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The Effectiveness of a Combination Weep Berm - Grass Filter Control System for Reducing Fecal Coliforms and Nutrients from Surface Runoff

John R. Barnett

University of Kentucky, 128 CE Barnhart Building Lexington, KY 40546

Richard C. Warner

University of Kentucky, 128 CE Barnhart Building Lexington, KY 40546

Dwayne R. Edwards

University of Kentucky, 128 CE Barnhart Building Lexington, KY 40546

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Abstract. *Control of nonpoint source pollution is essential for improving water quality. The Environmental Protection Agency reports that the three primary pollutants to the nation's waterways are bacteria, nutrients, and sediment. Runoff from grazed pastures and manure applied land often contains high concentrations of fecal coliforms and nutrients. To control and treat this runoff, a low-cost, highly effective control system was developed and tested at the University of Kentucky's Maine Chance farm. The control system consisted of a combination weep berm and vegetative grass filter. Cattle manure was applied up-gradient of the BMP prior to the first experiment. A weekly rainfall simulation was conducted for three consecutive weeks on three replicate plots. Test results concluded that the control system was able to reduced fecal coliforms (99%), total nitrogen (87%), and total phosphorus (44%). Results indicate that the control system is an effective, low-cost, low maintenance practice for reducing nonpoint source pollution to waterways.*

Keywords. Weep Berm, Vegetative Grass Filter, Fecal Coliforms, Nutrients, Surface Runoff

Introduction

The National Water Quality Inventory: 2000 Report stated that 39% of rivers and 45% of lakes surveyed across the United States had pollution problems, primarily due to high levels of bacteria, nutrients, and sediments. The US EPA has associated these pollutants with agricultural activities and hydrologic modifications (USEPA, 2000).

To effectively meet the goals of the Clean Water Act, non-point source pollutants must be properly managed. Best Management Practices (BMPs), such as grass filter strips, have been shown to improve water quality; however, a 4.5 m grass filter strip alone cannot sufficiently improve runoff to meet water quality standards (Coyne et al., 1998). Additional BMP practices are necessary to sufficiently improve water quality. The addition of a simple structure, such as a weep berm, may prove to be effective in reducing runoff contaminants.

Grass Filters

Grass filter strips have been studied extensively for their effectiveness in improving the water quality in runoff. The parameters identified to impact grass filter performance are vegetation type and height, terrain area and slope, soil type and infiltration rate, rainfall intensity and duration, and antecedent moisture conditions (Deletic, 2001). A study by Gharabaghi, et al. (2001) suggests that the first five meters of a grass filter are the most efficient, providing 95% of the removal of aggregates larger than forty microns. A 4.5 m filter strip can reduce sediment concentrations by 96%, fecal coliform concentrations by 75% and fecal streptococci by 68% (Coyne, 1998). Dillaha et al. (1989) found that a 4.6 m strip reduced total suspended solids by 70%, phosphorus by 61%, and nitrogen by 54%. Although the pollutant reduction within a grass filter is significant, water quality standards may still be exceeded in the effluent.

Weep Berm

A weep berm is a small berm constructed perpendicular to the direction of runoff that performs as a temporary detention structure.

Warner (2001) utilized weep berms for a construction site erosion control project in Alpharetta, Georgia and observed a 98% reduction in peak discharge as well as a 92% reduction in peak sediment concentration. It was noted that runoff produced by small, highly intense rainfall events were detained by the berm and a large reduction in sediment load was observed.

Objectives

The objective of this project was to investigate the overall effectiveness of the combination weep berm - grass filter control system in reducing effluent concentrations of fecal coliforms and nutrients. The project also evaluated the hydraulic performance of the control system.

Methods

The study was conducted at the University of Kentucky's Main Chance Farm located in Lexington, Kentucky. The predominate soil type was Maury Silt Loam. Three plots measuring 12.2 m in length and 2.4 m in width (Figure 1) were used. The average slope of the plots was 4% with a cross-slope of 1.3%. Each plot was bound by rust proof metal borders to insure that all runoff was contained in the desired area. Down-gradient of the grass filter, a wooden collection gutter intercepted surface runoff.

