Update to Permeable Pavement Research at the Edison Environmental Center

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ABSTRACT

The EPA's Urban Watershed Management Branch (UWMB) has been monitoring the permeable pavement demonstration site at the Edison Environmental Center, NJ since 2010. This site has three different types of permeable pavements including interlocking concrete permeable pavers, pervious concrete, and porous asphalt. The permeable pavements are limited to parking spaces while adjacent driving lanes are impermeable and drain to the permeable surfaces.

The parking lot is instrumented for continuous monitoring with thermistors and water content reflectometers that measure moisture as infiltrate passes through the storage gallery beneath the permeable pavements into the underlying native soil. Each permeable surface of the parking lot has four lined sections that capture infiltrate in tanks for water quality analyses; these tanks are capable of holding volumes up to 4.1 m^3, which represents up to 38 mm (1.5 in.) for direct rainfall on the porous pavement and runoff from adjacent driving lanes that drain into the permeable surface.

Previous technical releases concerning the demonstration site focused on monitoring techniques, observed chloride and nutrient concentrations, surface hydrology, and infiltration and evaporation rates. This presentation summarizes these past findings and addresses current water quality efforts including pH, solids analysis, total organic carbon, and chemical oxygen demand. Current findings support earlier findings for pH, total organic carbon and chemical oxygen demand where porous asphalt infiltrate values exceeded the infiltrate values of the other two permeable pavements; interestingly, porous asphalt suspended solids concentration is increasing with time.

INTRODUCTION

Stormwater runoff continues to be a major cause of water pollution in urban areas. Green infrastructure techniques that use the concepts of low impact development (LID) redirect urban stormwater away from conventional drainage systems, and instead reduce and treat stormwater at its source while delivering environmental, social, and economic benefits.

Unknowns in the application of LID in the urban environment are a continuing barrier to widespread adoption of the installation of permeable surfaces for stormwater management. EPA started construction in 2008 of a permeable pavement parking lot on the Edison Environmental Center (EEC) in Edison, NJ. The parking lot research and demonstration site, which is actively used by facility staff and visitors, provides EPA with a controlled data collection location and is also an outreach tool to demonstrate a working example of the stormwater control.

Data collection efforts on permeable pavements at the EEC began in late 2009 after completion of construction with plans to continue monitoring through 2019 at a minimum. Three permeable pavement surfaces, interlocking concrete permeable pavers (PP), pervious concrete (PC) and porous asphalt (PA), were constructed with the intent to monitor aspects of water quality and infiltrating rates and volumes. Monitoring is conducted through in-situ instrumentation, i.e., thermistors and water content reflectometers, water quality sampling of captured infiltrate and other physical means.

The first publication of results were based on testing of surface infiltration rates using a modified ASTM C1701 method (EPA, 2010). Through the first six months, infiltration rates for PC exceeded 4000 cm/hr, PP exceeded 2000 cm/hr and PA exceeded 100 cm/hr. Stander et al. (2013) demonstrated the efficacy of the in-situ monitoring system while the infiltrating ability of the permeable pavements was further demonstrated in Brown and Borst (2013). Hydrologic performance metrics of surface infiltration rates (Brown and Borst, 2014a) and annual evaporation (Brown and Borst, 2015a) vary by permeable pavement surface type, with PC having significantly larger infiltration rates and annual evaporation than the two other surfaces. Observed statistical differences between infiltrate concentrations of the three permeable surfaces have been detailed for chloride (Borst and Brown, 2014b) and for nitrogen, orthophosphate, total organic carbon (TOC), and pH (Brown and Borst, 2015b). Details of the overall water quality sampling efforts were described in Borst and Brown (2014b).

Many of the previously published water quality results of the permeable pavement infiltrate represent a subset of the sampling period that now extends from January 2010 through the end of May 2016. The results presented below summarize some basic water quality parameters, i.e., pH, suspended sediment concentration (SSC), TOC and chemical oxygen demand (COD) through 2015; these results show differences in the infiltrate from the permeable surfaces. For comparative purposes, water quality results include runoff samples from the parking lot's southern end, which are collected at curb cuts inlets to bioinfiltration units.

