Assessment of Bioswale Efficiency in Altering Stormwater Run-off Timing and Duration

By:

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ABSTRACT

Growing land cover and population densities generate increased impervious surface and pollution that deteriorates our water bodies. Impervious surface impedes ground water recharge and instead promotes the discharge of heavy metals, trash, and other pollutants, collected by stormwater runoff, into nearby water bodies. A bioswale has been implemented at SUNY Purchase College Campus in the outermost extent of the W1 parking lot to improve downstream stormwater runoff, as it contributes to the pollution of both Blind Brook and the Long Island Sound. The effectiveness of the bioswale was assessed through a paired watershed study of runoff quality from two similar, large parking lots, W1 and W2, located on the west side of campus. Stormwater runoff events were analyzed to test the effectiveness of the bioswale at increasing discharge durations and delays from rainfall peak to discharge peak. The median values for discharge durations and delays from rainfall peak to peak of W1, W2 and the bioswale were 37.3, 26.5, 17.25, and 1.75, 1.41, 6.2, respectively. W1 and W2 produced indiscernible median values for both analyzed temporal aspects of runoff. Therefore, it is inconclusive that the bioswale provided improvement of stormwater runoff impairment experienced in Blind Brook, or Long Island Sound.

ACKNOWLEDGEMENTS

I would like to thank my research advisor Dr. Ryan Taylor for guiding me through this project, for his valuable insight and for his aid in the installation of the equipment at all sample sites.

INTRODUCTION

Urbanization refers to the development and growth of cities in response to a rapid change in population density.[5] One unintended consequence of urbanization is an increase of impervious surface, such as roads and parking lots, in our towns and cities.[9] Impervious surfaces prevent the infiltration of stormwater into the soil and reduce groundwater recharge thereby increasing the velocity and volume of surface runoff.[1] This increased runoff enters nearby waterways at fast rates and creates hydrologic disruption, such as more incised channels, and enhanced risk of flooding.[1] In urban areas, stormwater runoff washes contaminants from cars and construction equipment etc., into storm drainages and subsequently into the nearby water bodies. According to the 2017 National Water Quality Inventory, urban runoff is a major pollutant source associated with water quality impairment.[11]

The New York Department of Conservation listed storm water runoff as the primary source of impairment causing increased levels of sediment and erosion in Blind Brook and preventing it from attaining its designated use of secondary contact recreation.[7] Furthermore, as a coastal tributary, Blind Brook's impairment contributes to the overall degradation of the Long Island Sound. The Long Island Sound is an estuary that has experienced extreme degradation due to immense eutrophication. The Blind Brook watershed has a history of storm water quality issues. A recent undergraduate senior project investigating storm water runoff at Purchase College determined that the majority of the measured turbidity values during the first, middle, and final flush were above the water quality standard of 1.29 FNU (Formazin Nephelometric Units).[14,6] In addition, a previous similar study found that testing sites on the eastern branch of Blind Brook had higher temperatures than those in the western branch, while sites in the western branch of Blind Brook had higher turbidity and total suspended solids.[4] Growing urbanization and impervious surface surrounding Blind Brook are main drivers of these types of water quantity and quality impairments.

Traditional stormwater infrastructure systems are designed to reduce the adverse effects of urbanization but more often fail to prevent the most serious of problems, such as downstream flooding, and is not as cost-efficient or sustainable as green infrastructure.[16] Green infrastructure is a cost-efficient management practice that utilizes elements such as vegetation and soils to mitigate wet weather impacts.[17] Green infrastructure is particularly beneficial in urban and sub-urban areas where environmental damage is more extensive and green space is limited.[16] Bioswales, a type of green infrastructure, are vegetated landscape depressions designed to reduce and delay stormwater runoff volumes, treat runoff pollution, and enhance groundwater recharge by utilizing vegetation and soils for retention, absorption and infiltration.[16,18]

Purchase College's efforts to mitigate the effects of impervious surface are exhibited primarily through the implementation of two types of green infrastructure technologies: green roofs and bioswales, in several locations across its campus. Specifically speaking, a new green roof has been installed on the entire Visual Arts building while the existing green roof located on the Central Mall between the academic buildings has recently expanded the amount of greenspace by 25%. Most recently, a bioswale was built along the outermost extent of the W1 parking lot. Most of the impervious surface on the west side of the campus is represented by the W1 and W2 parking lots. Both the W1 and W2 parking lots drain ultimately into the West branch (Cottage Avenue) of Blind Brook. The remaining infrastructures on the campus, academic and administrative buildings, and residence halls, drain into the East (Lincoln Avenue) branch of Blind Brook (Figure 1).

The W1 and W2 parking lots comprise of 290,000 ft^2 of impervious surface and are situated within different sized watersheds comprising of 463,000 ft^2 and 569,000 ft^2 of impervious surface respectively.[14] The differences in the total amount of impervious surface between these two parking lot watersheds is because W1 also receives runoff from the roofs of academic buildings that are not similarly located within the W2 watershed. In 2018, an undergraduate senior research project monitored runoff events from W1 and W2, using pressure traducers in catch basins, and was able to predict runoff volumes for watersheds of their size and composition (Figures 2, 3). W1 and W2 runoff volumes are of 6,816 m^3 and 4,824 m^3.[10] Since the 2018 study was completed, a major difference between both parking lots has taken place with W1 now including a bioswale designed to intercept the runoff of the outer-most 1/3 of its impervious surface area.

The paired watershed study designed herein monitors the differences in quantity of stormwater runoff between the W1 and W2 parking lots; with W2 serving as the control, and W1 receiving the treatment of the bioswale. A 2019 study shows that a bioswale displayed volumetric and peak flow rate mitigation, where 37 of the 39 analyzed storm events displayed no overflow and reduced peak flow rates.[13] Furthermore, a 2012 study in Philadelphia also shows that a grass bioswale reduced the annual runoff volume by 70%.[2] It is because of the promising mitigation that bioswales exhibit regarding stormwater runoff control, that one was implemented surrounding the W1 parking lot at Purchase College. Therefore, the goal of this observational field study was to determine the effectiveness of the new bioswale at altering the timing of peak-flow events of downstream flooding and the duration of discharge during storm events.

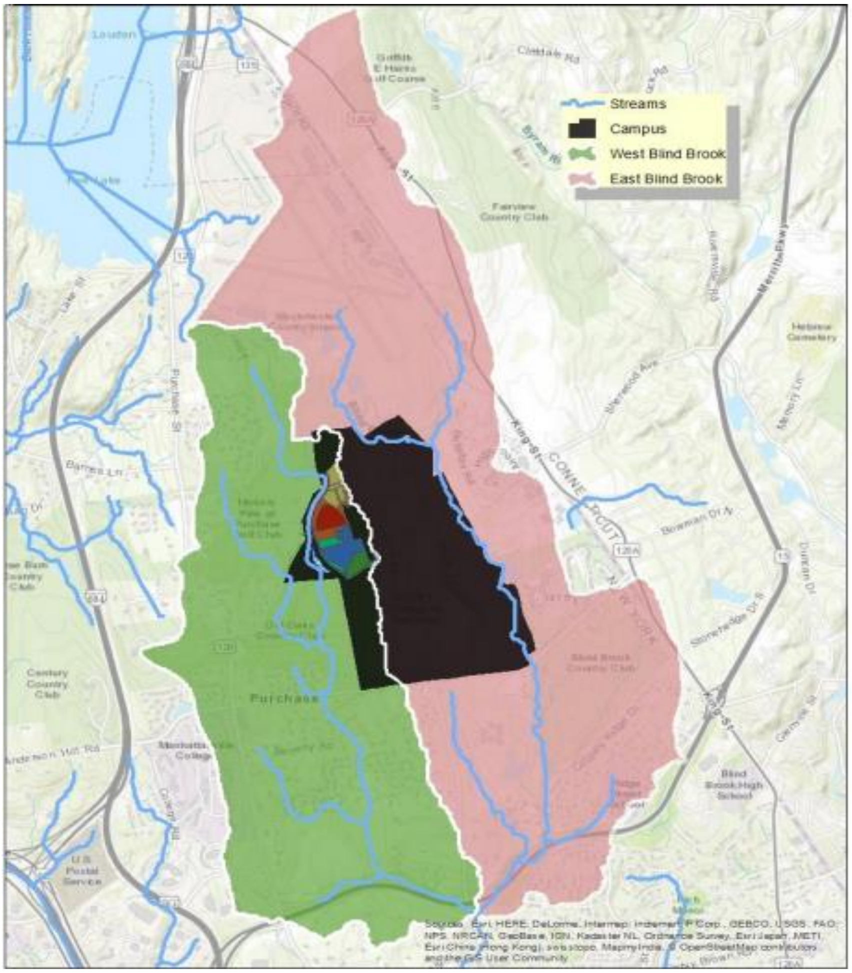

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Figure 1. Drainage of East and West branches of Blind Brook Watershed.[14]