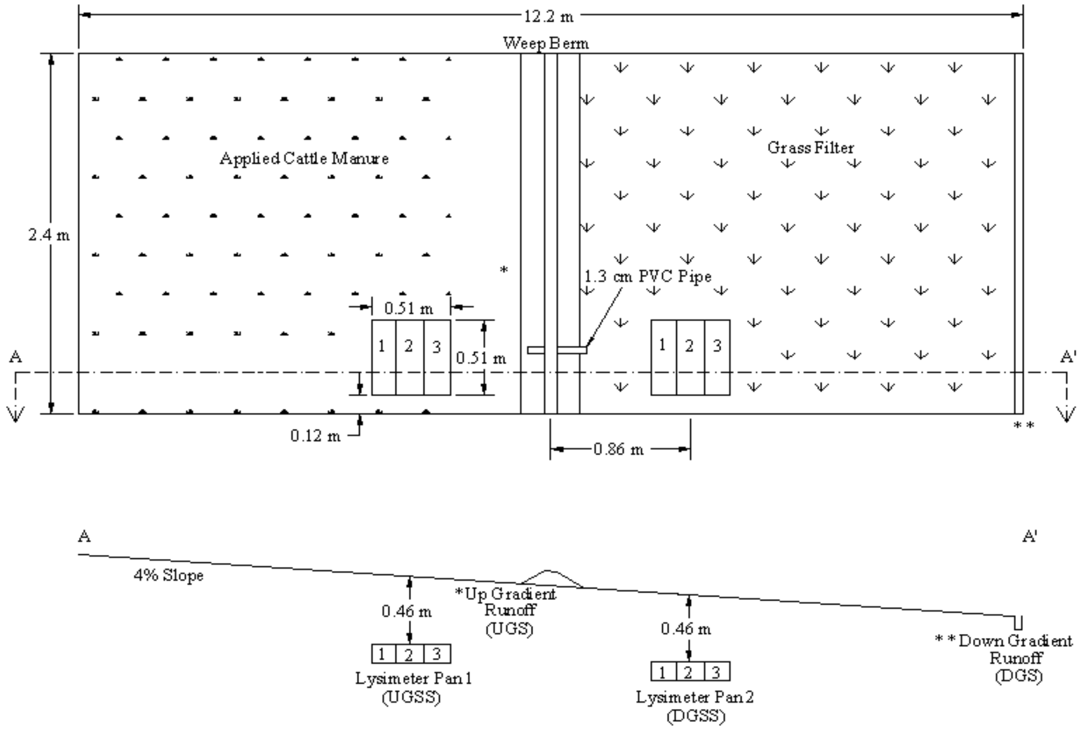

Figure 1 Plot Plan and Section Views

A weep berm 14 cm in height, with 2:1 side slopes, was constructed in the middle of each plot. The berm was constructed with moderate compaction using loamy topsoil. Fescue was sowed on the berm and covered with a coconut mat to promote growth and reduce the potential of erosion. A 12.7 mm diameter straight PVC pipe was installed through the berm, at an invert height of 8.9 cm, to facilitate dewatering at high flows. The weep berm and the outlet pipe were surveyed and an elevation-discharge relationship determined.

The desired rainfall rates and intensities were produced with two 2.7 m by 6.4 m rainfall simulators. Lexington municipal water served as the source for the rainfall. Since fecal coliforms were being monitored, it was necessary to eliminate the chlorine from the municipal water. This was accomplished by using 10 mg of anhydrous sodium thiosulfate per liter of source water.

Prior to each experiment, soil samples were collected from each plot above and below the berm to determine moisture content. Cattle manure was applied once at a rate of 0.94 kg/m^2 to the upper 5.9 m of the plots following the background assessment and just prior to the first simulation. The manure was distributed evenly throughout the plots.

Rainfall was initially applied to the plots at an intensity of 5.1 cm per hour for a 20 minute duration. The intensity was then increased to 7.6 cm per hour for approximately 40 minutes. If no substantial runoff was detained by the berm, the intensity was increased to 10.2 cm per hour and maintained until discharge through the weep berm outlet occurred at full pipe flow for approximately 10 minutes.

Three runoff samples were taken uniformly throughout each simulation. The first sample was collected when runoff initially began, the second approximately twenty minutes later, and the third at the end of the experiment. Samples were collected at two locations: one from the backwater of the weep berm and the other down-gradient of the grass filter. A volume weighted composite sample was created from the samples collected at each sampling location.

