Further Analysis of Loss of Ignition in Bioretention Units at the Edison Environmental Center

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Abstract

Bioretention units (BU) were constructed at EPA's Edison Environmental Center (EEC) to evaluate sizing of surface area to watershed area. Three sizes were tested in duplicate with changes in aspect ratio of length from inlet (northern) wall by doubling successive length from smallest (3.7 m) to largest (14.9 m); all BU widths were 7.1 m. The bioinfiltration planting media was comprised of 90% sand and 10% sphagnum peat moss by volume or approximately 99% and 1%, respectively, by weight.

Sediment samples for loss on ignition (LOI) analysis were collected in 2017 in three units and in 2018 the remaining three were tested. Samples were taken at a depth of 0.15 m and at 0.3 m intervals along the centerline and starting at the north wall of each unit. Results of the 2017 study were presented at the 2018 EWRI conference. The new 2018 LOI data support previous results. Taken together, results for LOI indicate the largest BU have a flat slope for LOI versus distance from inlets, while slope of remaining smaller units increases with distance from inlet; however, this increase in LOI abruptly drops off after 4 m. This makes sense for the smallest unit due to physical constraints, i.e. length of 3.7 m, but it is also seen in the middle-sized unit, i.e., 7.4 m length, as well.

Results of the LOI studies (2017 and 2018) and previous study of shrubs (2012) appear to be consistent. The build-up of carbon and greater plant health in the smaller bioretention units appears to be from more frequent inundation, while the largest units potentially deprive plants of moisture and growth potential. Results for the middle-sized units (7.4 m long) potentially imply the configuration of the bioretention units for this media and width most likely maximizes at a length of approximately 4 m.

Background

Six bioretention units (BU), widths 7.1 m as shown in Figure 1, were constructed at USEPA's EEC in Edison, NJ to evaluate sizing of surface area to watershed area. Three sizes were tested in duplicate with changes in aspect ratio of length from inlet (northern) wall by doubling successive length from smallest (3.7 m) to largest (14.9 m) representing three surface areas of 26.3, 52.5 and 105.1 m^2, respectively. The watershed areas for each BU was nominally 570 m^2 resulting in watershed to bioretention surface aspect ratios of 22, 11 and 5.5 to 1, respectively, for smallest to largest units. Units were instrumented with water content reflectometers (WCR) and thermistors to measure moisture content.