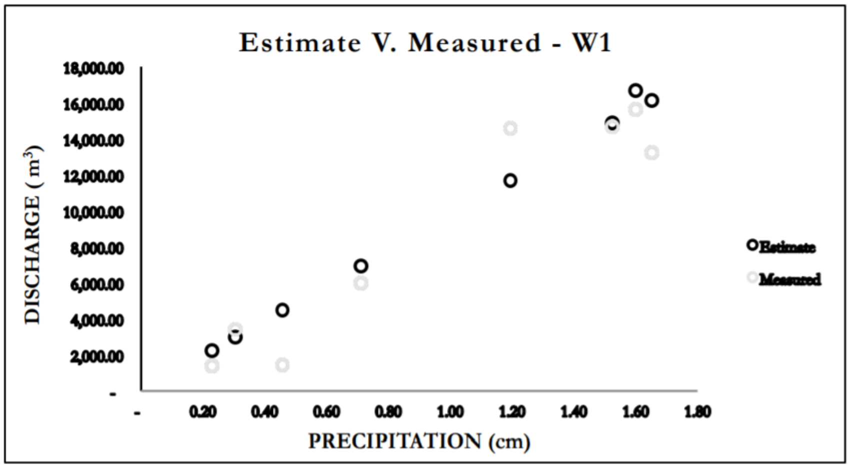

Figure 2. Estimate vs. Measured stormwater runoff volumes for the W1 parking lot.[10]

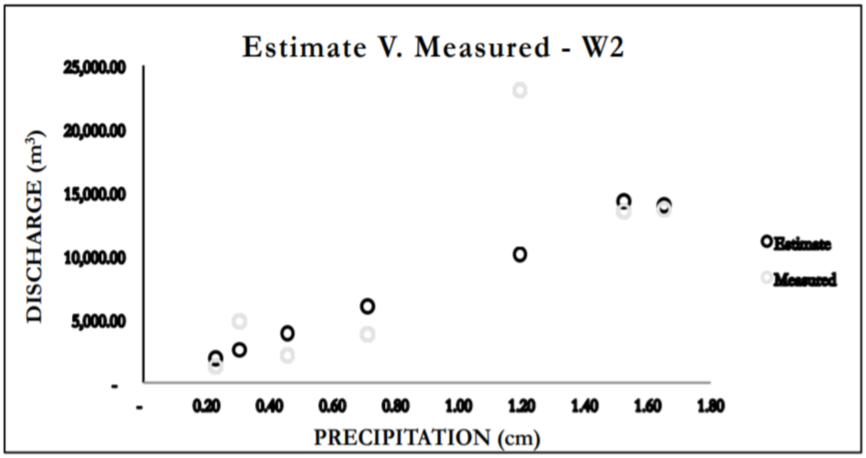

Figure 3. Estimate vs. Measured stormwater runoff volumes for the W2 parking lot.[10]

MATERIALS & METHODS

The study site encompasses five sample sites on the west side of the SUNY Purchase College campus (Figure 4). Water quantity data was taken from three different drainage pipe sites; (i) the W1 drainage pipe, (ii) the W2 drainage pipe, and (iii) the East-West Road drainage pipe. In addition, data was collected from an upstream section of Blind Brook on Cottage Avenue, the outfall pipe which collects and expels stormwater from both parking lots as well as East West Road, and a section of the bioswale. Each sample site was used to determine the quantity of stormwater runoff for every ideal storm event to occur between November and April.

HOBO RX3000 data loggers with pressure transducers, were installed at all sample sites to record water levels. The bioswale data logger was connected to both the bioswale and the W1 drainage pipe. A weather station was added to the bioswale site in combination with the RX3000 data logger to record the amount of rainfall of the study site. All the equipment for the data loggers was purchased through Onset Computer Corporation.

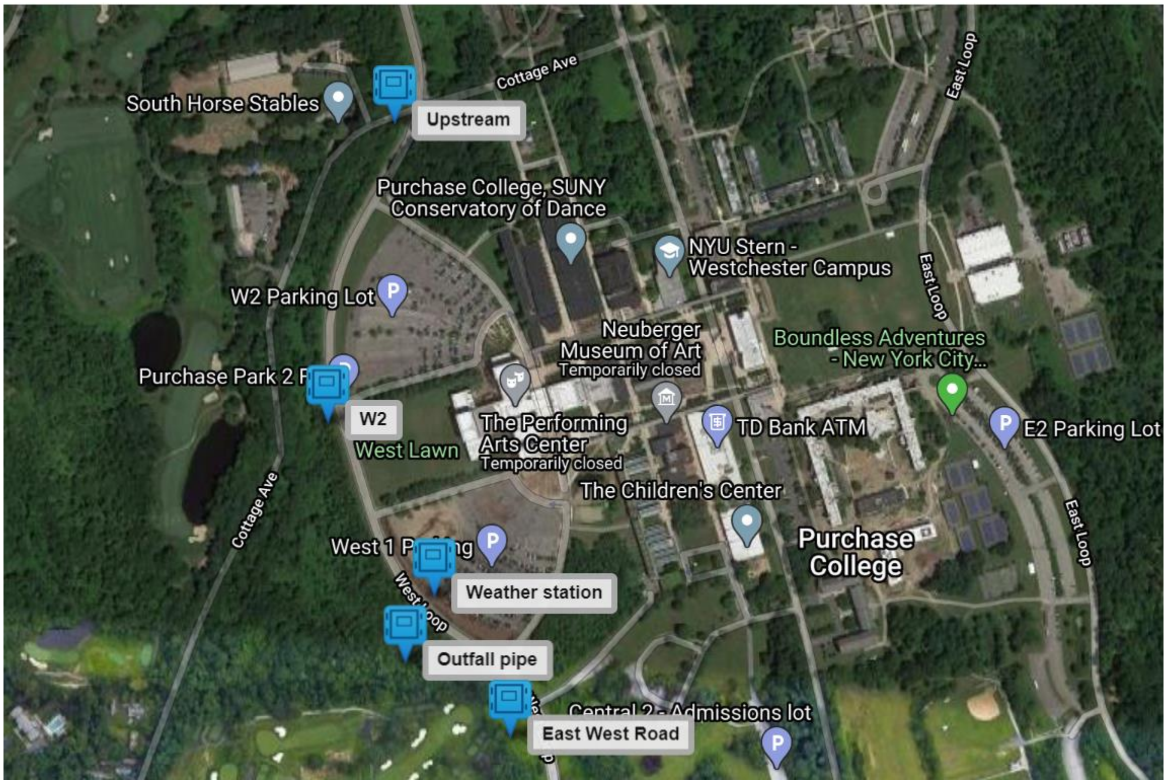

Figure 4. Aerial of SUNY Purchase College and location of sample sites around W1 and W2 parking lots. The weather station represents the bioswale and the W1 drainage pipe.

Each HOBO RX3000 data logger was mounted onto 6’ metal tripods alongside a solar panel (Figure 5). A total of five RX3000 data loggers were built, as two sensor cables corresponding to the bioswale and W1 drainage pipe were connected to the bioswales data logger. Each data logger contained a RX3000 four channel analog module and a desiccant cartridge. A 30 foot cable with a pressure transducer calibrated to measure water levels up to five foot depths was connected to the W1 data logger and four 20 foot cables with pressure transducers calibrated to measure water levels up to five foot depths were connected to the bioswale, W2, upstream and East West road data loggers. Lastly, a 30 foot cable with a pressure transducer calibrated to measure water levels up to 10 foot depths was connected to the outfall pipe. The RX3000 sends its data to a website which makes it very accessible and convenient.

To assemble each data logger, analog modules, battery, and solar panel cables were installed first. Then water level sensors were connected to the analog modules and desiccant cartridges were connected to the sensor cables. A waterproof rubber cable channel and its covers were installed once the sensor cables were in place. Silicone grease was used on the outer edges and on the inside of the rubber cable channel to ease its installation. Once the sensor cables were positioned onto the rubber channel, the rubber channel was positioned into its corresponding opening until fully sealed. Then, a plate was installed on top of the opening with thumbscrews to hold the rubber channel in place. The same steps were repeated for the bottom opening and any unused cable channel holes were sealed with plugs. Mounting plates were attached onto the solar panels and data loggers; both were mounted onto the tripod respectively with U-bolts. More on installation can be found at Onsets website in the HOBO RX3000 Remote Monitoring Station Manuel.

Figure 5. Tripod set up with mounted solar panels and HOBO RX3000 data loggers.

A tripod was set on each sample site. Once oriented on site, the U-bolts on each tripod leg were tightened with a ½ inch wrench and secured. Then the tripod was secured with the installation of ½ inch diameter ground rods through each anchor plate on each tripod leg. All upper and lower tri-clamp nut and bolt assemblies were tightened to secure the metal pole holding the data loggers and solar panels. Lastly, data loggers were sealed shut with zip ties. All data loggers were connected to Hobolink, where data was stored and retrieved, and set to collect data in 10-minute intervals. Time and water level recordings, collected by the data loggers and pressure transducers, enabled the calculation of quantities such as discharge durations and delays from rainfall peak to peak. Which are the two temporal aspects of runoff events that were analyzed to test the effectiveness of the bioswale. Discharge duration is the time difference between pipe fill and drain, and delay from rainfall peak to peak is the time difference between storm peak and pipe peak.

RESULTS

Rainfall Events

Over the course of six months, a total of 18 storm events occurred. On average, there were three storms a month, with a high of five storms in December and a low of one storm in January (Figure 6). In addition, 41 other small rainfall events produced no response from the bioswale and therefore were not included in the analysis. These excluded storm events produced a range of 0.3 mm to 2 mm of total rainfall with an average of 0.58 mm per rainfall.

