Final Report

Monitoring Downspouts Years 2 and 3

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For Blue Water Baltimore





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Determining the Efficacy of Simple Downspout Disconnection As a Stormwater Volume Reduction Practice

Downspout disconnection (DD) is a simple, low cost and low maintenance stormwater practice to reduce the amount of runoff and pollutants entering streams and eventually, the Chesapeake Bay. DD is an example of a low impact development, or LID, technique that may be readily adopted by homeowners. Although general practice guidelines and/or criteria for stormwater practices and LID techniques are developed by the State and adopted by local jurisdictions, refinement or modifications to them to address local watershed characteristics may be needed. In the City of Baltimore, an assessment of the potential benefit from DD is evaluated where the benefits of this practice are uncertain due to either, small lot sizes and soil characteristics that limit infiltration, or a combination of both.

Blue Water Baltimore (BWB) received funding from the National Fish and Wildlife Foundation to determine the effectiveness of DD on different soil types to better estimate the water quantity benefits on a watershed basis particularly in the Baltimore metropolitan area. The Center for Watershed Protection was contracted by BWB to develop and implement a monitoring study design to address the following:

- Determine limits to the 20% rule and setbacks as related to storm size
- Determine site requirements needed to capture a 1” storm in Baltimore City and surrounding suburbs
- Develop a working set of standards to estimate overall stormwater reduction from downspout disconnection, or a way to quantify downspout disconnection as a utility discount.

The guiding research question for this study was, “*Do lawns with less permeable or compacted soils have higher runoff volumes than lawns with more permeable soils?*” The report provides the study results and recommendations for DD in the City of Baltimore, MD. The results are applicable to the type of lawns evaluated as part of this study. The small sample size precluded any robust statistical significance testing thus limiting the broader application of the results to a more general population of urban lawns in the Baltimore metropolitan area.

Monitoring Study Design

A field-based experiment was designed to simulate the capacity of urban residential lawns to infiltrate rooftop runoff as a beneficial stormwater practice in the City of Baltimore, MD. A brief description of the monitoring study design is provided with the complete details provided in Appendix A.

A total of fourteen single family residential lawns were assessed to participate in the study, of which six were selected as the final study sites. An initial screening of the property’s physical characteristics was completed to include: slope of the yard, presence of physical obstructions (e.g. trees, posts), outdoor water spigot, turf coverage, and available lawn area. Both front and backyards were eligible study sites. Additional assessments of the lawn soil characteristics was to be completed to classify two types of lawns: compacted and non-compacted; however this was not completed due to project logistics. Soil texture characteristics were completed at the time of the experiment using the finger roll technique, while bulk density measurements were determined as a proxy for compaction, at the end of the study.

The downspout disconnection experiment included the simultaneous simulation of both rooftop runoff and rainfall. The rooftop runoff was generated by running water from the homeowner's spigot at a target flow rate through a 3-foot downspout discharged to a splash pad and onto the lawn to a receiving area. The set-up is shown in Figure 1. A lawn sprinkler was used to simulate rainfall with the same target flow rate as the rooftop runoff. The sprinkler was used to approximate the total amount of rainfall falling on the lawn but was limited in its ability to simulate the true characteristics of rainfall given its oscillation. However, the purpose of the sprinkler was to ensure that the experimental set-up accounted for the total amount of water in contact with the lawn during a precipitation event (e.g. rainfall on the lawn and rooftop runoff). The receiving area was defined by lawn edging and was based upon the low point on the lawn and its natural drainage area up to an area of 300 ft^2. A 2-gallon bucket was placed in a hole at the low point just below the surface of the soil to collect runoff generated from the experiment. The soil-lip of the bucket was sealed with Plumber's Putty to prevent the loss of runoff from the lawn as surface flow, shallow subsurface flow or from the lawn edging.

Figure 1. Monitoring set-up.

Downspout apparatus.

Runoff collection bucket with lawn edging.

Receiving area boundary defined by lawn edging with sprinkler simulating rain event on left hand side.