Figure 1 is a plan view of the permeable surfaces and the bioinfiltration units and the respective water quality sampling points of the collection tanks and curb cuts. For any given date, the results are averages of up to four sampling locations for the permeable pavements and are either standalone or average values of the two curb cut locations. For this paper, limited statistical analysis and graphs were performed using Microsoft Excel (Microsoft 2013).

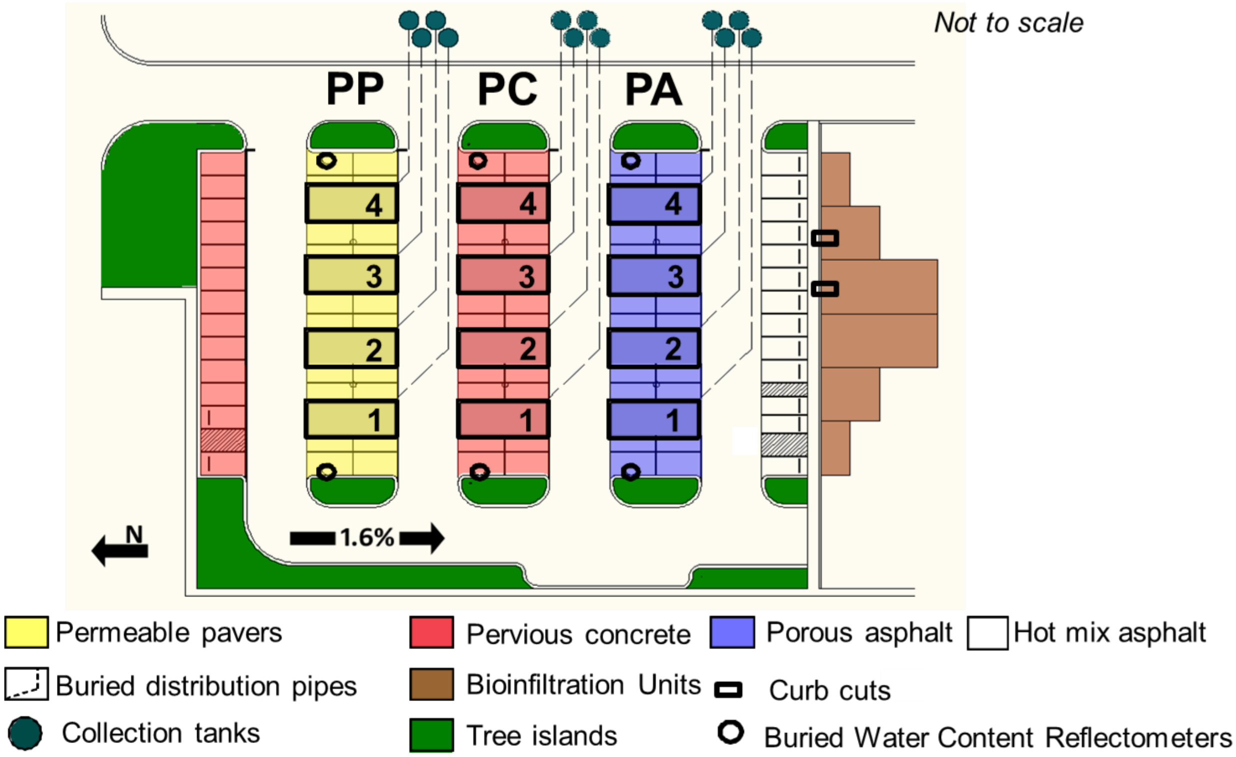

Figure 1. Layout of the permeable parking surfaces and the bioinfiltration units at the Edison Environmental Center

RESULTS

Figure 2 shows pH during the initial five years (2010 through 2015). As demonstrated, the pH of the rainfall is usually acidic (<7) and this is buffered by the PC and PP as the pH of infiltrate is normally well above 7. This result is anticipated; what was not anticipated were the consistently high pH values of the PA infiltrate. This high pH was previously discussed in Brown and Borst (2015b) but without any explanation; Brown and Borst (2015b) focused on 13 storm events sampled from October 2010 until September, 2011. Figure 3 indicates that the high pH for PA infiltrate has been observed from 2010 through 2015.

Figure 3 shows the SSC over time, while Figure 4 shows the most recent completed sampling year. Initially, the runoff and PP samples have the highest concentration (Figure 3) but this changed with time; the PA had the highest concentration in the last monitored year while the runoff is much lower (Figure 4).