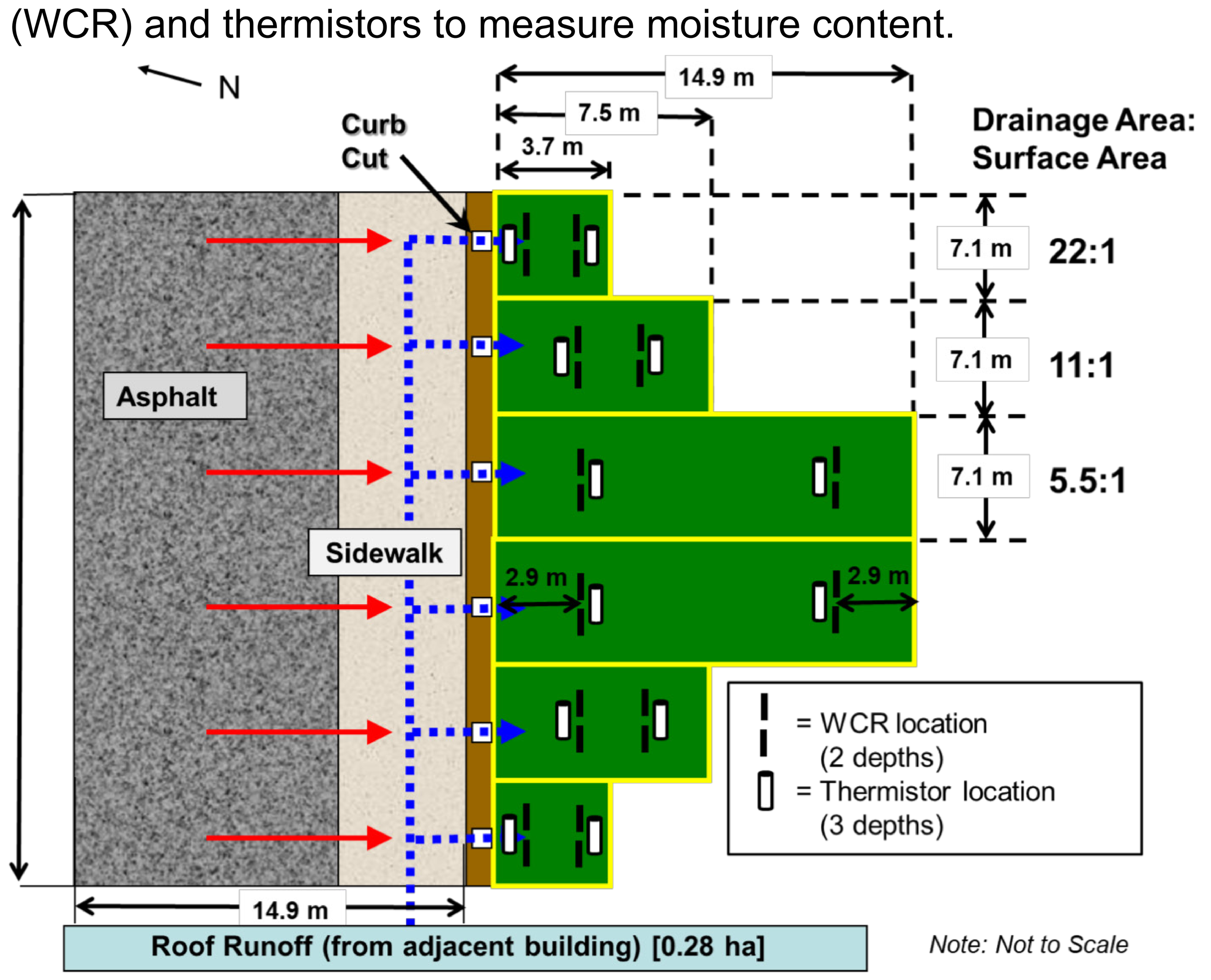

Figure 1. Diagram of bioretention units, drainage inputs and instrumentation.

Loss on Ignition Analysis

Soil samples were heated to 365 °C in a muffle furnace for two hours; the resulting loss of carbon is LOI. Box plots of the results as a percentage are presented in Figure 2. One-way analysis of variance (ANOVA) indicated there was significant difference ($p<0.05$) (StatSoft, 2011) between LOI in the BU and the Tukey HSD test revealed there was a significant difference between BU 6 and both BU 5 and BU 4 but no significant difference between BU 5 and BU 4. similarly when testing all 6 units, BU 6, 3 and 1 were all significantly different than BU 4 and 5.

