Nutrient Analysis of Beckett Ridge Water Quality Basin

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1.1 Abstract

In an effort to meet water quality requirements and study stormwater quality structures, Butler Soil and Water Conservation District collaborated with partnering organizations to transform a concrete-lined stormwater detention basin into a 1.1 acre wetland to capture stormwater runoff in the Beckett Ridge subdivision located in the Upper Mill Creek Watershed in West Chester, Ohio. Since the completion of the Beckett Ridge Water Quality Basin, water samples were collected from the inflow, outflow pool, upstream and downstream once per month for the analysis of nutrient levels. Inflow and outflow samples have also been collected from a nearby concrete-lined stormwater detention basin, referred to as the Control Basin. To determine the efficiency of the alterations, the 2007-2011 nutrient data were analyzed and compared for each basin. Using the data gathered from samples immediately after the Water Quality Basin was completed in 2006, a year to year nutrient level analysis was conducted from 2006 until 2011.

Nutrient Level Comparison between the Water Quality Basin and Control Basin

2.1 Introduction

It was expected that a significant decrease in nitrates would occur from all three inflows to the outflow pool at the Water Quality Basin and not the Control Basin. It was expected that the phosphate levels would increase if the water quality structure is functioning properly since the phosphates are being trapped in the outflow pool. Using the results of a Student's t-test analysis, it can be inferred that there was a significant decrease in nitrate levels from the south (A), middle (B), and north (C) inflows to the outflow pool of the Water Quality Basin. There was a statistically significant increase in phosphates from inflows A and C to the outflow pool at the Water Quality Basin. Based on the t-test results from the Control Basin, there are no statistically significant differences between the inflow and the outflow pool in phosphate levels or nitrate levels. The results support the hypothesis that there will be a significant decrease in nitrate levels from the inflow to the outflow pool for the Water Quality Basin. The results also support the hypothesis that the phosphates would increase in the outflow pool compared to the inflow. The hypothesis that there will be no significant decrease in nutrient levels at the Control Basin is supported by these results.

3.1 Analysis

3.1.1 Nitrates

Based on the results of a Student's t-test and assuming equal variances with a 95% confidence interval, it can be concluded that the level of nitrates in the Beckett Ridge Water Quality Basin

decreased significantly from inflows A, B, and C to the outflow pool. The following statistical values show the significance level between the inflow and the outflow pool of each of the three inflows. There is a north (A), middle (B), and south inflow (C), and one outflow pool which trap the water and sediments. As shown in figure 1, (P (inflow A)) = 0.0004, M (inflow A) = 1.98, (P (inflow B) = 0.0263, M (inflow B) = 1.44, (P (inflow C) = 0.002, M (inflow C) = 1.79. The mean of the outflow pool is 0.53. The samples used in the analysis were taken every second Saturday of each month from 2007 until 2011. When analyzing the data from the nearby concrete-lined control basin, there was no significant decrease in nitrates from the inflow to the outflow, as shown in figure 2, (P = 0.8865, M (inflow) = 1.39, M (outflow) = 1.35). Using these results, an inference can be made that the alterations made to build the constructed wetland are more efficient at decreasing nitrate loads than the concrete-lined basin in the same suburban area. Though sufficient data was not collected from the concrete-lined stormwater detention basin that the wetland replaced, using the Control Basin in order to run a comparative analysis, provides evidence to support the hypothesis that the alterations made to the previous detention basin may increase the effectiveness of reducing nitrates that are being released into Mill Creek from the suburban area of Beckett Ridge.

Figure 1. Average nitrate levels for the south inflow and outflow pool of the Beckett Ridge Water Quality Basin from 2007-2011.