The target flow rate for the experiment was calculated as 3.12 gallons per minute (gpm). This flow rate was based on the assumption of a1:1 rooftop area to receiving area ratio where the rooftop area was defined at 300 ft^2 and a 1 inch/hr rainfall intensity. The 1 inch/hr rainfall intensity was converted to gpm (or flow rate) using the following equation, where the 300 ft^2 is the rooftop area.

$$300\,ft^2 \times \frac{1in}{hr} \times \frac{1hr}{60\min} \times \frac{7.48gal}{ft^3} = 3.12gal/\min$$

The flow rate was adjusted using this equation when the receiving area was less than 300 ft^2 in order to maintain a simulated 1:1 rooftop area to receiving area ratio.. The 1 inch/hr intensity rainfall event was determined to be representative for the Baltimore area and can account for a range of storms up to the 5-year event. That is, the average recurrence interval associated with this intensity will increase by simulating a fixed intensity over a 2-hour period. For example, after 30 minutes, the intensity simulated will be representative of a high probability storm (more frequent than the 1-year storm). The sustained 1 inch/hr intensity for a 2-hour period approaches the recurrence interval of a 5-year event (see Appendix A for details). Although it would be ideal to test the effect of a range of rainfall types, it was beyond the scope of this study.

The experiment was repeated at each site three times and ran for up to 2 hours with saturated areas delineated every twenty minutes. Soil moisture measurements were taken using a hand held device and used for relative measures of soil moisture rather than actual values before and after the experiment. The experiment was stopped when the amount of water entering the runoff collection bucket was approximately half of the amount of water being placed on the lawn. The 50% volume was based on field logistics to empty the bucket prior to it filling again. The experiments were ideally set-up to be completed within one week to minimize inconvenience to the homeowner with a minimum of 48 hours between experiments and no more than 0.5” of precipitation 24 hours before the experiment. The 48 hours is based on a 1mm/hr infiltration rate for D soils (Dunne and Leopold 1987), where it would take up to 2 days to infiltrate. A copy of the field sheets are provided in Appendix A-1 along with the field method for soil texture characterization.

Results

Runoff reduction was observed from all of the six residential lawns with each of the lawns exhibiting variable runoff behavior in regards to the timing and pattern of runoff. The results are based on seventeen of the eighteen experiments (the experiment repeated 3 times at each of the six sites). The second experiment on Site 6 was removed from the database as the runoff collection bucket was moved for the third experiment. It was found that runoff was pooling during the second experiment at a low point other than the one initially identified. The set of results from the first experiment were kept as the pattern marked by the survey flags showed that the saturated, or runoff-producing areas did not extend to the other low point and therefore it was assumed that no runoff would have been collected for this first experiment, regardless of the bucket location. The majority of the experiments ran for the full two hour duration, with the xception of five experiments (e.g. all Site 3 experiments and two of Site 1). A summary of the study results are presented in Table 1 and described below.

Table1. Summary of downspout disconnection study results.

								Average Runoff Reduction (%)	
Site ID	Bulk Density, sieved (g/cc)	Soil texture	Percent rock, by weight	Turf cover	Receiving area (ft2)	Flowpath length (ft)	Target flow rate (gpm)	1" rainfall	2" rainfall
Site #1	1.8	Clay loam	10.7		240	20	2.50	88	78
Site #2	1.2	Loam	32.8	Mix of weeds & turfgrass with some bare spots	264	22	2.75	100	100
Site #3	1.6	Clay	24.6	Mix of weeds and turgrass, good coverage	266	19	2.8	86	76
Site #4	1.6	Clay	25.7	Mix of weeds and turgrass, good coverage	231	20	2.4	100	89
Site #5	1.5		44.0	zoysia grass, dense coverage	143	13	1.5	100	100
Site #6	1.6	Clay loam	10.3	weeds, minimal turfgrass present	240	16	2.5	100	98

On average, runoff reduction was high for both the 1” and cumulative 2” simulated rainfall events. Runoff reduction ranged from 86% to 100% for the 1” rainfall event with an average of 95% and 76% to 100% for the 2” rainfall event or an average of 90%. Two of the sites did not produce any runoff (Sites 2 and 5). Runoff began the quickest at Site 1 at 20 minutes into the third experiment with bailing the runoff collection bucket soon after at 28 minutes. In contrast, Site 4 did not produce runoff until 1 hour 48 minutes with bailing beginning 3 minutes afterward. Typically, once the bucket filled, runoff entered the bucket at a relatively quick rate filling initially in less than 10 minutes. However, runoff from Site 6 occurred at a relatively slow rate where runoff was observed 35 minutes into the experiment, yet the bucket did not fill until nearly 55 minutes into the experiment. Not surprisingly, the sites and experiments with higher initial soil moisture content and bulk density achieved the least amount of runoff reduction. Although soil moisture was not controlled for this experiment, it appears to be (and is known to be) a factor contributing to the amount of runoff reduction. The patterns of the delineated runoff contribution area, demarcated by the survey flags, also suggest that micro-topography of the lawns may also be an important factor for runoff. For example, pooling of water was observed in lawns with small depressions present. Tables 2a-b summarize the runoff reduction for each experiment at each site.

