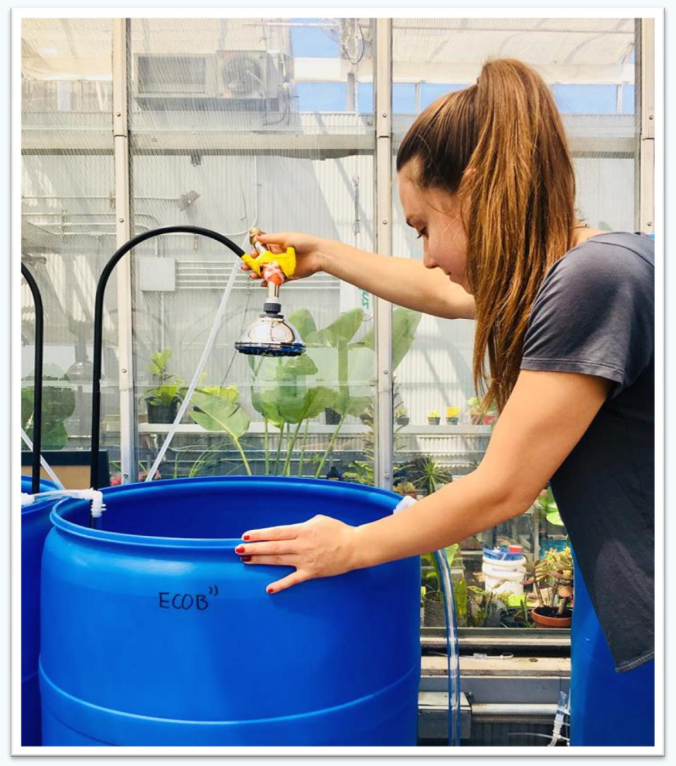
A New Green Infrastructure Approach for Addressing Water Quality Challenges: A Comparison Study of Traditional Flow Through Systems and Hybrid ecoWEIR Technology for Both Planted and Non-Planted Systems

Annie Block[1], Nia Rene[2], Dr. Brianne Smith[3] and Dr. Jennifer Cherrier[4]

1. UWIN URP 2018 student at Columbia University (aib2124@columbia.edu) 2. Brooklyn College – City University of New York

ABSTRACT



Non-point source nutrient loading from surface and subsurface runoff is one of the leading causes of impairment to United States waterways. This nutrient loading directly impacts the health of aquatic ecosystems resulting in fish kills, dead zones and harmful algal blooms. In addition, these runoff related impacts also affect human health and local and national economies (ie. commercial fishing and tourism). Green infrastructure (GI) has been gaining recognition as a cost effective approach for addressing runoff related pollutant loading. However, the design of many GI systems is passive and water retention and nutrient removal efficiencies have been shown to be highly variable. A new hybrid system (ecoWEIR) activates GI to control retention times and soil conditions and therefore minimizes this variability. The goal of this study was to gain background information about these two forms of GI by comparing ecoWEIR to current flow through system outflows in planted and non-planted systems. Simulated rain events were carried out, and outflow samples were collected to analyze phosphorus (PO4), total nitrogen (TN), and dissolved organic carbon (DOC) concentrations as well as fecal coliform. Our results showed higher PO4 removal in both planted and non-planted ecoWEIR systems but highest removal was observed in the planted systems. The addition of grass significantly increased the outflow concentrations of both DOC and TN which we attribute to soil manure amendments. Despite these increases, we still observed slightly greater removal of both in ecoWEIR systems. While ecoWEIR appeared to be more effective at nutrient removal than flow through systems, further simulated rain event studies should be carried out once system plant/microbial communities have matured. With increased urbanization and projected climate change, non-point source runoff will be more acute. It is therefore important to find new technologies like ecoWEIR to enhance the performance of GI systems to address these challenges.