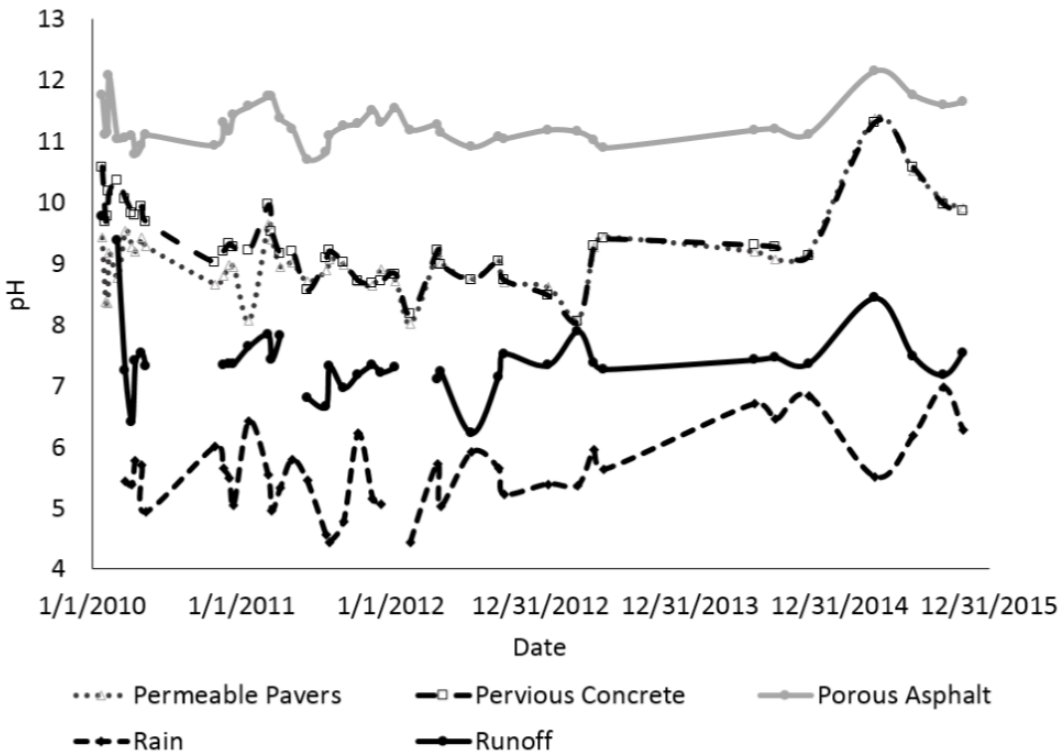

Figure 2. pH during first five years of sampling (2010 through 2015)