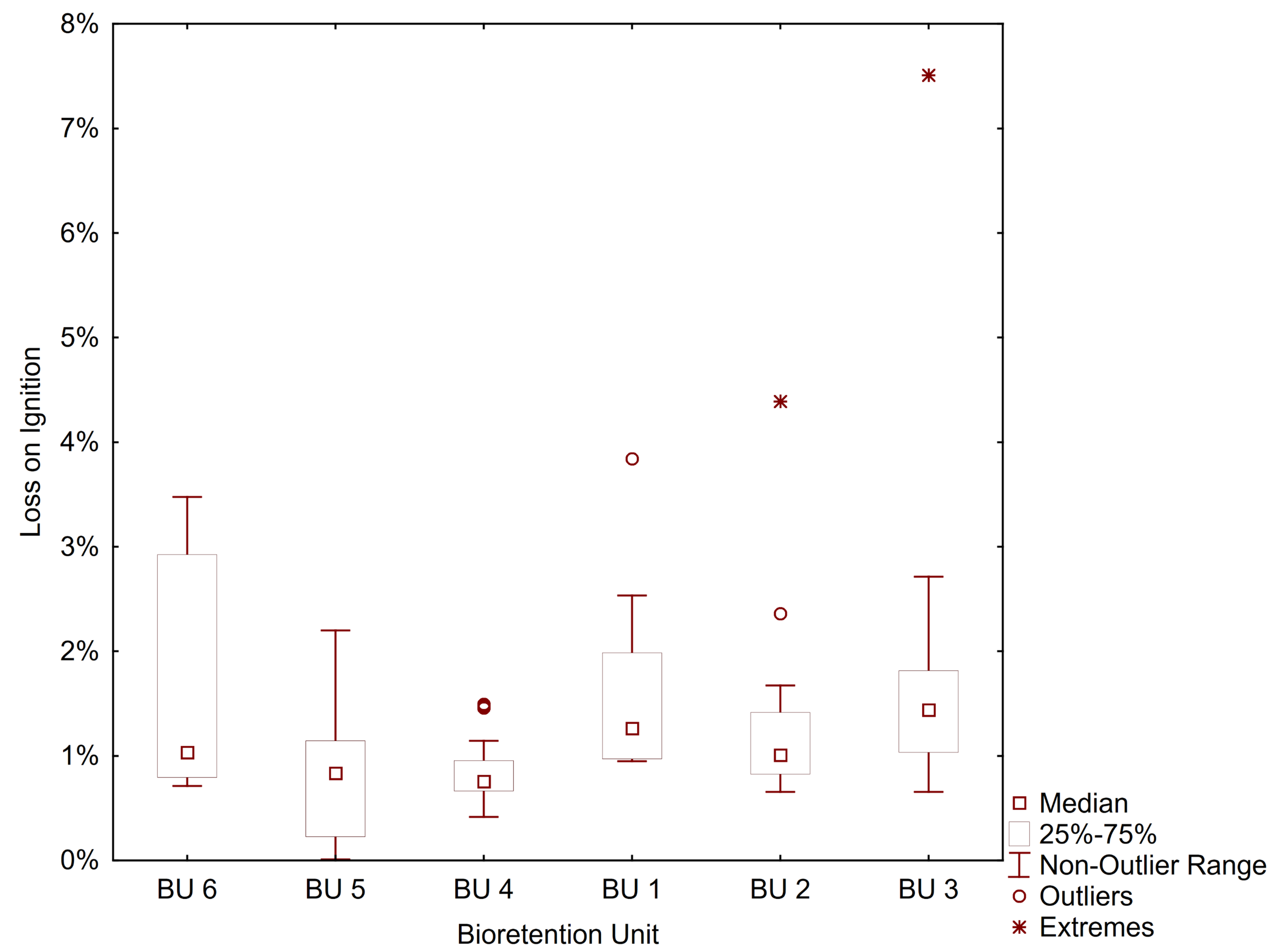

Figure 3 Box plots of loss on ignition analysis for each bioinfiltration unit

Initially, results of LOI on the western units (1, 2 and 3) do not seem to be as consistent with the eastern units (4, 5 and 6) but there are some differences between east and west sides. BU 3 and 4 had pipes that brought influent water into the units about 1 meter – the outliers shown in Figure 2 for units 2 and 3 were closer to the north wall than where the influent pipes discharged and may not have received much, if any, flow. Also, BU 1 had a cap on the roof runoff component. A previous study (Brown et al. 2015), indicated the bayberry on the western side were larger than the eastern side due to greater periods saturation of soils. This may be why there is significant difference in LOI between BU 3 and its counterpart in surface area BU 4.

When the outlier for BU 1 and extreme for BU 3 (each at 0.15 m from north wall) are removed and LOI is averaged for all 6 units at distance from the front, a trend emerges that is similar to results of the study of units 4-6. Figure 3 shows regression analysis (Microsoft® Excel® 2016) and a maximum LOI mean is achieved at 3 m and quickly drops off by 4 meters (note: by including data point at 3.2 m $R^2 > 0.5$ is achieved, while terminating at 3 m R^2 drops to 0.45). The previous study of LOI in BU 4-6 (O'Connor, 2018) indicated larger units did not equate to better performance and Brown et al. (2015) saw significantly better bayberry growth in the smaller units.

Acknowledgements

Nicole Porco of Fordham University collected and analyzed samples for BU 1-3 as part of a volunteer summer internship at EEC. PARS Environmental, Inc. collected and analyzed all other samples.