INTRODUCTION

- Many of the coastal waters throughout the United States are negatively impacted by non-point source nutrient loading. Sources of non-point source nutrient runoff:
  - Surface flows (ie: storm water runoff and fertilizer)
  - Subsurface flows (ie: septic)
- Nutrient loading affects the aquatic ecosystem health: harmful algal blooms, hypoxic zones & habitat loss
- Impaired aquatic ecosystem health affects human health and economy:
  - Contaminates shellfish and drinking water supplies
  - $10 million lost annually in commercial fishing, and $1 billion lost in tourism

Figure 1: Harmful algal bloom off the shore of San Diego, CA. Image taken from NOAA

Figure 2: Image showing the effects of nutrient loading on aquatic life. Image taken from NOAA

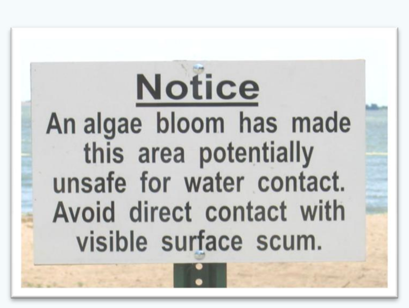


Figure 3: Beach closure sign. Image taken from USGS

- Green infrastructure is one solution to help solve nutrient loading
  - increases the natural absorption of water by intercepting and treating runoff
- However, the design of many GI systems is passive and pollutant removal is variable:
  - cannot control water retention times and soil conditions
- A new hybrid system (ecoWEIR, patented) has been developed to help combat these limitations:
  - allows for the control of water retention time and soil conditions
  - creates and maintains a 2-layered system which allows for the processes of nitrification and denitrification to occur through both aerobic and anaerobic environments respectively (fig 4)
- No research has been done to date on the background nutrient concentrations of these systems

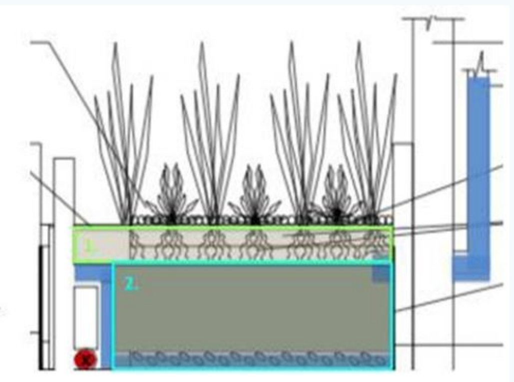


Figure 4: ecoWEIR design showing the two layered system that allows for both nitrification (layer 1) and denitrification (layer 2)

GOAL, OBJECTIVE & RESEARCH QUESTION

Goal: To evaluate background concentrations of potential pollutants in both flow through and ecoWEIR technology systems and to asses how each can remove these pollutants (ie: phosphorus, total nitrogen, dissolved organic carbon and fecal coliform)

Objectives:

1. Conduct controlled mesocosm studies of both the flow through and ecoWEIR systems to compare and contrast how these two systems differ from one another in outflow pollutant concentrations
2. Understand how this changes using both planted and non-planted systems

Research Questions:

1. What background concentrations of pollutants (ie: PO4, TN, DOC and fecal coliform) do each of these systems potentially contribute to receiving water bodies?
2. How might planted systems change these background concentrations?