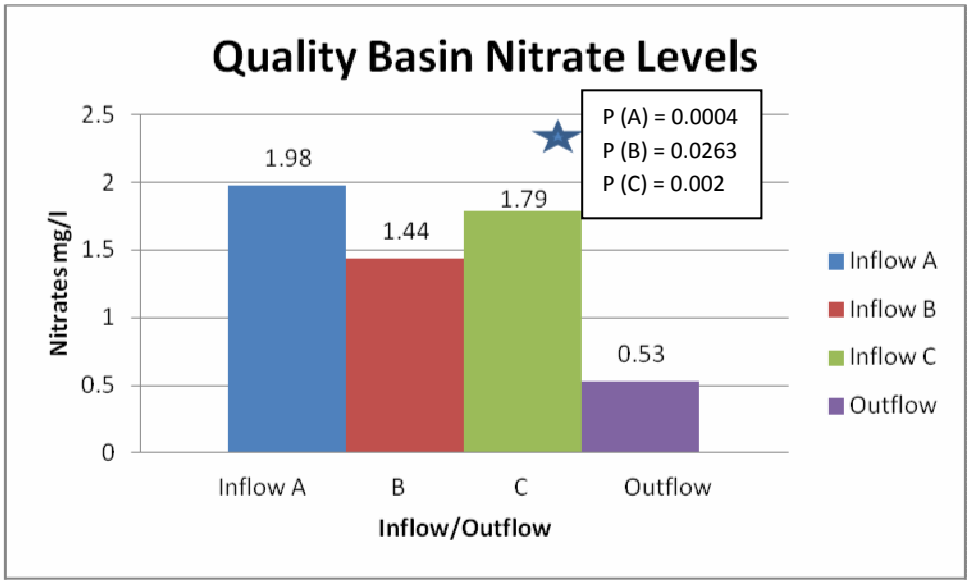
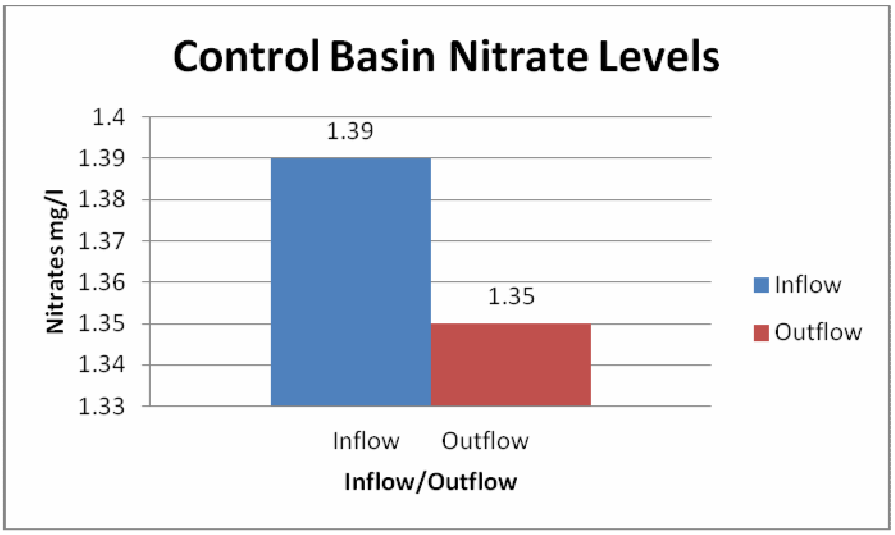


Figure 2. Average nitrate levels for the inflow and outflow of the Control Basin from 2007-2011.



3.1.2 Phosphates

Using the same t-test analysis for the phosphate levels as the nitrates, a statistically significant increase in phosphates occurred from inflows A and C to the outflow pool at the Water Quality Basin, as shown in figure 3, (P (A)) = 0.0137, M (A) = 0.35, (P (C)) = 0.0093, M (C) = 0.34, M(outflow) = 0.72). There was a non-significant increase in phosphate levels between inflow B and the outflow pool. The level of phosphates show a non-significant increase at the Control basin from the inflow to the outflow, see figure 4, (P = 0.220, M (inflow) = 0.39, M (outflow) = 0.56).