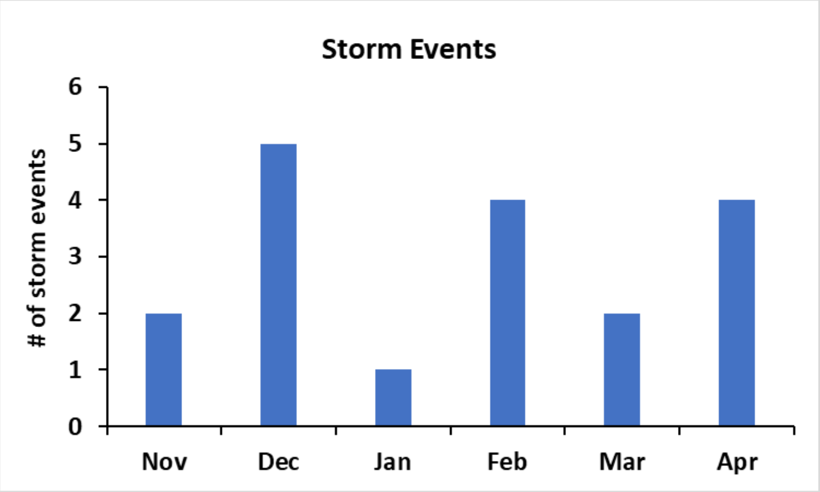

Figure 6. Number of monthly storm events.

Total Rainfall

Over the course of this study, there was 476.5 mm of total rainfall. The average total amount of rainfall per storm event was 26.5 mm. The largest storm event occurred on April 12th and produced 56.5 mm of rainfall. The smallest storm event occurred on December 17th and produced 2.4 mm of rainfall (Figure 7). Most of the heavy rainfall occurred between November and January, the first three months of data collection. Furthermore, December produced the greatest total rainfall, with three out of its five storms producing above average rainfall amounts.

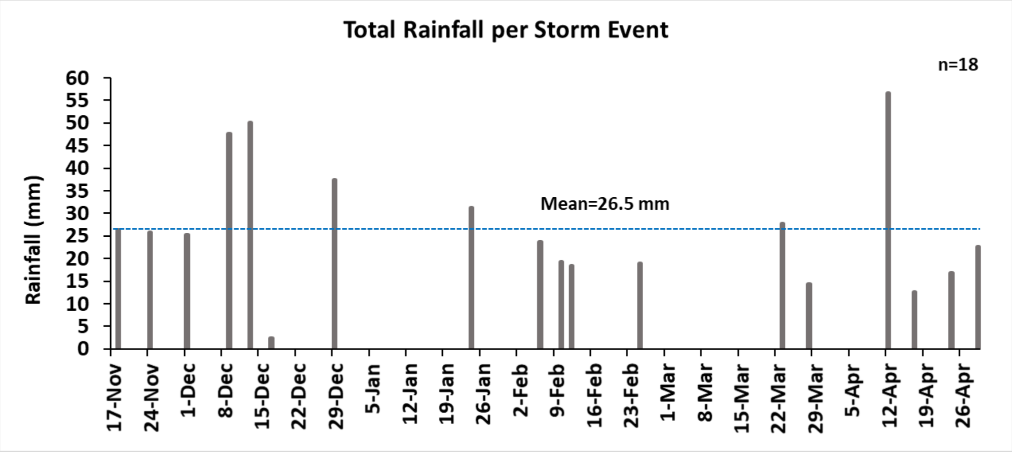

Figure 7. Total rainfall per storm event. Dotted line represents the mean.

Mean Rainfall Intensity

Mean storm fall intensity represents the average amount of rainfall that falls over time. On average, a rainfall's 10-minute mean was 0.20 mm. Expectedly, the highest 10-minute mean took place on April 12th and was 0.52 mm. The lowest 10-minute mean was 0.01 mm and took place on December 17th (Figure 8). Most above average, intense rainfalls occurred between November and January. Though it should be noted, these more intense rainfalls did not regularly produce above average amounts of rainfall during this period (Figure 7). Furthermore, it should also be noted those above average rainfalls occurring after January were more intense than those that occurred in the fall, they just occurred less frequent.

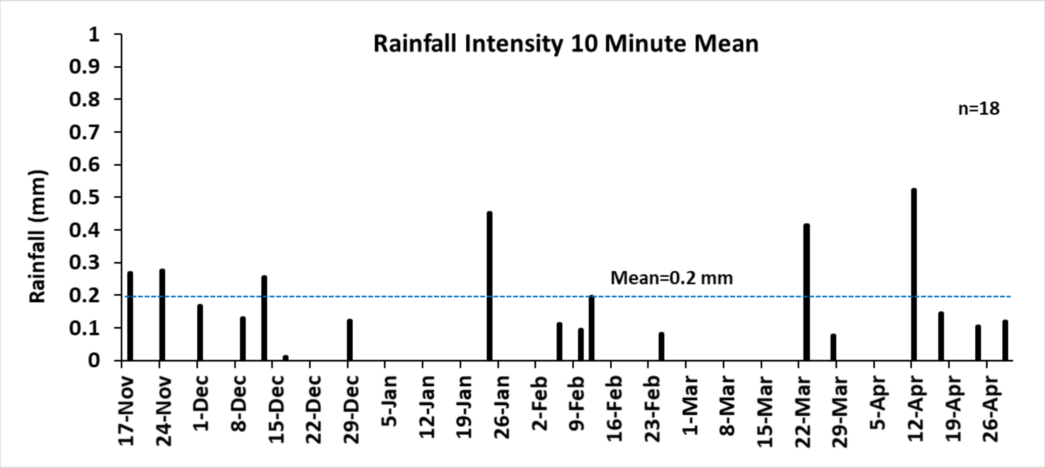

Figure 8. Rainfall 10-minute mean per storm event. Dotted line represents the mean.

Peak Rainfall Intensity

Peak rainfall intensity refers to a storms highest amount of rainfall over time. On average, storms peak at 1.75 mm of rain/10 minutes and ranged from 0.3 mm to 6.4 mm of rain (Figure 9). Seven out of the 18 storm events peaked with amounts above average and two of those storm events barely passed the threshold. It should be noted, while it was over twice as intense then most intense events, the rainfall event with the highest peak intensity, produced only slightly higher than average total rainfall.

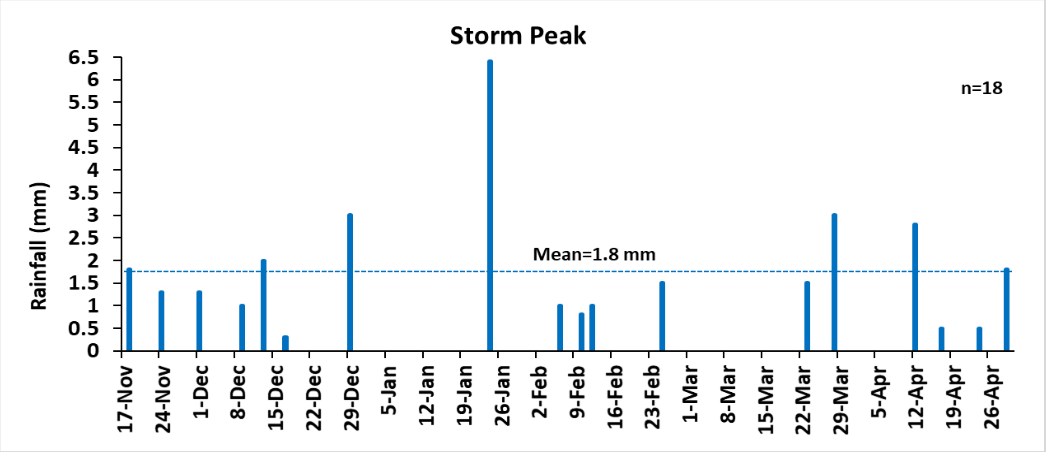

Figure 9. Storm peaks. Dotted line represents the mean.

Rainfall Timing

In addition to the quantity of rainfall produced, two measures regarding the timing of those rainfall events was recorded. First, was the duration of the storm event. Storm durations varied from 11 hours to 61.8 hours. On average a storm event would last 28.2 hours (Figure 10). The longest storm events occurred in December. December also produced the most above average storm events. However, there was a greater frequency of above average storm durations between February and April.

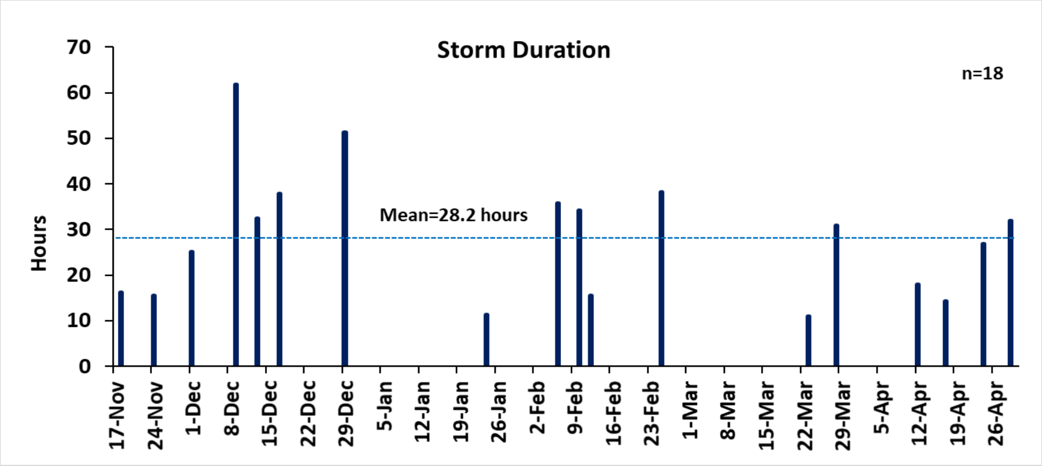

Figure 10. Storm duration per storm event. Dotted line represents the mean.