METHODS

Experimental Setup

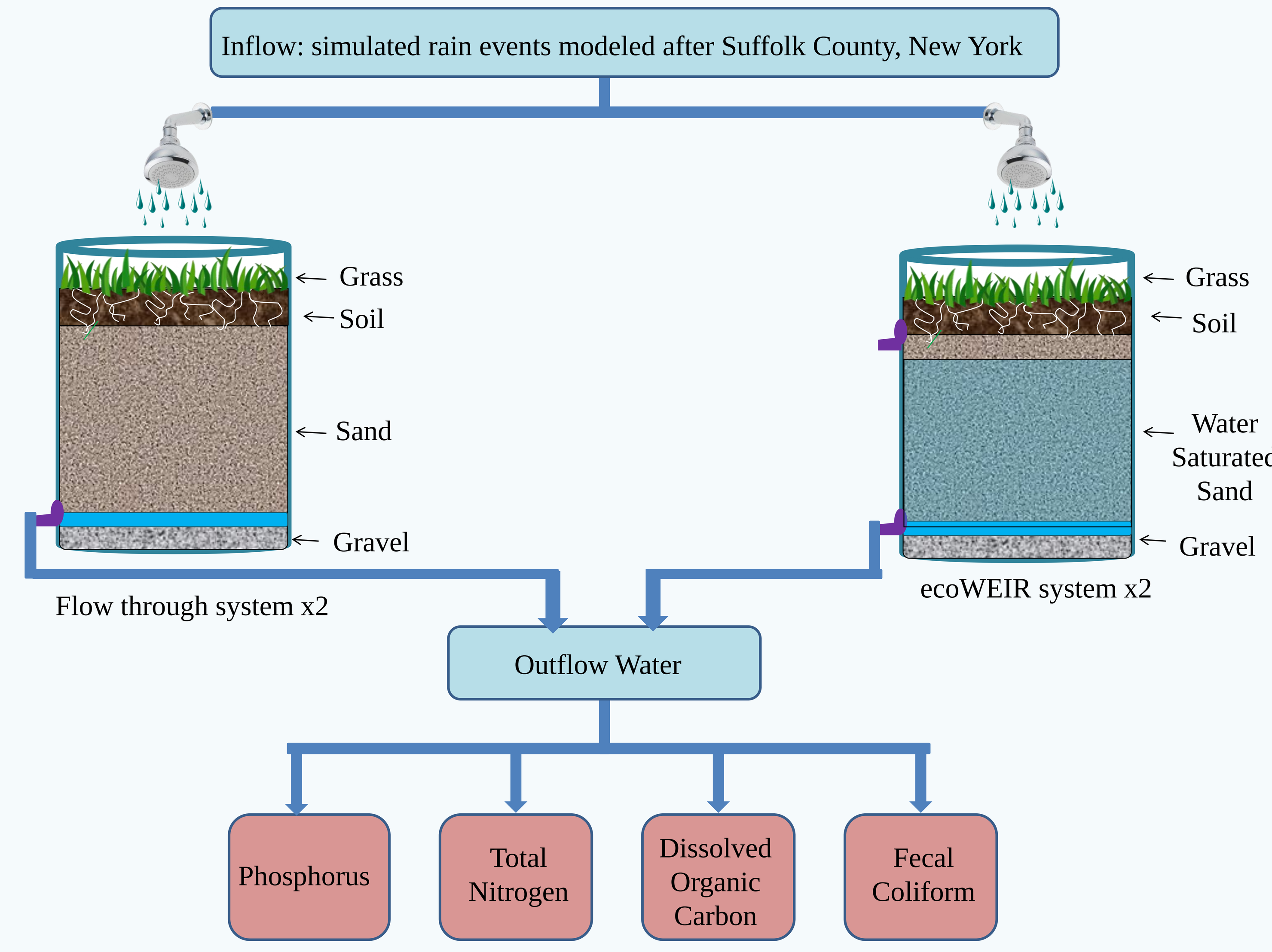


Figure 5: Experimental setup of each rain event. Each treatment was tested in duplicate. During each rain event, 5 gallons of water were added to each system. Water drained immediately through the flow through system, and outflow samples were collected. After 48 hours, outflow samples were taken from ecoWEIR. Flow through and ecoWEIR treated outflow samples were analyzed for PO4, TN, DOC and fecal coliform using standard published methods. This whole process was repeated in both planted and non-planted systems.