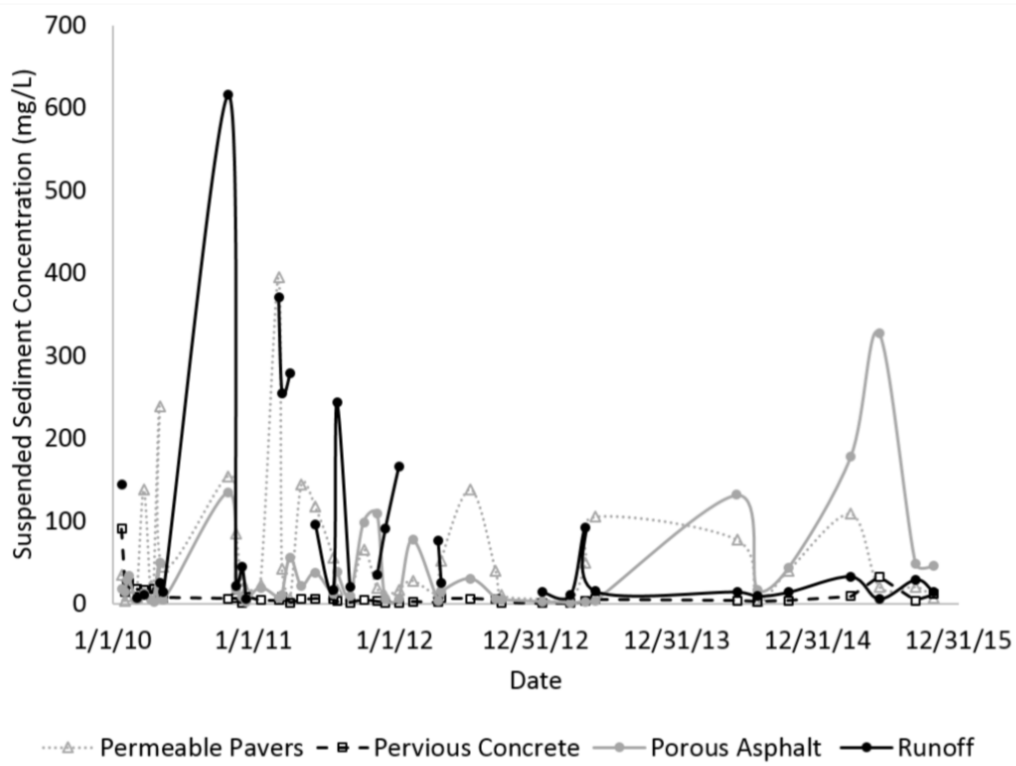

Figure 3. Suspended sediment concentration during first five years of sampling (2010 through 2015)

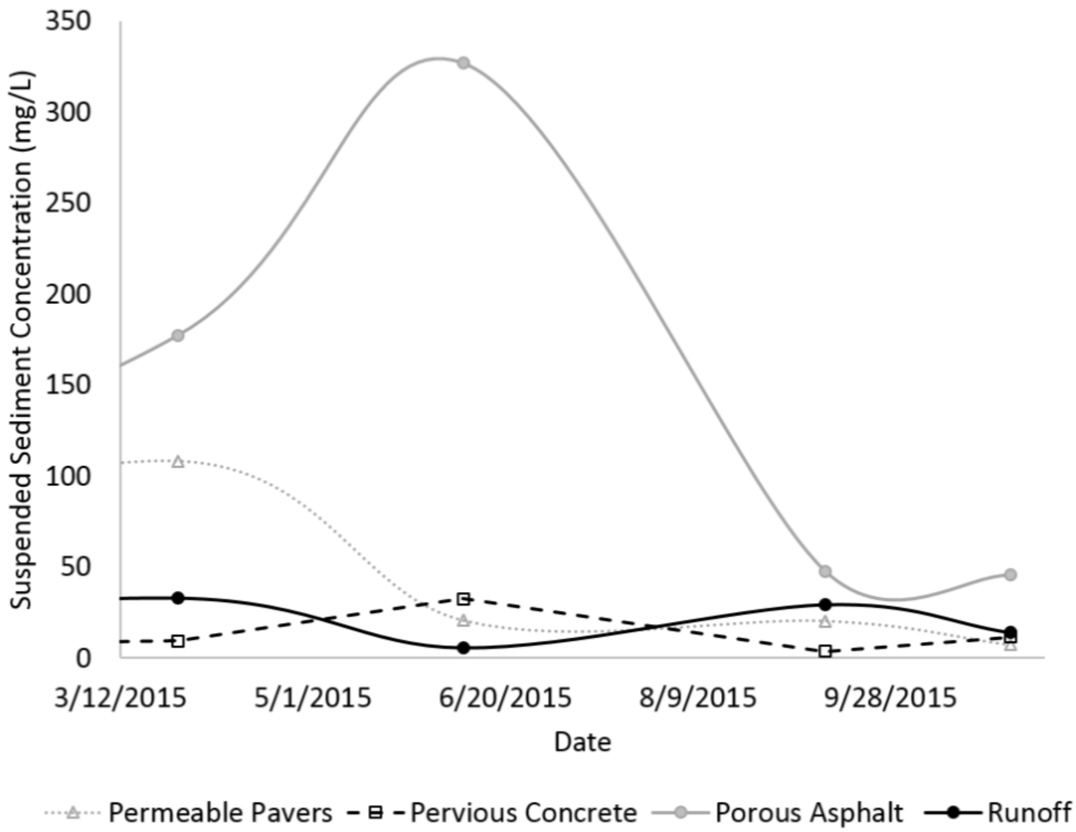

Figure 4. Suspended sediment concentration during most recent completed year of sampling (2015)