Second was the delay between the initial onset of the rainfall event and its peak intensity. The storms delay from onset to peak varied from 1 hour to 33.5 hours, with an average of a 12.8-hour delay (Figure 11). Most storm events reached their peak within 10.5 hours. Seven out of the 18 storm events reached their peak with above average delays.

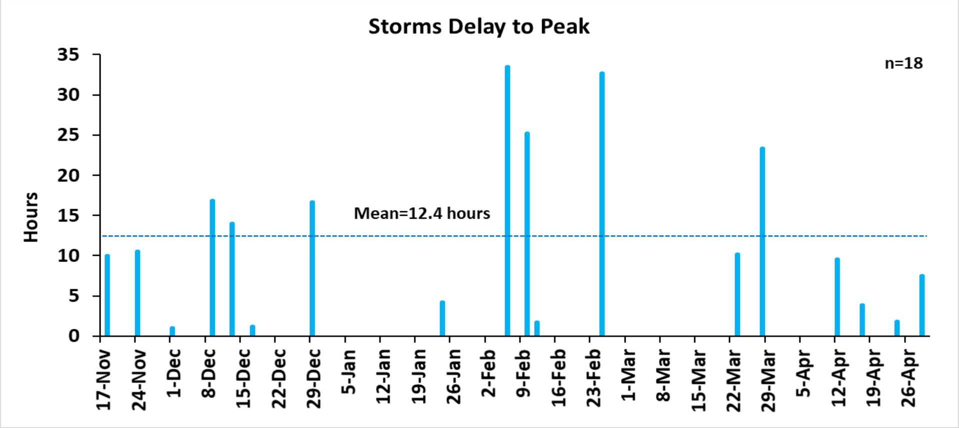

Figure 11. Storm delay to peak. Dotted line represents the mean.

Runoff Event Timing

As the primary focus of this study was to evaluate how effectively the timing of runoff events from large scale parking infrastructures can be disrupted by retrofitting them with a bioswale, the temporal aspects of runoff events were measured in two different ways. The first measure determined if the delay between the peak of the rainfall event and the peak of the runoff event was increased. On average the W1 drainage pipe delays from rainfall peak to peak fill was five hours. W1 longest delay to peak was 20.2 hours and its shortest was 0 hours, meaning that at some point the rainfall and W1 peaked at the same time (Figure 12). Majority of the delays between W1 peaks following the rainfalls peak were below average delays. Six out of the 18 storm events caused above average delays to peak for W1. Five out of the six times W1 peaks delayed above average occurred between February and April.

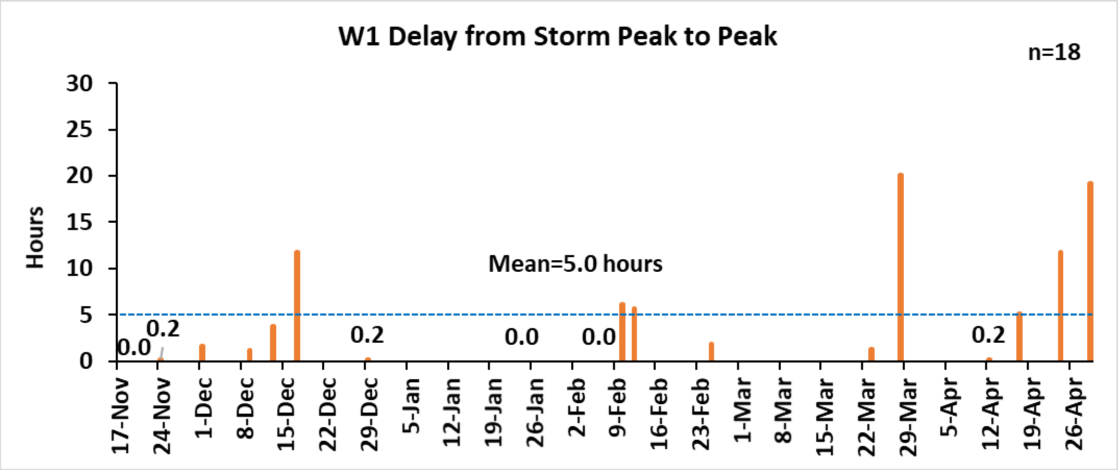

Figure 12. W1 drainage pipe delay from rainfall peak to discharge peak. Dotted line represents the mean.

W2 drainage pipe delays from rainfall peak to peak fill was on average 3.5 hours. W2 longest delay to peak was 19.1 hours and its shortest delay was 0.1 hours (Figure 13). Six out of the 18 storm events produced above average delays from storm peak to peak for the W2 drainage pipe; two of which barely passed the threshold. Most of the W2 above average delays from storm peak to peak fill occurred before January.

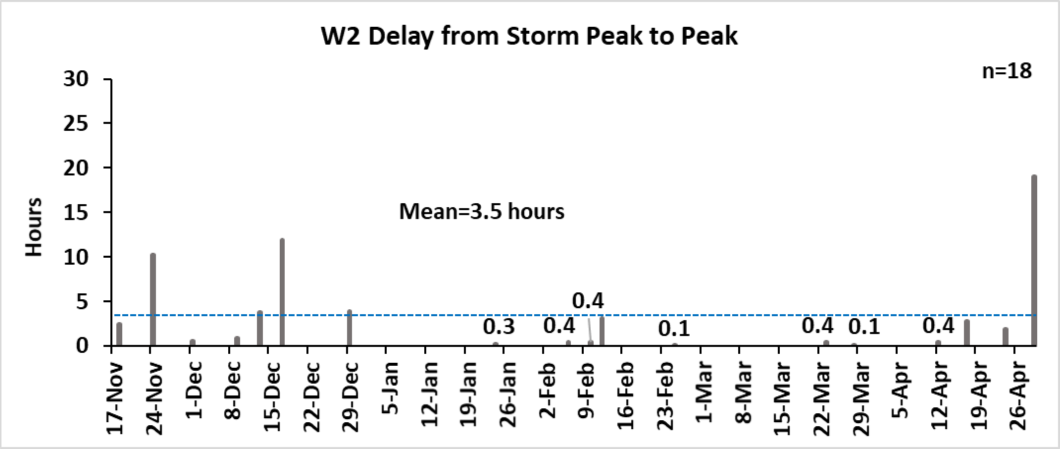

Figure 13. W2 drainage pipe delay from rainfall peak to discharge peak. Dotted line represents the mean. Unnoticeable values were labeled.

The second response variable recorded was the duration of the runoff event. W1 drainage pipe discharge durations on average would last 40.1 hours. W1 quickest discharge lasted 15.7 hours and its slowest discharge lasted 88.2 hours (Figure 14). Seven out of the 18 W1 discharge durations were above average. Five out of the seven above average discharge durations occurred before February. In December, the W1 drainage pipe underwent its longest discharge durations.

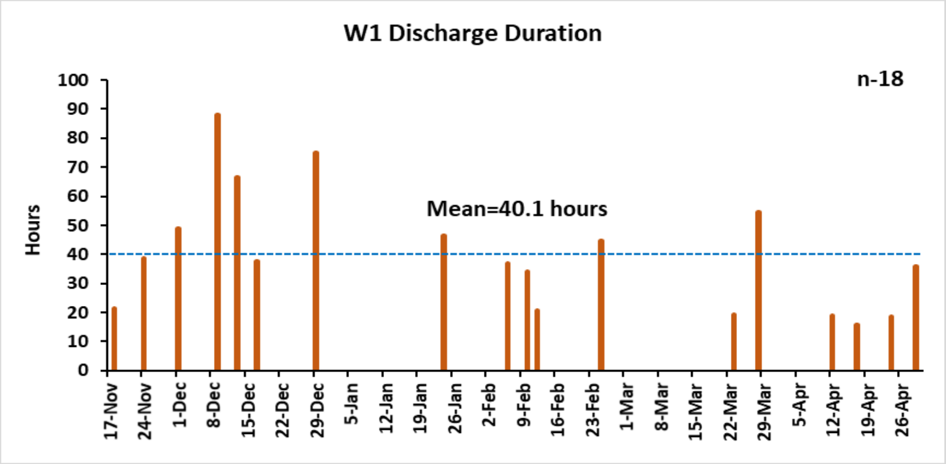

Figure 14. W1 drainage pipe discharge duration. Dotted line represents the mean.

On average W2 drainage pipe discharge durations lasted 33.2 hours and ranged from 15.7 hours to 65.3 hours (Figure 15). Eight of the 10 W2 discharge durations were above average. February and December held the highest frequency of lengthier discharge durations for the W2 drainage pipe.

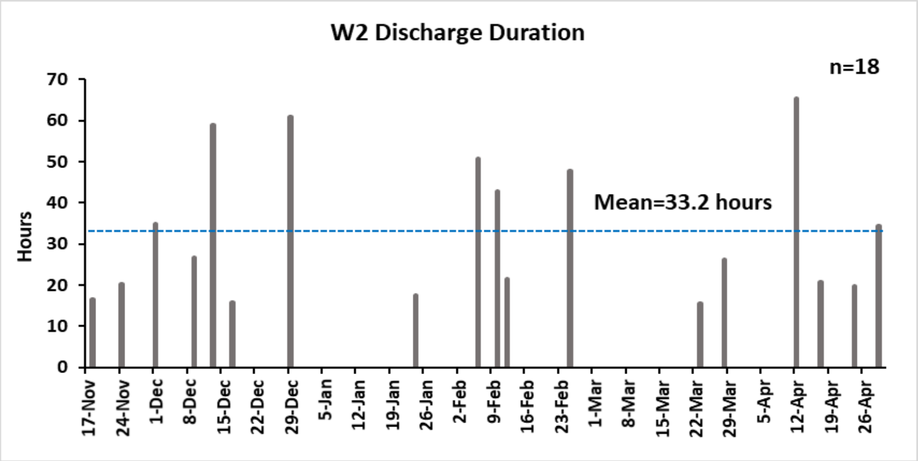

Figure 15. W2 drainage pipe discharge duration. Dotted line represents the mean.