A total of four simulations were conducted consisting of an initial background assessment and three replicated experiments. The initial background assessment was conducted to determine the existing level of contamination. Prior to the first experiment cattle manure was applied to each plot; therefore, the first simulation mimicked continuously grazed cattle pastures. The second and the third simulations were conducted in the same manner as the first; however, no additional manure was applied. These experiments thus simulated rotational grazing practices in which the cattle had been removed from the pasture.

Parameters monitored during the study included: fecal coliforms, total nitrogen, and total phosphorous.

Experimental Results

Surface flow data was measured to assess the control system's hydraulic performance. Rainfall up-gradient of the berm was detained by the berm, infiltrated, evaporated, evapotranspirated, or discharged through the straight pipe at high stages. Stage data was recorded to determine both the volume retained up-gradient of the berm and the flow dewatered through the straight pipe located through the weep berm. The runoff rate was also measured down-gradient of the grass filter.

Fecal bacteria are naturally occurring bacteria found in animal excrement; therefore, a large increase in fecal coliforms was observed following the application of cattle manure. After the initial application of the cattle manure, the fecal coliform count increased to an overall average of 2.3×10^5 counts per 100mL.

Comparing the runoff up-gradient of the berm and the runoff down-gradient of the grass filter, high reduction rates were observed. The control system effectively reduced fecal coliform counts 99%, 64%, and 61% during each sequential rainfall simulation. After the third rainfall experiment, the average fecal coliforms exiting the weep berm – grass filter control system was 340 counts per 100mL illustrating nearly a 1,000 times decrease in concentration compared to the average of the first rainfall simulation, which was 230,000 counts per 100mL. Figure 2 illustrates the average fecal coliform concentrations up-gradient and down-gradient of the control system and the overall reduction achieved by the control system. Table 1 lists the averaged fecal coliform concentrations reported from each experiment.

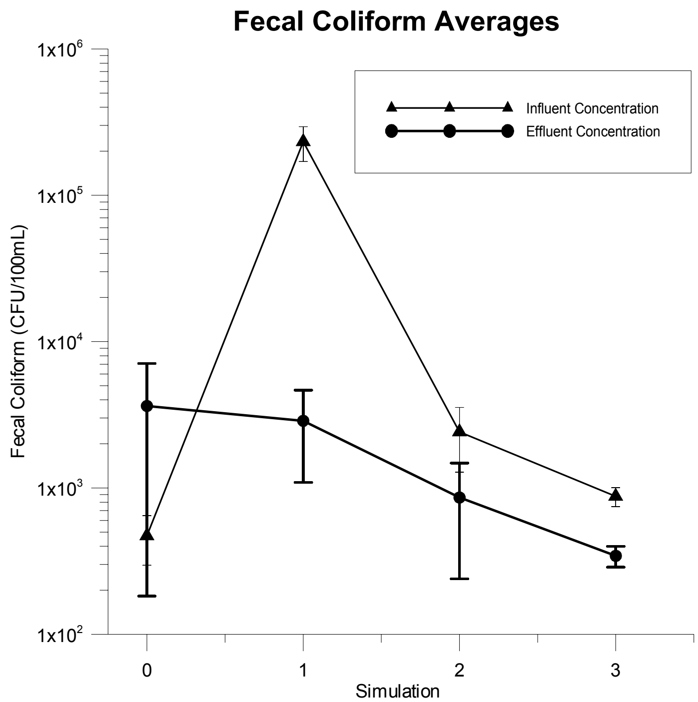

Figure 2. Fecal Coliform Concentrations

Table 1. Fecal Coliform Data

Run	Up-Gradient Concentration (CFU/100mL)	Down-Gradient Concentration (CFU/100mL)	Overall Reduction
1	2.9×10^5	2.9×10^3	98.8%
2	2.4×10^3	8.6×10^2	64.3%
3	8.8×10^2	3.4×10^2	60.8%

Nutrient reductions are listed in Table 2 and graphically displayed in Figure 3. The weep berm - grass filter control system was highly effective in reducing total phosphorous and total nitrogen by 44% and 87%, respectively during the first rainfall simulation. As anticipated, the nutrient data illustrated a diminishing incremental reduction in efficiency for the second and third experiments due to a large reduction observed during the first experiment. It is important to note that the weep berm – grass filter control system achieved a high reduction for the rainfall simulation immediately following application of waste material; therefore, the potential for off-site pollution is largely eliminated.