Previously, for the October, 2010 to September, 2011 time period, significant differences in TOC concentrations were found between the PA infiltrate and the other permeable pavement infiltrate, while runoff was not significantly different from PA (Brown and Borst, 2015b). Brown and Borst (2015b) also indicated that PC and PP infiltrate were not significantly different from each other. This trend appears to be maintained through the 2015 sampling year as represented in Figure 5, where the mean TOC concentration of the PA infiltrate is larger than the PC and PP infiltrate concentration and similar to the runoff concentration (runoff is identified as “CC” for curb cut sampling location in Figures 5 and 6). This is also true of COD (Figure 6), though COD appears to be a bit more variable than TOC (above mean error bars are only shown in Figure 5 and 6). The error bars represent standard of deviation and the standard of deviation value exceeds the COD means for PC and PP infiltrate concentration (coefficient of variation is 1.3 and 1.2, respectively).

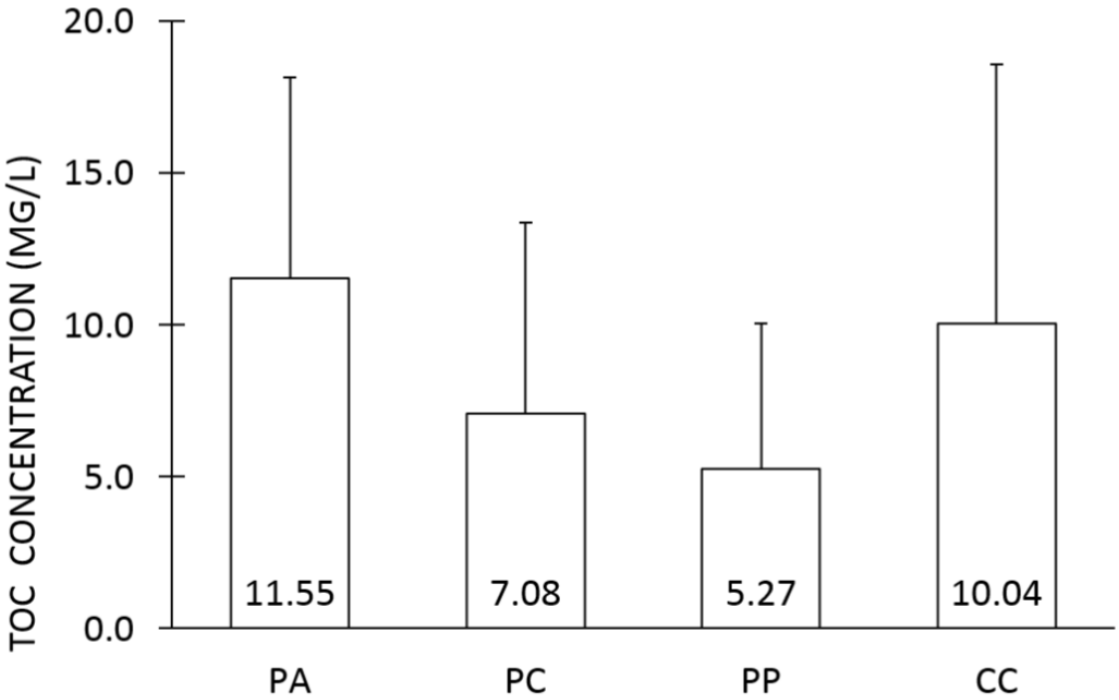

Figure 5. Bar chart of total organic carbon concentration during first five years of sampling (2010 through 2015)