Bioswale

As the results of this study are dependent upon the effective functioning of the bioswale itself, the hydrological response of the bioswale itself was measured on three dimensions. The first measure of peak fill demonstrates the maximum amount of runoff received by the bioswale. For the rainfall events recorded in this study, on average the bioswale would fill to a peak at 0.10 mm of runoff storage. Bioswale peaks ranged from .003 mm to .35 mm of runoff storage (Figure 16). The bioswale peaked above average six times. Five out of the six above average peaks occurred before February. All other below average peaks were due to either small total rainfall accumulation amounts or rapid rates of rainfall and runoff infiltration into the soil.

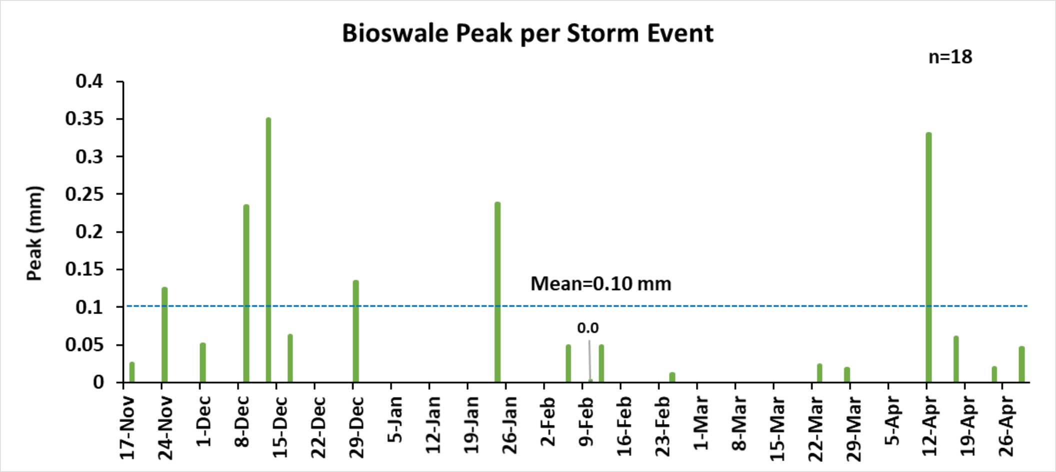

Figure 16. Bioswale peak per storm event. Dotted line represents the mean. Unnoticeable values were labeled.

Bioswale Peak vs. Rainfall Quantities

Figures 17-20 illustrate the relationship between bioswale peaks and rainfall quantities, such as rainfall peak (Figure 17), rainfall discharge duration (Figure 18), rainfall intensity

(Figure 19) and total rainfall (Figure 20). The r-squared values were low for all but one rainfall quantity. With r-squared values of 0.20, 0.47, and 0.31, there is no confident, existing correlation between bioswale peaks and rainfall peaks, rainfall discharge duration, and rainfall intensity. However, with the r-squared value of 0.71 in figure 20, and a p-value of 1.2E^{-5} in the regression analysis test, the idea that the peak amount in the bioswale increases as the total amount of rainfall increases can be supported. Therefore, out of all four rainfall quantities, total rainfall can predict for bioswale peak amounts with an accountability for 70% of its variability, whereas all other quantified measures of rainfall events appear have little to no predictive value.

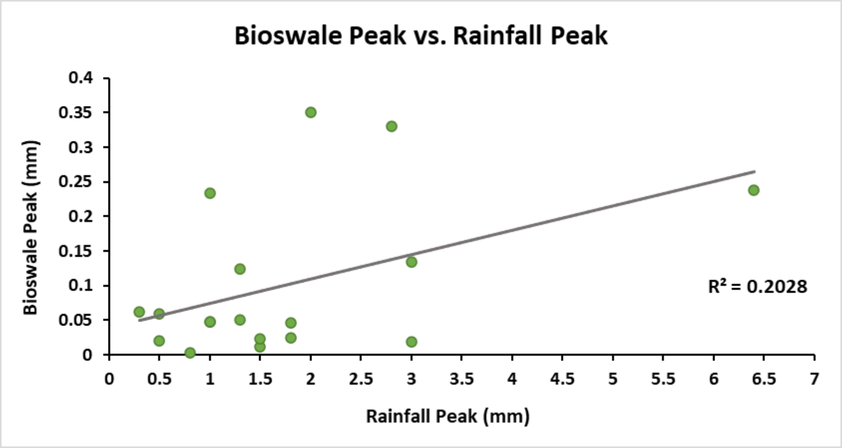

Figure 17. Bioswale Peak vs. Rainfall Peak.

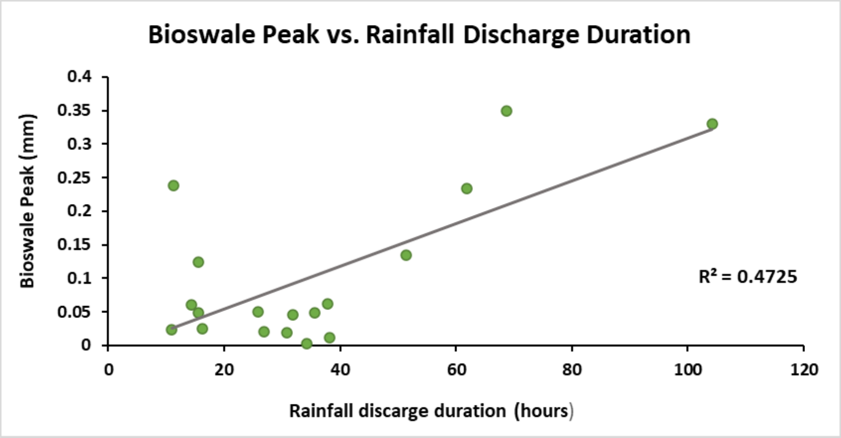

Figure 18. Bioswale Peak vs. Rainfall Discharge Duration.

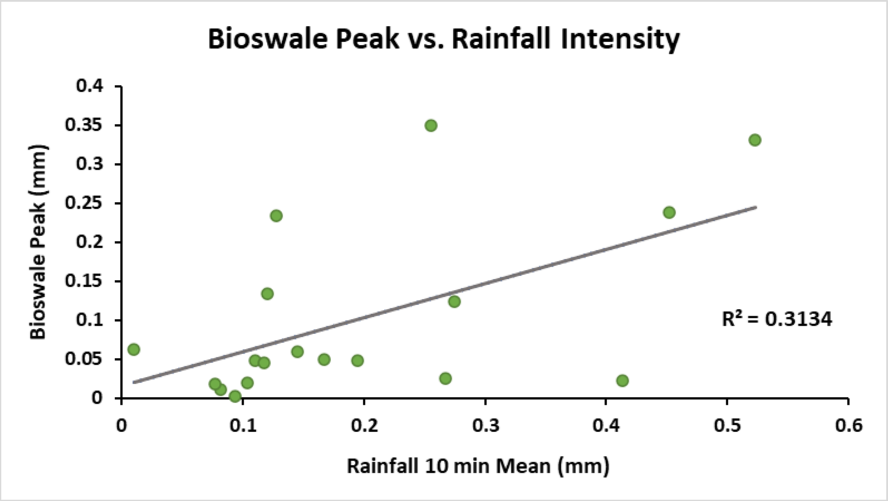

Figure 19. Bioswale Peak vs. Rainfall Intensity.

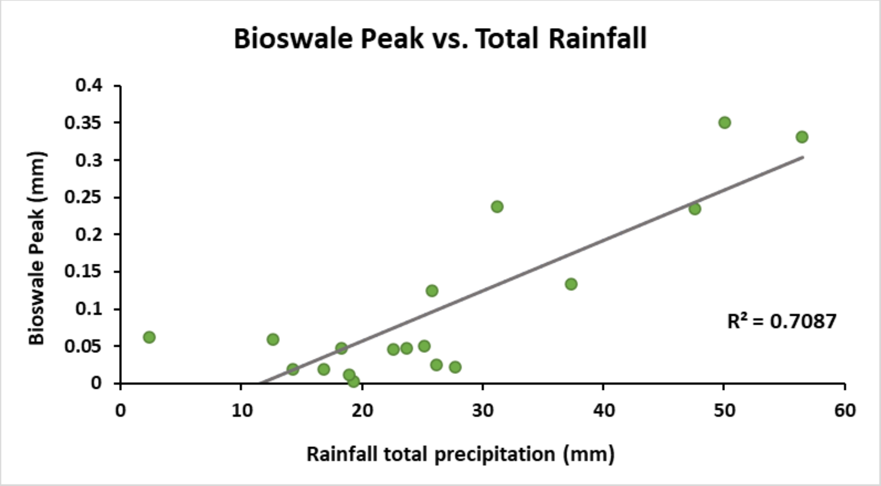

Figure 20. Bioswale Peak vs. Total Rainfall.

