loads exported from the BRC during the 5-month monitoring period were calculated as 0.215 kg and 0.013 kg for TN and TP, respectively. Removal rates, a measurement of treatment, compare mass loadings of runoff versus outflow. Reduction rates during the 5-month monitoring period were 71% for TN and 76% for TP. An initial hypothesis for the appearance of an increase in nitrogen removal is the cycling of plant material through the fill media of the BRC. Plant growth, death, and decay over the 15-year life of the BRC will have contributed the aforementioned carbon needed to the fill media to serve as a catalyst needed for the treatment of nitrogen.

Discussion

While initial results for TP and TN appear to suggest an improvement in the treatment of nutrients as the BRC has aged, they do not yet provide a full assessment of the nutrient treatment provided by the Chapel Hill BRC. Previous research has found that effluent concentrations of nitrogen and phosphorus are higher during late summer through winter. This trend can be seen in the initial data collected at the Chapel Hill BRC as effluent nitrate concentrations range from two to three times higher in the winter months (0.16 – 0.28 mg/L) than the highest effluent concentration observed during the spring (0.08 mg/L). As the initial monitoring period only covered the end of winter through the end of spring, a large portion of the seasonal effect of treatment was not captured within the initial results. Consequently, it would not be prudent to extrapolate treatment capability of the Chapel Hill BRC system to an annual basis without capturing data from an entire year.

Future Research

Continued monitoring of the site in Chapel Hill provides a unique opportunity to re-examine a practice 15 years after it was initially monitored. By providing a full seasonal picture of pollutant removal, changes in performance (for better or worse) with time can then be used in basin-wide assessments of this important stormwater practice.

References

Hunt, W. F., Jarrett, A. R. R., Smith, J. T., and Sharkey, L. J. (2006). "Evaluating Bioretention Hydrology and Nutrient Removal at Three Field Sites in North Carolina." *Journal of Irrigation and Drainage Engineering*, 132(6), 600–608.