Table 2a. Percent runoff reduction at 1 hour, or 1” of simulated rainfall.

Site	#1	#2	#3
1	91.3	88	85
2	100	100	100
3	99.6	86.6	71
4	100	99.6	99.2
5	100	100	100
6	100	n/a	99

Table 2b. Percent runoff reduction at 2 hours, or 2” of simulated rainfall

Site	#1	#2	#3
1	n/a	78	78.7*
2	100	100	100
3	90.1	76.8**	62.3***
4	99.3	86.2	82.5
5	100	100	100
6	100	n/a	95

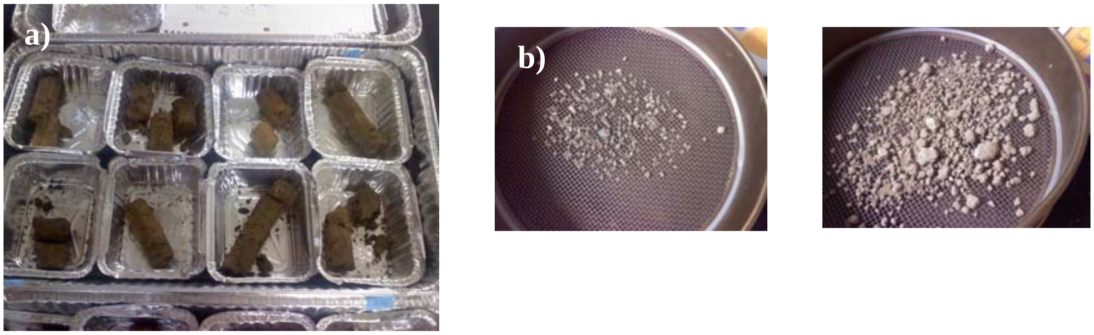
[1*] Measured at 1 hr 54 minutes, but 5.5" of water remaining in bucket.
[2**] Runoff stopped at 1 hr 44 min. End of experiment at 1.5 hrs, no additional water input
[3***] Runoff stopped at 1 hr 45 min. End of experiment at 1 hr 20 min. no additional water input

Soil texture characteristics were found to be mostly clay or clay loam soils based on the finger roll test with bulk densities ranging from 1.2 to 1.8 g/cc. These values are consistent for clay loam and clay soils where a normal range is given as 1.0 g/cc to 1.6 g/cc (Brady, 1990). Soils with bulk densities approaching 2.0g/cc are considered to be highly compact. Table 3 shows the range of soil and land cover bulk densities for comparison purposes. The bulk densities were corrected for the pebble content of the soil as two of the six sites were found to have a significant amount of pebble content in the surface soil when setting up the experiment and taking soil samples. The pebble content for the soils ranged, on average from 10% to 44%. Images of the soil samples are shown in Figure 2. The two sites with the lowest bulk densities and highest pebble content were the sites that had 100% runoff reduction. The remaining four sites had variable runoff responses, although the runoff reduction from all sites is considered high.

Table 3. Soil bulk densities (g/cc) for a range of soil types and cover conditions.

Soil Type or Cover Condition	Surface Bulk Density (g/cc)
Undisturbed Soils	
Compost	1.0
Sand	1.1 to 1.3
Silty Sand	1.4
Silt	1.3 to 1.4
Silt Loam	1.2 to 1.5
Clay	1.0 to 1.2
Glacial Till	1.6 to 2.0
Disturbed Soils	
Pasture	1.4 to 1.5
Urban Lawns	1.5 to 1.9
Athletic Fields	1.8 to 2.0
Asphalt	2.2
Concrete	2.2 to 2.3

Figure 2. Example images of soil samples and their pebble content, a) Soil samples from Sites 5 and 6, b) a comparison of pebble content from soil samples.