RESULTS

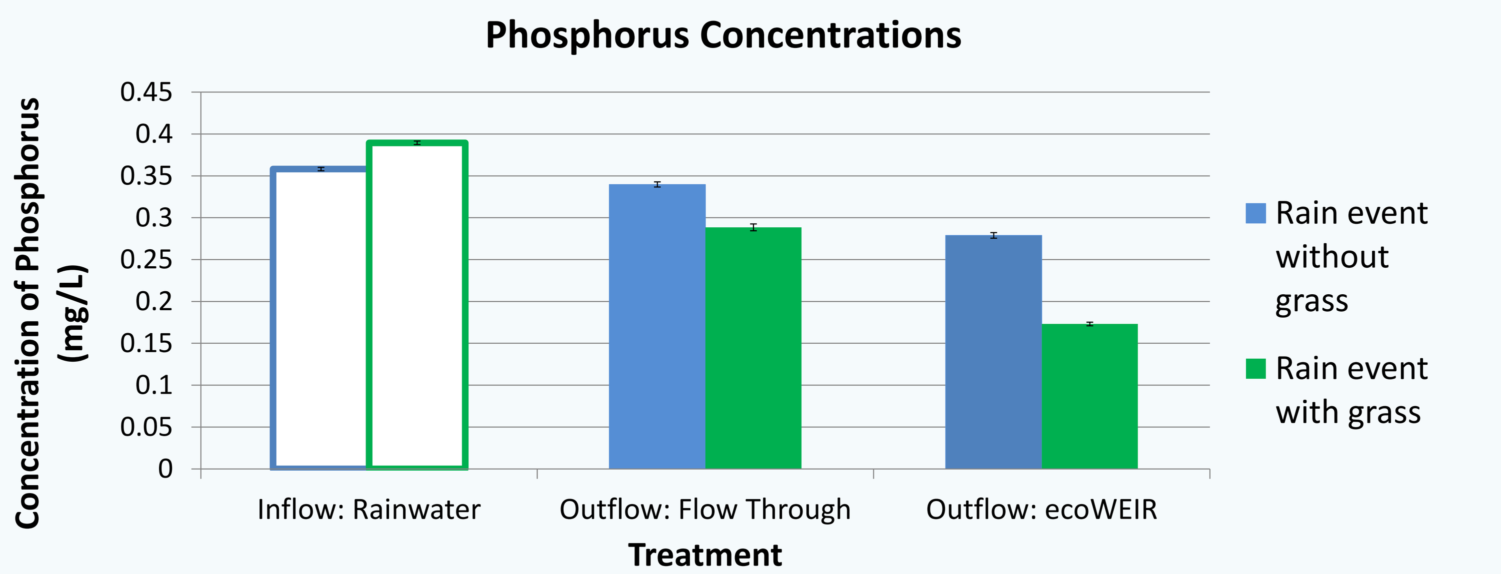


Figure 6: Phosphorus concentrations of the inflow and outflow samples in both planted and non-planted systems. ecoWEIR is more efficient at removing PO4 than flow through systems. Neither system is a source of PO4; rather, PO4 is present in NYC treated tap water. Error bars represent +/- 2 SD of duplicate samples.

RESULTS CONTINUED

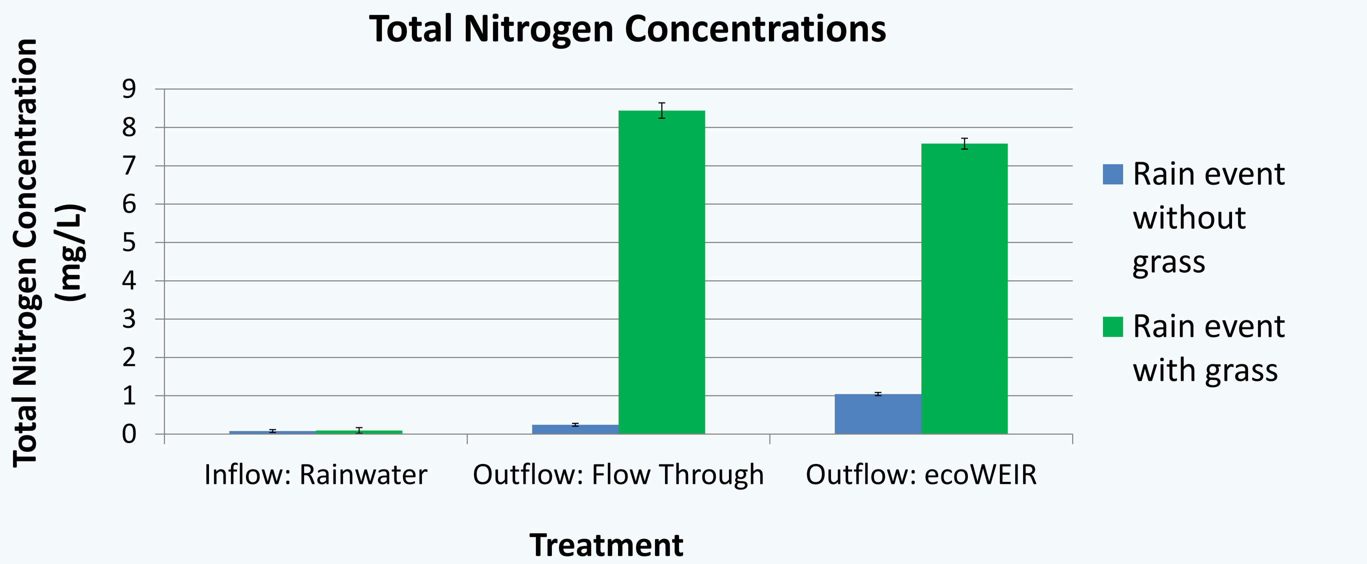


Figure 8: Total nitrogen concentrations of the outflow and inflow samples in both planted and non-planted systems. The addition of grass and soil significantly increase TN concentrations in both system outflows. Error bars represent +/- 2 SD of duplicate samples.