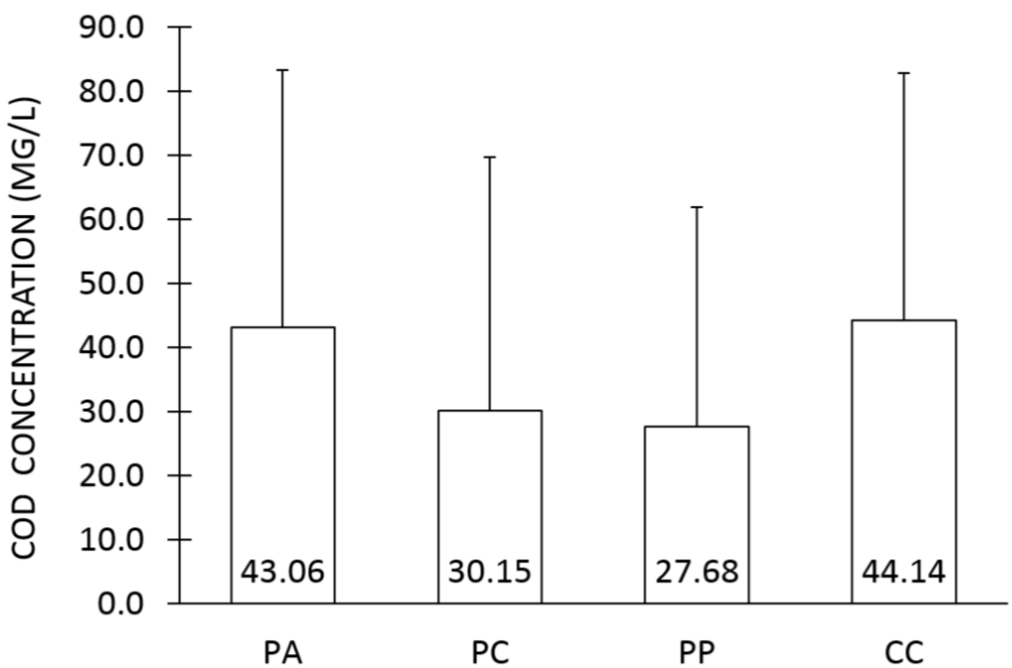

Figure 6. Bar chart of chemical oxygen demand concentration during first five years of sampling (2010 through 2015)

DISCUSSION

The observed SSC in the runoff and the infiltrate seems to be changing with time. An explanation for the higher then lower SSC of the PP infiltration concentration may be due in part to the materials used in construction. The common subbase reservoir for all three permeable surfaces is comprised of recycled concrete aggregate (RCA) from the EEC crushed on site to specified size of American Association of State Highway and Transportation Officials (AASHTO) No. 2 aggregate. However, the pavers were placed directly on a 2 in. thick bed of AASHTO No. 8 stone, which then rested on a 4 in. thick bed of ASSHTO No. 57 stone before being placed on the subbase. These ASSHTO No. 8 and No. 57 stone may have contributed to the initial higher SSC concentration of the PP infiltrate, but as this is washed out the observed SSC would begin to be reduced.

Brown and Borst (2013) indicated that sediment from a nearby landscaped area without effective sediment and erosion controls may have contributed to some clogging observed in the PA surface. This sediment may have also contributed to the higher SSC initially observed in the runoff but runoff SSC has decreased with time.

Clogging of the PA surface should not yield increased SSC with time as these solids would be trapped at the surface and less infiltrating water would be available. The increase observed in SSC with time for the PA infiltrate therefore requires an alternative explanation; it is hypothesized that this increase in PA infiltrate SSC may be related in part to deicing chemicals. Deicing chemicals are known to have damaging effects on concrete (Wanga et al. 2006). Brown and Borst (2014b) indicated that chloride was released more slowly through PA than the PP and PC with higher concentration observed in the PA infiltrate through spring and summer. In observing Figure 4, PA SSC concentration is peaking during June sampling event in comparison to the two other permeable surfaces and the runoff. Visible aggregate was observed in the PA infiltrate of a recent sampling event (5/25/16), more so than in the samples of other infiltrate surfaces.

The porous concrete at the EEC has raveled, which is the deterioration of the pavement surface caused by the dislodging of aggregate particles. There were patches that crumbled in 2011; this failure was attributed to “a bad batch” and was replaced by the installer. However, after the severe winter of 2013-2014, with February being below average and the coldest February since 2007 (Robinson, 2014), the condition of PC generally worsened late in the winter of 2013-2014 with large areas failing. This failure has been attributed to deicing application. Recommendations for concrete are that “Deicing chemicals should not be used… in the first year” (NRMCA, 2015). Due to continued deterioration, there is a planned replacement of the PC with interlocking concrete pavers during the summer of 2016.

Brown and Borst (2015b) indicated that as PP and PC TOC infiltrate concentration were significantly less than observed runoff concentration, these permeable pavements were retaining TOC. On the other hand, the PA infiltrate concentrations, as shown in Figure 5 and 6, indicate no net removal of organic material as TOC and COD concentrations are not reduced from observed runoff (labeled as CC in figures).

Current and future monitoring efforts will allow for greater statistical analyses to provide more in depth explanation of the processes of how the permeable surfaces interact with the runoff and direct rainfall overtime.

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NOTICE

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