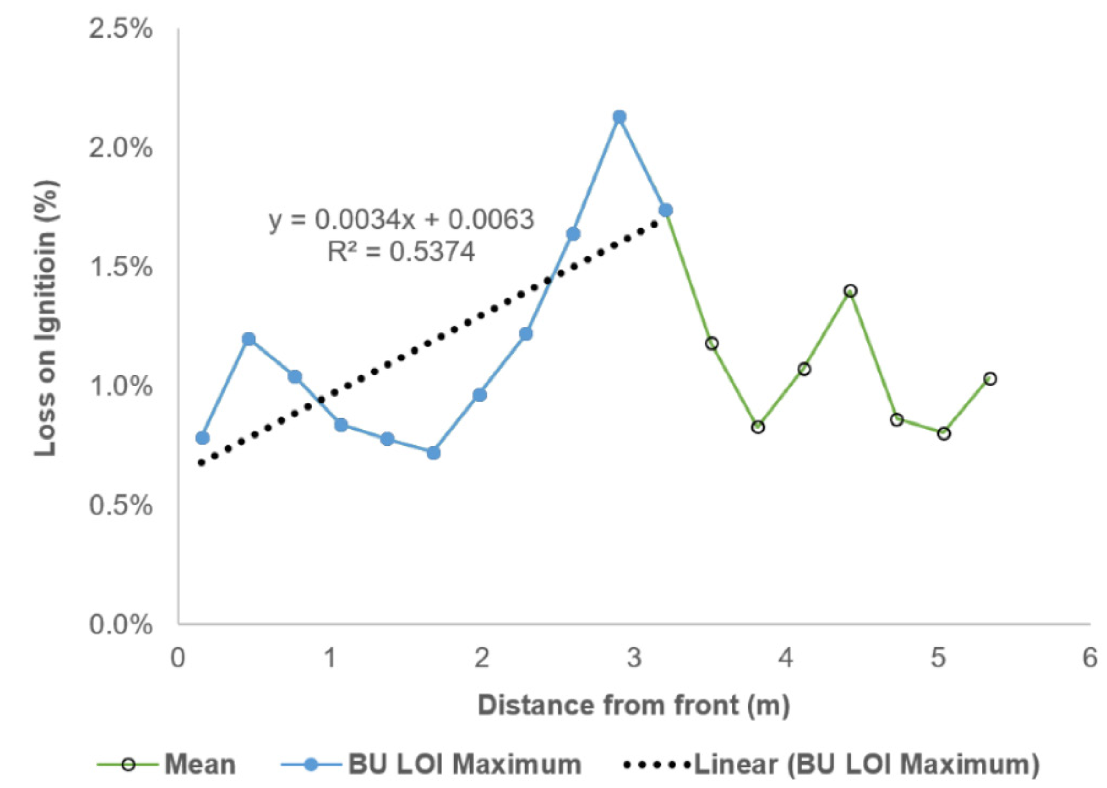

Figure 3. Mean loss on ignition at distance and regression analysis.

Study at Three Depths

Samples were collected at three depths (0.15, 0.30 and 0.60 m) in December 2018 in BU 1, 2, 5 and 6 at four locations along the eastern side. This will be followed by another round of sampling in late spring along the western side. Initial statistics of the December samples do not show statistically meaningful differences when all data are analyzed but there are signs of statistical differences when subsets of data are analyzed. For example, when all three depths are compared there is no statistical difference but when 0.15 m is compared directly to 0.60 m, there is a significant difference. Also when the data are analyzed by the General Linear Model (StatSoft, 2011), the analysis is considered significant when data are limited to first maxima which again occurs near 3 m from the front.

When data at depth 0.15 m is combined with analysis for Figure 3 and data from BU 3 and 4 removed, R^2 increases from 0.54 to 0.58.

Conclusions

The smaller BU are accumulating more organic carbon than the largest units 3 and 4. The smaller units are inundated more frequently leading to greater surface flows. This may bring organic matter to the back of BU 1 and 6, but this trend appears in BU 2 and 5 as well, near the halfway point between the front and back. The largest units do not build-up of organic matter in this way.

The build up of organic matter is from collected runoff and plants in the BU. Healthier plants will produce more organic matter which can provide better habitat for microbes and macroinvertebrates in the soil and better pollutant removal as pollutants tend to sorb to organic matter.

While specific results are dependent on configuration, media composition and flow, generally, greater watershed to surface areas could increase performance of stormwater controls.

References

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