Figure 3. Average phosphate levels from the inflow to the outflow pool at the Beckett Ridge Water Quality Basin from 2007-2011.

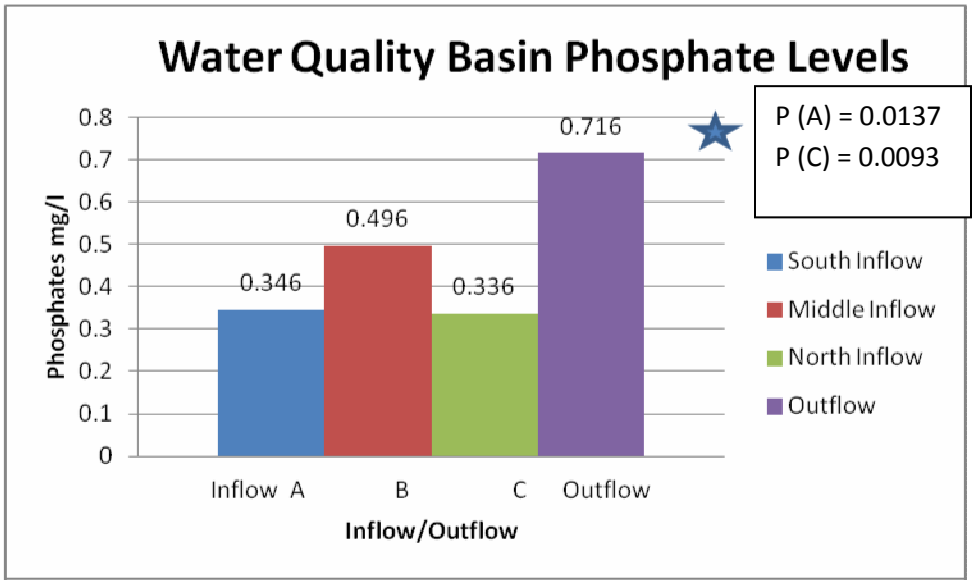
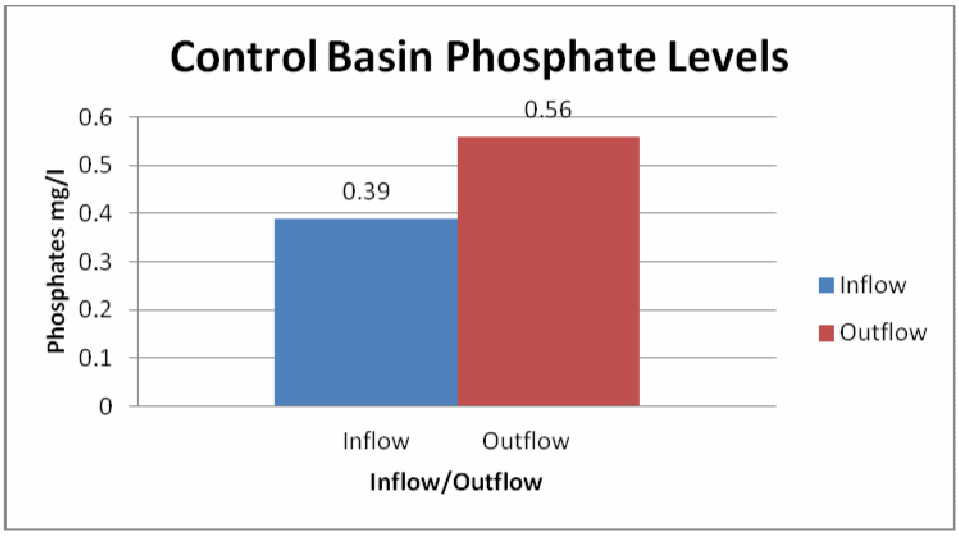


Figure 4. Average phosphate levels from the inflow to the outflow at Control Basin from 2007-2011.