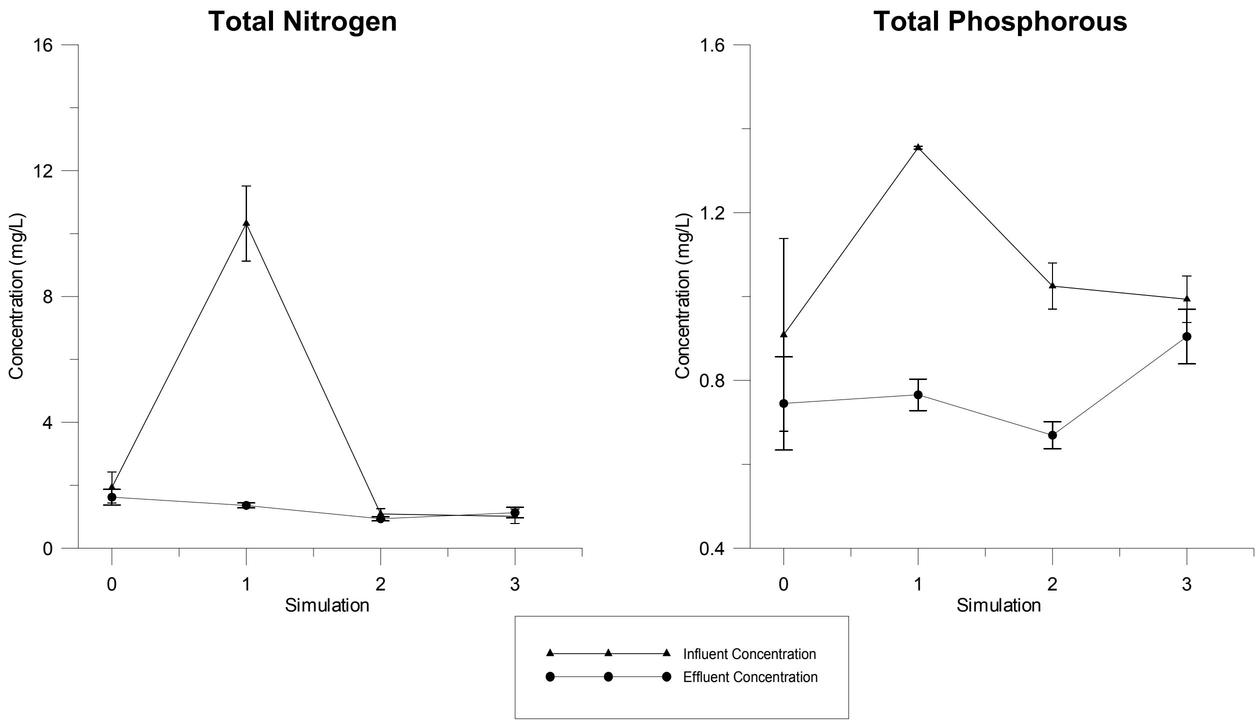

Figure 3. Runoff Nutrient Concentrations

Table 2. Nutrient Reductions

Total Nitrogen			
Run	**Up-Gradient Concentration (mg/L)**	**Down-Gradient Concentration (mg/L)**	**Overall Reduction**
1	10.32	1.13	86.8%
2	1.09	0.94	13.9%
3	1.02	1.36	0.0%
Total Phosphorous			
Run	**Up-Gradient Concentration (mg/L)**	**Down-Gradient Concentration (mg/L)**	**Overall Reduction**
1	1.35	0.77	43.5%
2	1.03	0.67	34.7%
3	0.99	0.91	9.0%

Conclusion

The effectiveness of a combination weep berm – grass filter control system was field-tested using three replicate plots subjected to three rainfall events. The three plots were instrumented to enable monitoring of surface runoff up-gradient of the weep berm and down-gradient of the grass filter. In this study, the control system was highly effective in reducing critical non-point source pollutants. Overall, the control system performed well hydraulically and improved effluent water quality, even under worst-case conditions. The control system achieved average reductions of fecal coliforms, total nitrogen, and total phosphorous 99%, 87%, and 44%, respectively.

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