Efficiency of UVM Bioretention Cells in Reducing Peak Flow Rates and Total Suspended Solids with Increased Precipitation

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Introduction

In urban landscapes with large areas of impervious surfaces, bioretention systems are used as a Best Management Practice to control stormwater, reduce peak flow and improve water quality of effluent (Davis et al., 2009). Reducing peak flow increases infiltration and evaporation, delaying stormwater flow which relieves stress on the receiving storm sewer pipes and waterways (Cameron and Horner, 2010). Bioretention systems reduce total suspended solid (TSS) concentrations, which have previously correlated with levels of nutrients (e. g. phosphorus) and heavy metals (Wakida et al., 2014). However, as bioretention systems are increasingly installed, it is important to ensure they are designed to remain effective in future weather conditions due to climate change. In Vermont, annual precipitation rates are increasing and heavy rain events are projected to become more frequent and more intense (Frumhoff et al., 2007). With these changing conditions, it is important to consider the effectiveness of bioretention cells with increased precipitation to prepare our stormwater management systems for future.

Figure 1. UVM Bioretention Cell 1
Stormwater runoff from the street enters the cell through the curb cut, then flows over the gravel pathway into the weir box where inflow samples are taken (shown on right side of photo). Runoff spills over a 90° V-notch weir to measure volume, and permeates through the cell. This cell is fitted with a rain pan, which mimics passive addition of rain and adds additional precipitation directly to the cell via the white pipes. Each cell is lined, directing all effluent to drain into an underground pipe where outflow samples are collected and volume is measured before it is released into the storm sewer. Control cells do not have a rain pan.

Objective

To investigate the effect of different precipitation scenarios (i.e. the volume and intensity increases predicted with climate change) on the ability of UVM bioretention cells to reduce hydrologic peak flow and TSS concentration of stormwater runoff.

Experimental Design & Sampling

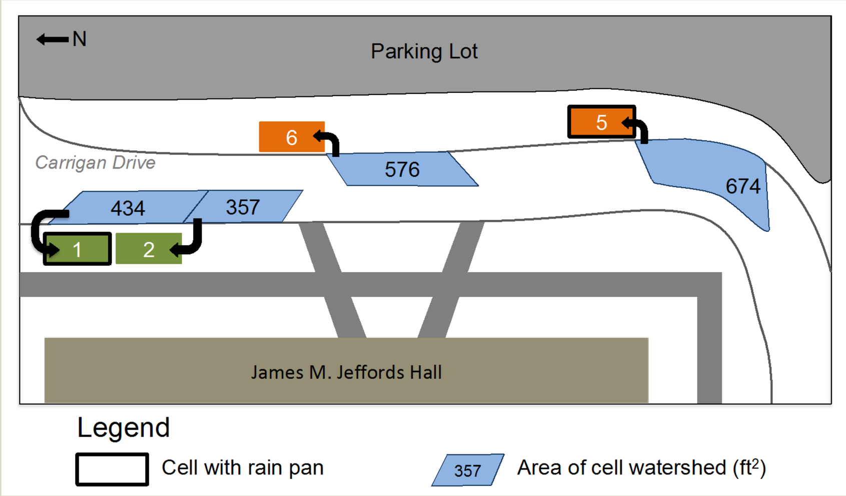

Figure 2. UVM Bioretention Experimental Design
Runoff drains into eight UVM Bioretention Laboratory cells from mini-watersheds on Carrigan Drive. In this study, two sets of paired cells (cells 1 & 2; cells 5 & 6) were sampled. Cells 2 and 6 received only ambient rain and road runoff. Cell 1 and cell 5 (enhanced precipitation) had rain pans increasing precipitation by 15% and 20%, respectively, as well as larger watershed sizes than the watersheds of the cells with which they were paired.