4.1 Discussion

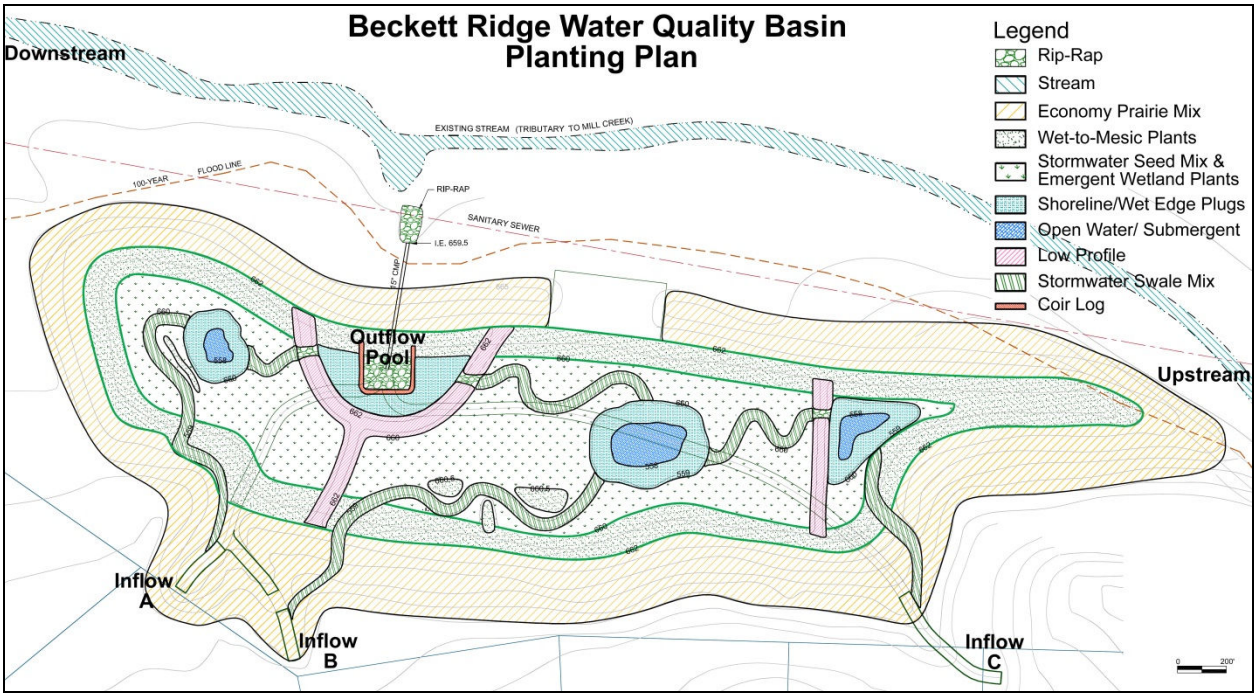
The alterations that possibly contribute to a nitrate reduction include the installation of various plants and expanding the flow area from a narrow concrete path to a large area of vegetation. The

plants that were installed may aid in the decreasing of nitrates in the outflow by utilizing the nitrates that are entering the inflow of the basin, thus decreasing the nitrate levels in the outflow. Some of plants installed at the basin include, Swamp Milkweed, New England Aster, Blue Flag Iris, and Broad Leaf Arrowhead. Wetland plants take up the nitrates that enter the stream to undergo de-nitrification or they will absorb the nutrient. Since nitrates are more readily available to plants than phosphates, it would be expected to see a decrease in nitrates since the plants line the inflows.

Another factor that may contribute to the nitrate reduction could be the increase in flow area from a narrow concrete path to a large vegetated area, allowing the water to stop flowing before it reaches the stream. This enables the settling of sediments and gives the plants time to absorb the nitrates before they reach the outflow pool. However, without each of these factors studied independently it is difficult to link the nitrate reduction to one specific working of the constructed wetland.