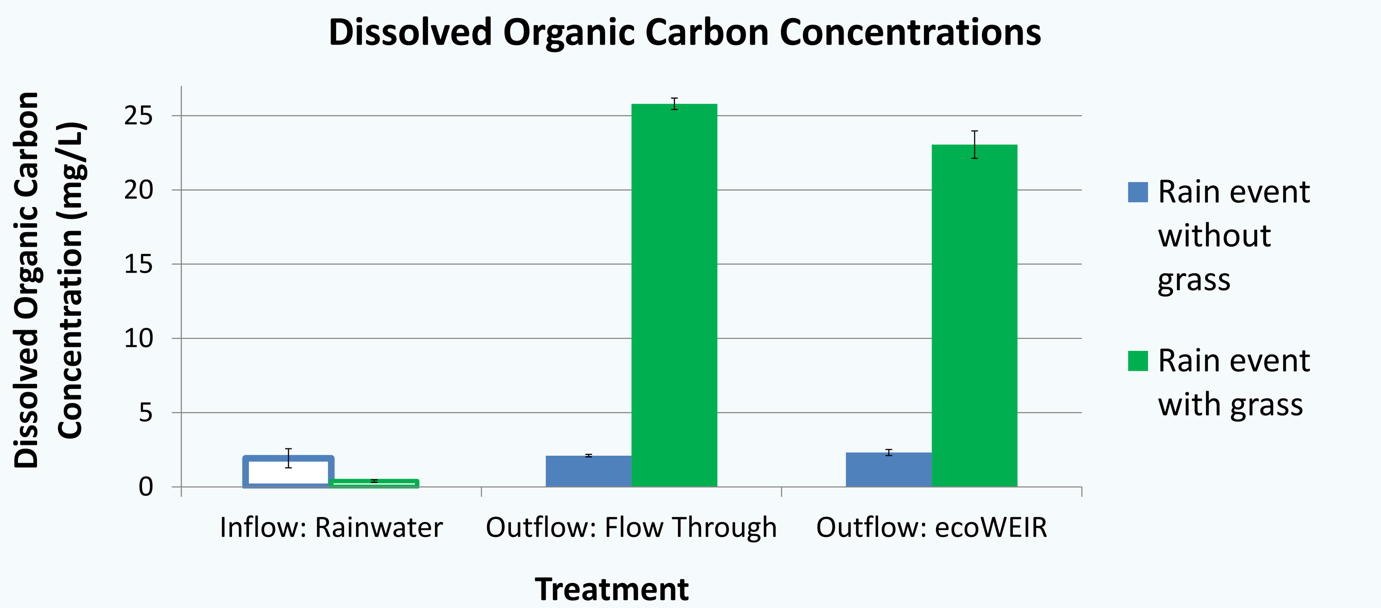


Figure 7: Dissolved organic carbon concentrations of the outflow and inflow samples in both planted and non-planted systems. The addition of grass and soil significantly increase DOC concentrations in both system outflows. Error bars represent +/- 2 SD of duplicate samples.

There was no significant change in the number of fecal coliform colonies in outflow samples from both flow through and ecoWEIR systems.

CONCLUSION

- Inflow water (ie: New York City filtered tap water) is a source of phosphorus which needs to be considered with irrigation practices and maintenances of GI systems (fig 6)
- The soil used in planted systems is a source of TN and DOC as it is amended with manure (fig 7 & 8). This needs to be considered in amended GI systems with different types of soils.
- ecoWEIR is more effective at removing PO4, TN & DOC than flow through systems (fig 6-8)
  - Anaerobic layer that is created and maintained in the ecoWEIR system may allow for the desorption and uptake of PO4 and enhance potential for denitrification to occur (fig 2)
- Additional studies are needed to assess background contributions in more detail
  - Additional simulated rain events, testing of different soil substrates, and use of mature plants with enriched plant/microbial communities
- This relates to UWIN in thrust A2-4 through the use of creative design (ecoWEIR) to help solve some of the challenges related to urban storm water and runoff management, specifically in reducing pollutant loading to coastal waters.

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