The second measure of the bioswale's responsiveness to each storm was the duration of the infiltration event. On average bioswale discharge lasted 24.2 hours and ranged from 5.5 hours to 64 hours (Figure 21). The bioswale retained rainfall above this average duration eight times throughout the six-month data collection period. These longer retention periods occurred between November and January. The bioswale retained rainfall longer all of December and started to discharge more rapidly starting February.

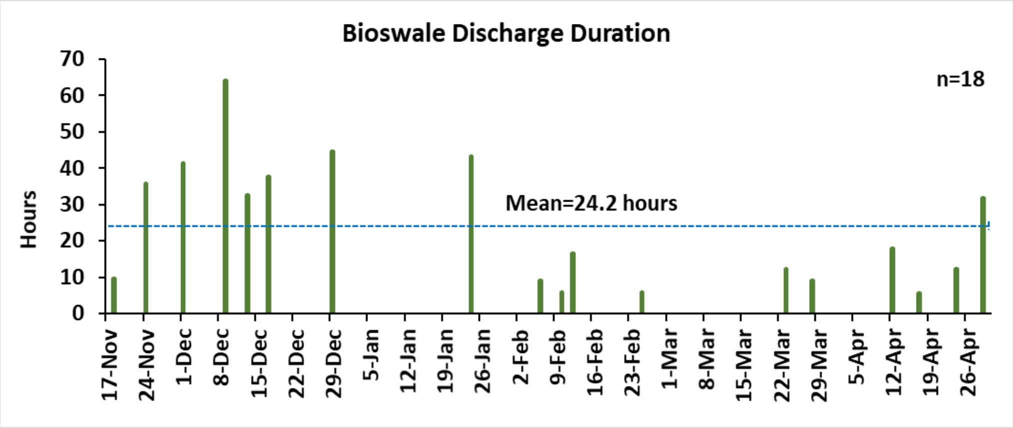

Figure 21. Bioswale discharge duration per storm event. Dotted line represents the mean.

Bioswale Discharge Duration vs. Rainfall Quantities

Figures 22-25 illustrate the relationship between bioswale discharge durations and rainfall quantities such as rainfall peak (Figure 22), rainfall discharge duration (Figure 23), rainfall intensity (Figure 24) and total rainfall (Figure 25). R-squared values of 0.07, 0.05, 0.002, and 0.17 displayed the non-significant correlation between bioswale discharge durations and all rainfall quantities. Therefore, bioswale discharge durations cannot be predicted from rainfall quantities.

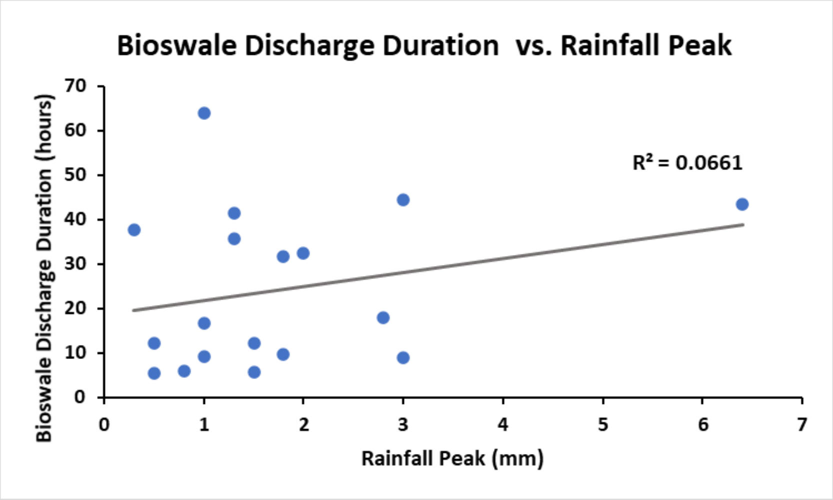

Figure 22. Bioswale Discharge Duration vs. Rainfall Peak

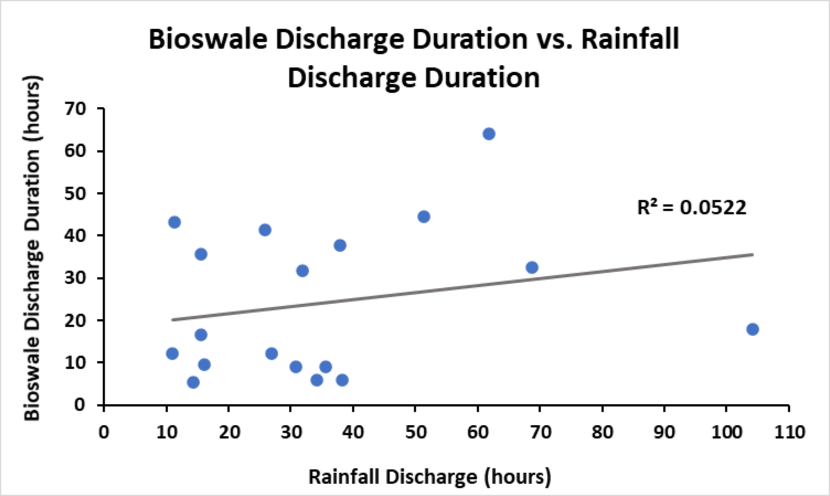

Figure 23. Bioswale Discharge Duration vs. Rainfall Discharge Duration.

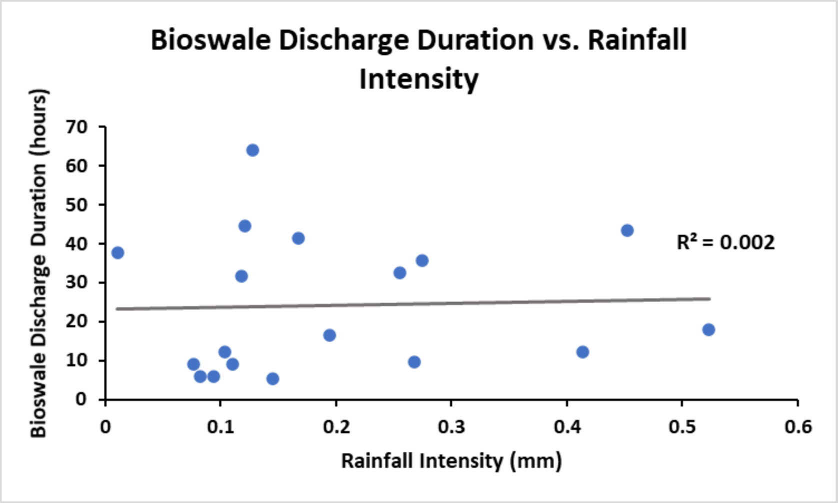

Figure 24. Bioswale Discharge Duration vs. Rainfall Intensity.

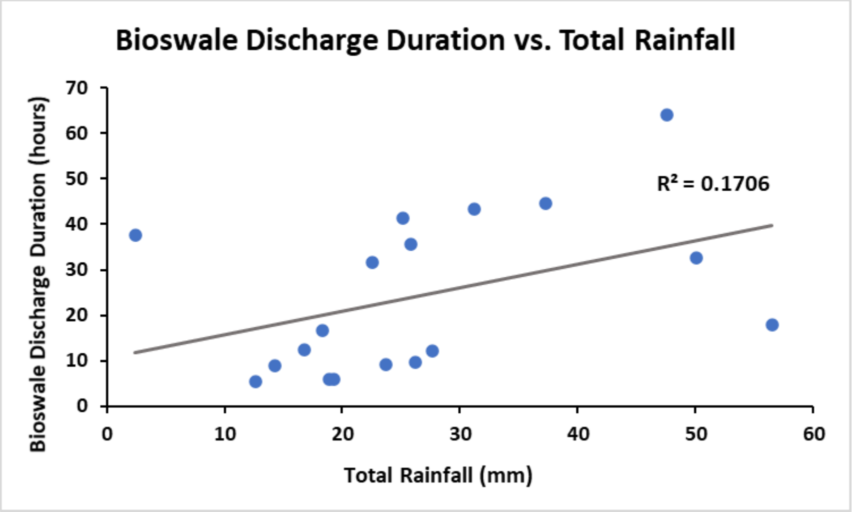

Figure 25. Bioswale Discharge Duration vs. Total Rainfall.

The final measure for the responsiveness of the bioswale was how quickly it fills to the maximum extent for the storm event, recorded. On average it took the bioswale 8.1 hours to reach its peak fill after the storm reached its peak. The fastest the bioswale reached its peak was in 0.5 hours. Its slowest delay to peak was 30 hours (Figure 26). The bioswale delays to peak were above average seven times. The bioswale took the longest to reach its peak twice in December, once in March, and all throughout April.