An increase in phosphates showing at the outflow pool of the Water Quality Basin is evidence that that water quality structure is functioning as intended. The basin is designed so that sediments are trapped in an outflow collection pool without actually exiting the basin to reach the stream. The basin planting plan is shown in Figure 5, which illustrates the three inflows, the outflow collection pool and the previously existing concrete lined detention basin. Samples collected from the outflow pool are showing an increase in phosphates which indicates that the sediments that are entering the basin through the three inflows are being trapped. This allows the sediments to settle out of the water.

Figure 5.



4.1.1 Summary

Using the data collected from the Beckett Ridge Water Quality Basin and the Control Basin, a statistically significant decrease in nitrates occurred from the south, middle, and north inflows of the Water Quality Basin to the outflow pool. Because each of the parts of the wetland were not studied independently, it can only be inferred that the alterations, such as the added wetland vegetation or increase in flow area, made to the Beckett Ridge Water Quality Basin are efficient at filtering nitrates from the stormwater runoff. In comparison, there was no significant decrease in nitrates at the Control Basin. The phosphates increased from the inflow to the outflow pool at the Water Quality Basin and the outflow of the Control Basin. There was a statistically significant increase in phosphates from inflows A and C to the outflow pool of the Water Quality Basin which indicates that the sediments are in fact being trapped in the collection pool, allowing them to settle and not reach the adjacent stream. There was also an increase in phosphates from inflow B to the outflow pool, but not significant. The increase of phosphates at the Control Basin showed to be non-significant. However, the Control Basin is designed to allow the water to flow directly to the stream without allowing the sediments to settle out like the Water Quality Basin.

Upstream and Downstream Nutrient Level Analysis

5.1 Introduction

Decreasing the amount of stormwater pollutants that were being discharged from the Beckett Ridge area into Mill Creek was a reason for constructing the Beckett Ridge Water Quality Basin. To determine if the basin is effectively doing so, nutrient levels from upstream of the basin and nutrient levels from downstream of the basin need to be monitored to determine if the amount of nutrients upstream of the basin are increasing or decreasing with time. Using the upstream and downstream nutrient data that was collected in 2006, after completion of the Water Quality Basin, a year to year analysis was conducted to determine if the nutrient levels were showing an overall decrease from 2006 to 2011. There were three months of data collected and analyzed after the basin was completed to represent 2006, so three similar months were chosen out of each of the following five years to do the comparison.