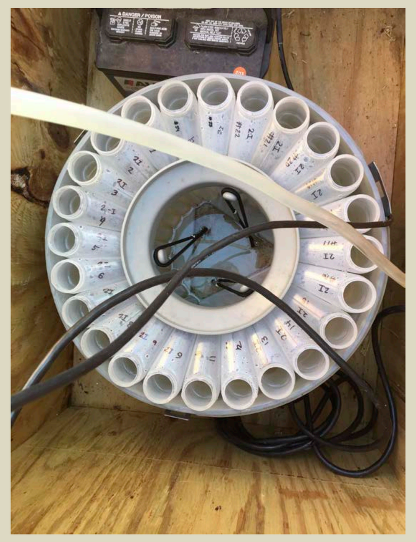

Figure 3. ISCO auto samplers collected composite stormwater samples (3 samples per bottle) and flow data (volume every minute) for 12 rain events from May – August 2015. Sub-samples were collected every few minutes once water levels were >0.02 ft and continued until all bottles were filled or water level dropped below the threshold.

Figure 4. A vacuum pump was used to filter for TSS. New testing methodology was adopted during the last rounds of sampling, which included filtering larger quantities of water for increased accuracy.

Figure 5. These TSS filters show solids after filtering water samples. Filters were dried and weighed to determine the concentration of TSS in the effluent.

Results

Table 1. Percent Reduction of TSS and Peak Flow Rate in Sampled Storms

	Cell 1		Cell 2		Cell 5		Cell 6	
Date of Storm	Peak Flow Rate	TSS	Peak Flow Rate	TSS	Peak Flow Rate	TSS	Peak Flow Rate	TSS
6/8/15			67	96				
6/14/15			62	100				
6/18/15			56					
6/20/15			81	42				
6/28/15			76	100				
6/30/15			96*					
7/15/15	100	100						
7/17/15	99	100			94			
7/21/15	96	54			68		97	90
7/26/15	100	100			100	100	97	100
7/30/15	97	78			100	100	100	100
8/1/15						99		

*Flow rate data from this storm was excluded from further analysis, as the inflow rate was 2.6 standard deviations above mean, and outflow was 2.2 stdev above mean.

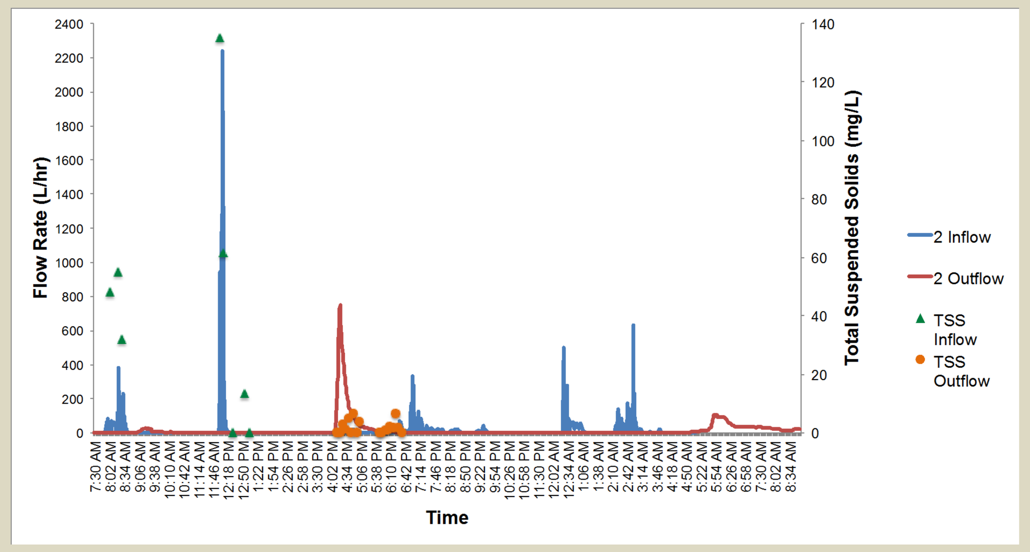

Figure 6. Hydrograph and TSS Concentrations for Cell 2 during the June 30, 2015 storm event. The hydrograph depicts flow rate of the inflow (blue) and outflow (red) over time. Inflow rate peaks at a higher rate more than 4 hours before the peak flow rate of outflow. The TSS was measured from a series of samples collected soon as discharge began at inflow and outflow. Outflow effluent (orange) consistently contained lower amounts of TSS than inflow (green).