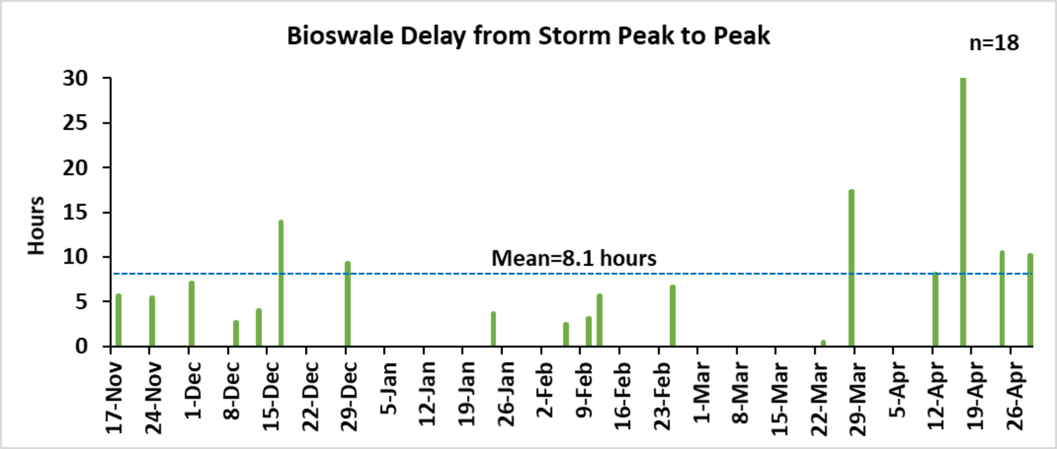

Figure 26. Bioswale delay from storm peak to peak. Dotted line represents the mean.

Peak Runoff Timing Comparison

The two primary response variables evaluated in this study are differences in the timing of peak runoff events and durations between W1 and W2. In terms of peak runoff timing, the bioswale peaked after the W1 drainage pipe on fifteen out of the eighteen storm events (Figure 27). Similarly, the W2 drainage pipe peaked after the W1 drainage pipe on six out of the eighteen storm events (Figure 28). The average difference between the W1 drainage pipe peaks and bioswale peaks was seven hours. The biggest peak difference was 30.7 hours and the smallest peak difference was zero hours, meaning at some point the bioswale and W1 peaked at the same time (Figure 27). The average difference between W2 peaks and W1 peaks was 3.7 hours. The biggest peak difference was 20.3 hours and the smallest peak difference was 0.1 hours (Figure 28).

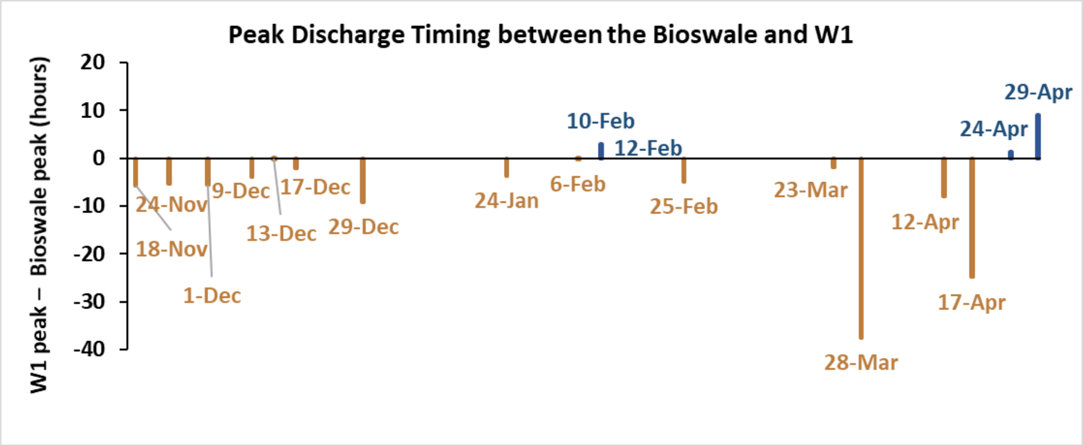

Figure 27. Difference between the W1 drainage pipe peaks and bioswale peaks per storm event. Negative values represent the storm events where the W1 drainage pipe peaked before the bioswale.

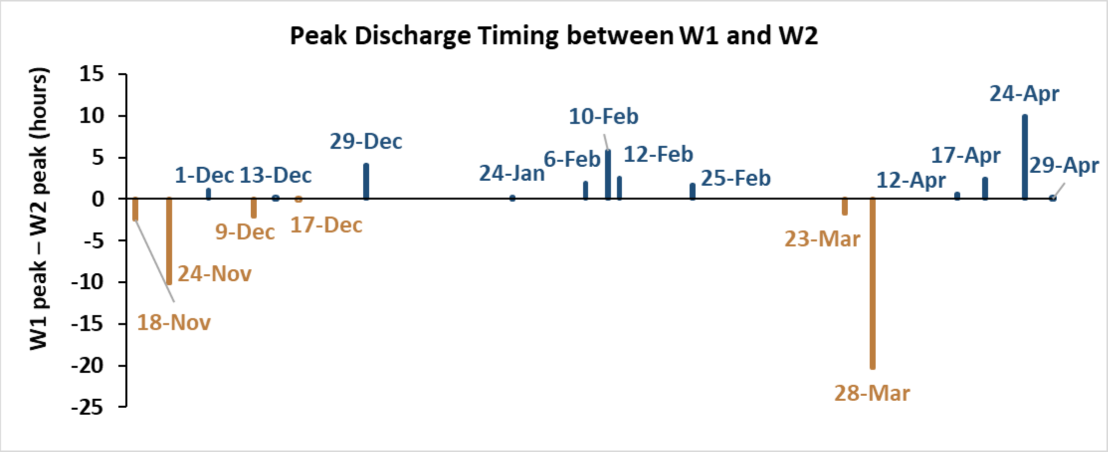

Figure 28. Difference between W2 drainage pipe peaks and W1 drainage pipe peaks per storm event. Negative values represent the storm events where the W1 drainage pipe peaked before the W2 drainage pipe.

Comparisons

On average the bioswale delayed to peak fill longer than W1 and W2. The bioswale would take twice as long as W2, on average, to reach its peak fill after the storm reached its peak. As shown in figure 29, W2 median value and mean was 1.42 hours and 3.5 hours, respectively. W1 median value and mean was 1.75 hours and 5.0 hours, respectively. The bioswales median value and mean was 6.2 hours and 8.1 hours, respectively. W1 and W2 displayed no significant difference between mean or median values. However, the bioswales mean and median values were distinctively higher than both drainage pipes; meaning it takes significantly longer to fill than W1 and W2.

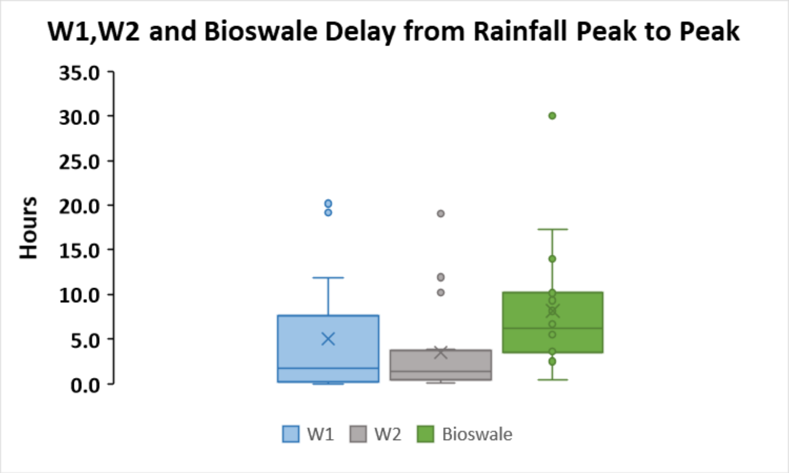

Figure 29. W1, W2, and Bioswale delays from rainfall peak to peak. The x represents the average and the line across each box represents the median.

On average the bioswale would discharge faster than W1 and W2. W1 took almost twice as long as the bioswale, on average, to discharge. W1 had a mean of 40.1 hour discharge durations with a median of 37.3. W2 had on average of 33.1 hour discharge durations with a median of 26.5 and the bioswale had on average 24.2 hour discharge durations with a median of 17 (Figure 30). Again, there was no discernable difference found between W1 and W2 mean and median values, and on average the bioswale did seem to drain quicker than both drainage pipes.

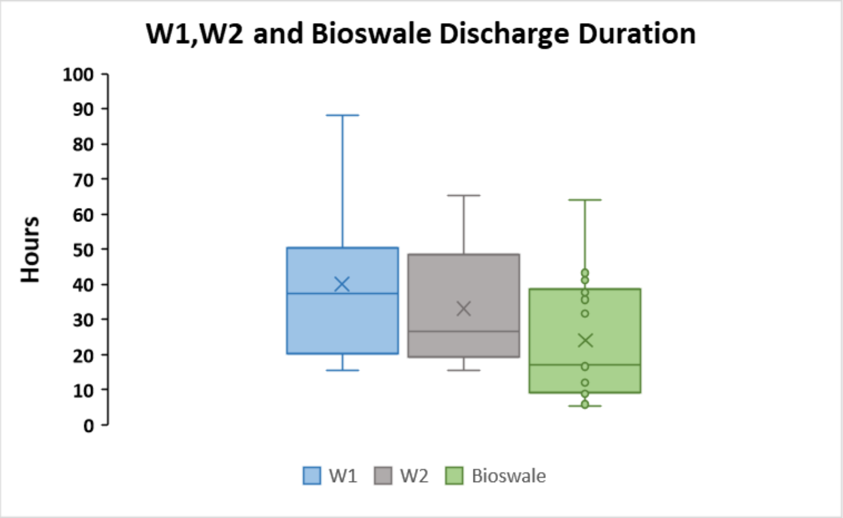

Figure 30. W1, W2 and Bioswale discharge durations. The x represents the average and the line across each box represents the median.