6.1 Analysis

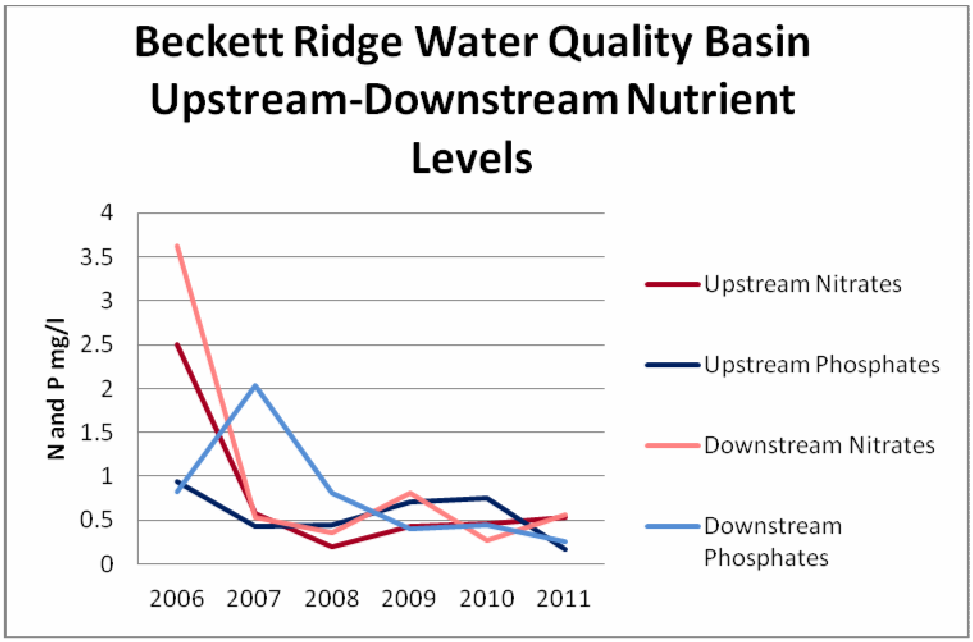
The outcome of the analysis for upstream and downstream nutrient levels not only show an overall decrease in both nitrates and phosphates from 2006 to 2011, but also a closing in the range of both nitrates and phosphates from upstream to downstream. In 2006 the average downstream nitrate level was 3.63 mg/l whereas the 2006 average upstream nitrate level was 2.50 mg/l, making the 2006 difference from upstream to downstream 1.13. In 2011, the average downstream nitrate level was 0.56 mg/l. The average upstream nitrate level was 0.53 mg/l, a difference of .03 from the upstream to the downstream. The average upstream phosphate level was 0.95 mg/l in 2006 and 0.17 mg/l in 2011. The average downstream phosphate level was 0.83 mg/l in 2006 and 0.26 mg/l in 2011.

6.1.1 Discussion

In order to further assess the efficiency of the constructed wetland at the Water Quality Basin, the upstream and downstream nutrient levels were analyzed from 2006, when the constructed wetland was completed, until 2011. The graph in figure 5 shows an overall decrease in both phosphates and nitrates. From the closing in the difference, an inference can be made that the components of the constructed wetland, either individually or collectively, are effective at decreasing the amount of nutrients being released into Mill Creek from this portion of the Beckett Ridge neighborhood compared to that of a concrete-lined storm water detention basin. The level of the nitrates in 2006 were 3.63 mg/l for downstream and 2.50 mg/l for upstream. The Wadeable Stream guidelines for nitrates fall between 0.05 and 0.5 mg/l and 0.5 mg/l. By 2011 the nitrate levels decreased to 0.56 mg/l for downstream and 0.53 mg/l for upstream. The phosphate levels in 2011 decreased to 0.17 for upstream and 0.26 for downstream. The EPA recommended guidelines for phosphate levels is between 0.1 and 0.25 mg/l. The decrease in downstream and upstream phosphate levels from 2006 to 2011 brought the levels closer to the EPA guideline range.

In 2007, there was a spike in downstream phosphates at the Water Quality Basin. This may have been caused when the site was cleared of vegetation to build the wetland and replant native vegetation. Though the wetland construction was completed in the summer of 2006, the replanted vegetation was still in the beginning stages of establishment, allowing more sediment to reach the stream than if there were established vegetation at the site. The components that make up the constructed wetland in the suburban area of Beckett Ridge were not studied independently from the time it was constructed. Therefore, the results of these analyses only provide evidence toward the hypothesis that the alterations made to the previously concrete lined stormwater detention basin, whether it be the vegetation or the increase in flow area, make the Beckett Ridge Water Quality Basin more effective than before.

Figure 6. Average upstream and downstream nutrient levels from 2006 until 2011.



7.1 Summary

From 2006 to 2011 average nutrient levels decreased for both upstream and downstream of the Water Quality Basin. In 2006 the nitrate difference between the upstream and downstream levels was a greater than the difference in 2011. Though the difference in the phosphate levels from upstream to downstream do not change drastically from 2006 to 2011, there was still an overall decrease in phosphates for both the upstream and downstream. This supports the inference that the alterations made to the Water Quality Basin, again, individually or collectively, are more effective than the concrete-lined detention basin at filtering the nitrates and phosphates from the stormwater runoff before entering Mill Creek.