- A t-test of dependent means showed that both ambient and enhanced precipitation cells showed significant reductions in both peak flow rate ($t_{(7)}$=-2.148, p=0.0034; $t_{(7)}$=-18.0, p=0.0039) and TSS concentration ($t_{(6)}$=-14.0, p=0.0078; $t_{(6)}$=-14.0, p=0.0078).
- There was no significant difference between the reduction in peak flow rate or TSS concentrations in ambient versus enhanced precipitation cells ($t_{(7)}$=-12.0, p=0.1094; $t_{(6)}$=0.0, p=1.0).
- All cells delayed the release of runoff into the storm sewer, and consistently delayed drainage by several hours.

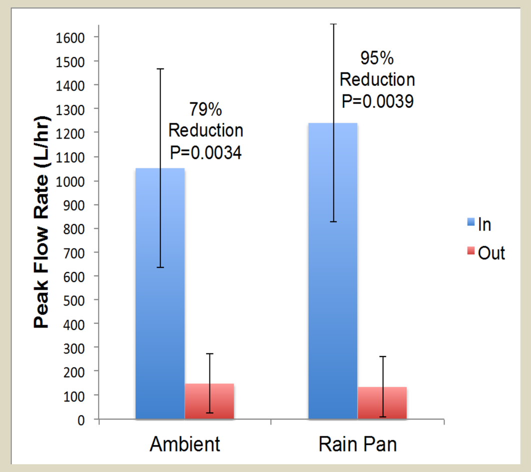

Figure 7. Comparison of Influent and Effluent Peak Flow Rates of Ambient Cells and Enhanced Precipitation Cells
*Error bars represent one standard error from the mean

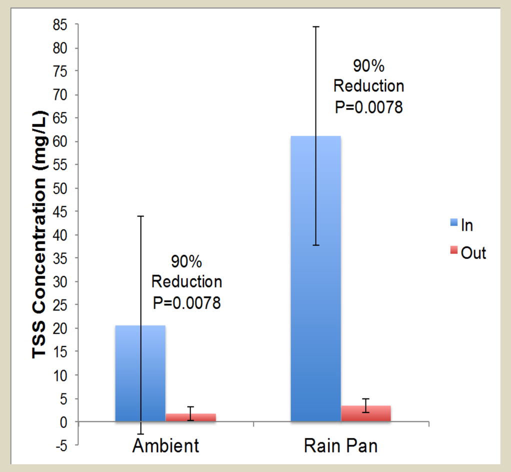

Figure 8. Comparison of TSS Concentration in the Influent and Effluent of Ambient Cells and Enhanced Precipitation Cells
*Error bars represent one standard error from the mean

Discussion

The UVM bioretention cells would most likely continue to effectively reduce peak flow rates and TSS concentrations of stormwater even with increased precipitation predicted with climate change. Both ambient cells and rain pan cells performed similarly in significantly reducing peak flow rates during storms, indicating that additional precipitation did not affect their ability to retain and delay the release of effluent. TSS concentrations showed similar results, as both ambient and enhanced precipitation cells significantly reduced TSS concentrations in effluent. The cells studied were especially effective during smaller storms. Mild precipitation events often produced little to no effluent, resulting high volume reductions. TSS removal was effectively 100% in cases of smaller storms where there was no effluent to test. However, rain pans added water directly to the cell rather than to the weir box, leaving the volume of additional rainwater as an unknown variable. In future studies, precipitation measurements could be used to fill in this data gap.

Conclusions

The bioretention cells at UVM will most likely continue to effectively manage stormwater runoff in increased precipitation conditions as currently installed, although the scale of this study was limited. Further research is recommended to validate results and monitor the long-term efficiency of the bioretention cells.

Literature Cited

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