DISCUSSION

Compared to other studies, such as Purvis (2019), the range of total rainfall received over this study was incredibly low. This low range can be accounted for by the dry winter and first month of spring that we experienced. Measured monthly rainfall averages were always short from the expected monthly rainfall averages (Figure 31). In addition, the low range of total rainfall could partially be result of the relatively short data collection period of 6 months. Other studies, such as Purvis (2019) and Qingfu (2017), conducted longer analyses of one to two years respectively, to examine the performance of their tested bioswales. A longer data collection period would have allowed for the possibility of greater storm event frequency and rainfall amounts.

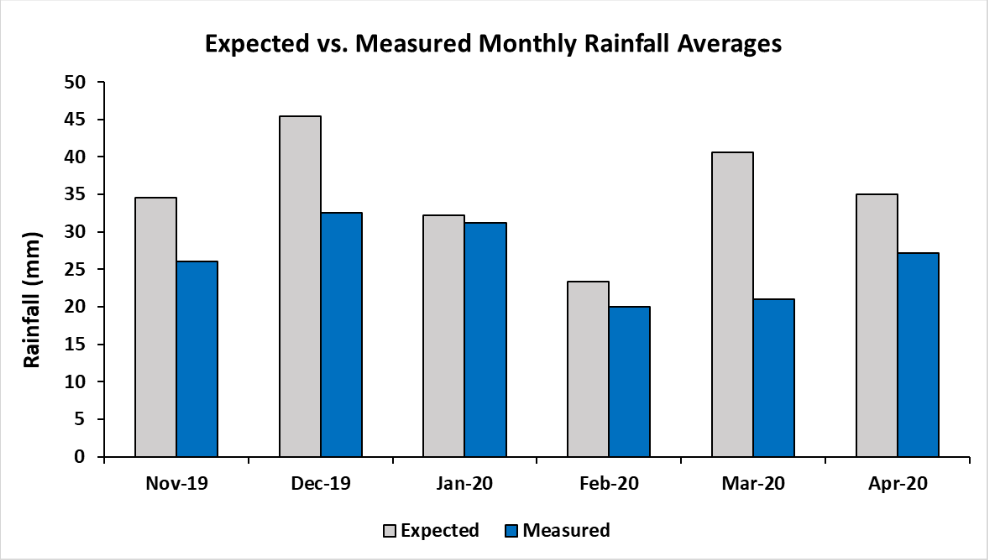

Figure 31. Expected vs. Measured monthly rainfall averages for the 6-month data collection period. Expected rainfall data are from https://www.timeanddate.com/weather/usa/white-plains/climate.

Most rainfalls amounts were below the 24.5 mm average. Only one third of the storm events presented above average rainfall amounts. However, half of the storm events presented above average durations, meaning they lasted at least 28.5 hours. In addition, it is highly unlikely that 28.5-hour storm events would produce 24.5 mm rainfalls.[12] Storm events with such duration periods produce on average 102 to 381 mm of rain.[12] Additionally, it is the 10 to 30 minute storm events that are expected to produce the 24.5 mm rainfall amount that was on average the rainfall experienced in this study. Perhaps, these unusually, small, and extended rainfalls could partially account for the small discharge peaks presented in the bioswale, as small and relatively slow rainfalls would not produce large amounts of runoff. Notably, construction on the W1 parking lot throughout the study period most likely obstructed the stormwater runoff pathway into the bioswale. Reduced access into the bioswale could also account for the small discharge peaks.

Similarly, on 15 out of the 18 storm events the bioswale peaked before the W1 drainage pipe. However, two out of the three storm events in which the W1 drainage pipe peaked after the bioswale occurred during the last two rainfalls, April 24th and 29th. Prior to and during the data collection period there was ongoing construction in the W1 parking lot. It is possible that the construction, e.g. berms intercepted the stormwater runoff. Perhaps the bioswale did not connect until some of the ongoing construction completed and allowed for the runoff to course its intended path. Although, such cannot be conclusive without the analysis of the following months data.

Expectedly, total rainfall was the only variable that could relatively predict bioswale peak, with an accountability for 70% of its variability. Bioswales directly collect rainfall but most importantly receive the runoff the rainfall produces. Rain peak and intensity represent the highest amount of rainfall and the average rainfall over time, respectively. Rain peak and intensity had no predictive value potentially because they only represent one of the two water quantities bioswales collect. Rain duration also had no predictive value because the bioswale does not immediately fully drain when a storm ends, as it continues to receive runoff traversing the parking lot beyond the termination of the storm as well.

Delays from rainfall peak to discharge peak from the bioswale as well as the bioswale discharge durations (Figure 14, 15), seem to have a temporal inverse relationship with one another. Longer discharge durations took place before the month of February. Whereas longer delays from rainfall peak to discharge peak took place after the month of January. This displays a pattern of longer retention rates when experiencing faster runoff fills and supports the idea that slower runoff fills would not accumulate and would infiltrate as they arrive and or more rapidly. To further test the relationship between both variables, bioswale discharge durations and delays from rainfall peak to peak were plotted on a x-y scatter plot (Figure 32). However, despite the temporal pattern in the data, the r-squared value of 0.06 revealed no functional correlation. Although, the shape of my data sparked a potential interest, bioswale discharge duration has no predictive value for bioswale delay to peak fill from rainfall peak fill.

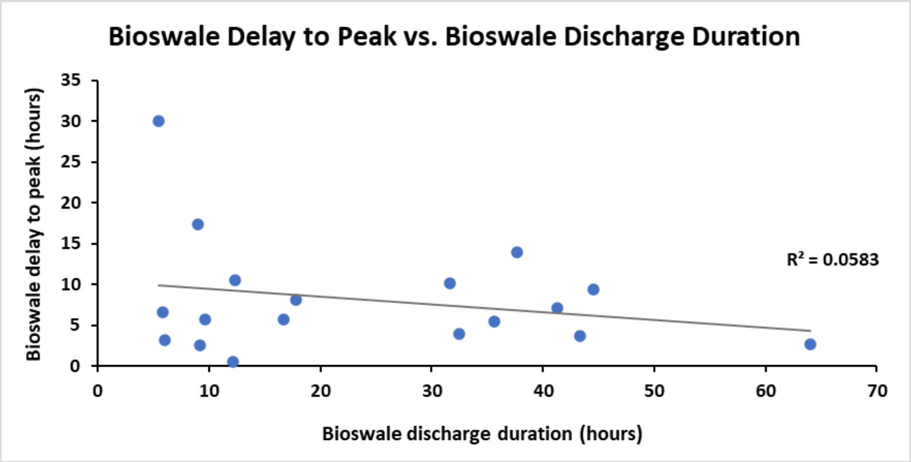

Figure 32. Bioswale delay from rainfall peak to discharge peaks vs. Bioswale discharge durations.

With respect to the comparison of W1, W2 and bioswale delays from rainfall peak to peak discharge, the bioswale did take significantly longer to fill than did W1 and W2. Since there was no definitive difference between W1 and W2 delays to peak, the bioswale did not mitigate peak flows from the W1 lot. Notably, at best W1 had potentially slightly longer detention periods than W2 and the bioswale but it was not significantly different than W2. Therefore, the bioswale significantly did not mitigate runoff volumes experienced in blind brook, either in terms of when peak flows are delivered downstream, or for the length of time the runoff is discharged.

This paired study was expected to show the difference between unmanaged parking lot runoff and managed parking lot runoff. Reduced delays to peak and extended discharge periods were expected as variables of an effective bioswale, as seen in Purvis (2019) and Qingfu (2017). Specifically, W1 was expected to peak after W2 and drain slower than W2 because it received the treatment of the bioswale. However, the data depicted an inconclusive difference in the function of either of those variables. There were many variables that possibly altered expected measures such as the overall dry winter we experienced, and the potential obstruction of intended runoff into the bioswale by construction within the W1 parking lot. Since there is no evidence that W1 performed differently than W2, this test of the effectiveness of the bioswale is inconclusive. It could be argued, however, that the bioswale did function to a certain extent, as seen through W1 demonstrating slightly longer runoff retentions and delays to peak than W2, but since these changes are not significant, it did not perform to the extent needed to conclude the bioswale has provided significant improvement and mitigation of stormwater runoff quantity impairments experienced in Blind Brook, or Long Island Sound. Conceivably what is needed to mitigate quantity impairment is the implementation of other green infrastructures such as permeable pavements, which as shown in Beyerleins (2012) study, resulted in 99.8% runoff volume reduction. In addition, perhaps research should be done on just how much green infrastructure is needed to generate a distinctive mitigated difference.

CONCLUSIONS

The bioswale did work to an extent but its crucial role was to mitigate the runoff peaks and discharge durations between the W1 and W2 parking lots and there was no definitive evidence to support such. There were many variables that possibly altered expected measures of bioswale delay to from rainfall peak to discharge peak and discharge durations, such as the dry winter we experienced, the lower than average rainfall amounts, and the obstruction of the bioswale pathway by construction. A longer study period could also have given better insight to the bioswales functionality with and without construction on the W1 parking lot. Additionally, there are other low impact developments such as permeable pavements and rain gardens that mitigate runoff volumes and pollution and could be implemented on campus.

Purchase College efforts to mitigate its suburban footprint is evident through the many green infrastructures implemented across its campus to reduce its runoff and pollution levels. However, more testing is necessary on the efficiency of the bioswale, as this 6-month runoff quantity analysis depicted inconclusive results. This research can be used as a baseline for future senior projects examining urban hydrology or further testing the efficiency of the bioswale. The bioswale should reduce runoff volumes and increase delays to peak and discharge durations.

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