Analysis

The results of the study are used to address the following:

- Determine limits to the 20% rule and setbacks as related to storm size
- Determine site requirements needed to capture a 1" storm in Baltimore City and surrounding suburbs
- Develop a working set of standards to estimate overall stormwater reduction from DD, or a way to quantify DD as a utility discount.

Determine limits to the 20% rule and setbacks as related to storm size

The "20% rule" is a reference to the Center for Watershed guidance on sizing stormwater practices in Manual 3 of the Urban Subwatershed Restoration series (CWP,2007). Specifically, it states that,

> *Rain gardens and infiltration practices can be sized as a fraction of the impervious surface that drains to them. In general, the surface area of the practice should be about 10 to 20% of the impervious drainage area. Additional guidance on these practices can be found in Appendix F.* (p 139).

The "20% rule" does not apply to simple downspout disconnection where the rooftop runoff is directed to a pervious area and there is no modification of the soil to facilitate infiltration or volume excavated for storage.

This study evaluated a 1:1 ratio of rooftop drainage area to pervious receiving area. The current rule for downspout disconnection in Maryland is limited to a maximum rooftop area of 500ft^2 with a minimum flow path length of 15ft. The minimum flow path length for all sites was met with the exception of Site 5 that had a length of 13 ft. However, Site 5 had 100% runoff reduction and after the full two hour duration of the experiment, the saturated area was at a maximum of 6.2' from the downspout (or less than ½ of the flow path length). At Site 6, the saturated area slowly progressed throughout the experiment to a maximum of 14.4' for the first hour of the first experiment and reached the full length of 16' for the 3rd experiment. At the other sites, the runoff reached the collection bucket by the first hour, or 1" of rainfall. For example, it was estimated that the linear distance from the downspout to the edge of the saturated area was approaching or reached the 20ft flow path length for Sites 1, 3 and 4. However, the pattern or areal extent of the runoff varied considerably from site to site. For example, the saturated area for Site 3 was linear in nature as it expanded from the downspout to the bucket, then spread outwardly whereas Sites 1 and 4 expanded laterally from the downspout and then moved as a 'wave' or 'front' to the bucket. Based on these results it may be concluded that the minimum flow path length of 15ft is needed to capture all or part of the runoff from a 1" rainfall, however in this limited set of experiments the average was closer to 20 ft.

The study results are based upon a 1:1 rooftop to receiving area. An increased rooftop to receiving area ratio may be assumed based on the data generated from this experiment. For example, when soil moisture content was low at the beginning of the experiment (e.g. first set of experiments at the site), the lowest runoff reduction estimated was 91.3% following a one hour duration or, cumulative 1” of simulated rainfall (see Table 2a). Theoretically, if the rooftop: receiving area was increased to 2:1, it may be assumed that approximately 45-50% of the runoff may be retained or infiltrated on site given dry soil moisture conditions. The results suggest that for these relatively small simulated rooftop drainage areas of less than 300 ft^2 with varied soil conditions that the 1:1 ratio is adequate to reduce runoff produced for 1” and even up to 2” rain event. Although not evaluated as part of this study, a larger ratio of rooftop impervious area to receiving area may suffice and should be at a maximum 2:1 to achieve 50% runoff reduction when soil conditions are dry. The scaling of this ratio, however, is based on the assumption that this relationship is linear, when in reality the data and other research show the highly nonlinear relationship between soils and runoff.

Determine site requirements needed to capture a 1” storm in Baltimore City and surrounding suburbs

The average percent runoff reduction from the study sites was estimated to range between 71% and 100% after a simulated 1” rain event (at the 1 hour mark in the experiment based on the three experiments at each site) (Table 2a). Sites 2 and 5 had 100% runoff reduction, or no runoff. The results suggest that the 15ft minimum flow path length is needed to reduce runoff from the 1” rain event. The results showed that after 1” of simulated rainfall the distance from the downspout to the collection bucket was saturated when runoff occurred. This distance ranged from 16 to 20 ft for the study sites, or an average of 19.6ft. A flow path length that is anything less than the average of 19.6 ft would likely result in less runoff reduction, or runoff occurring sooner. Given the small sample size for this study, there is not enough evidence to modify the Maryland rule for residential sites in Baltimore.

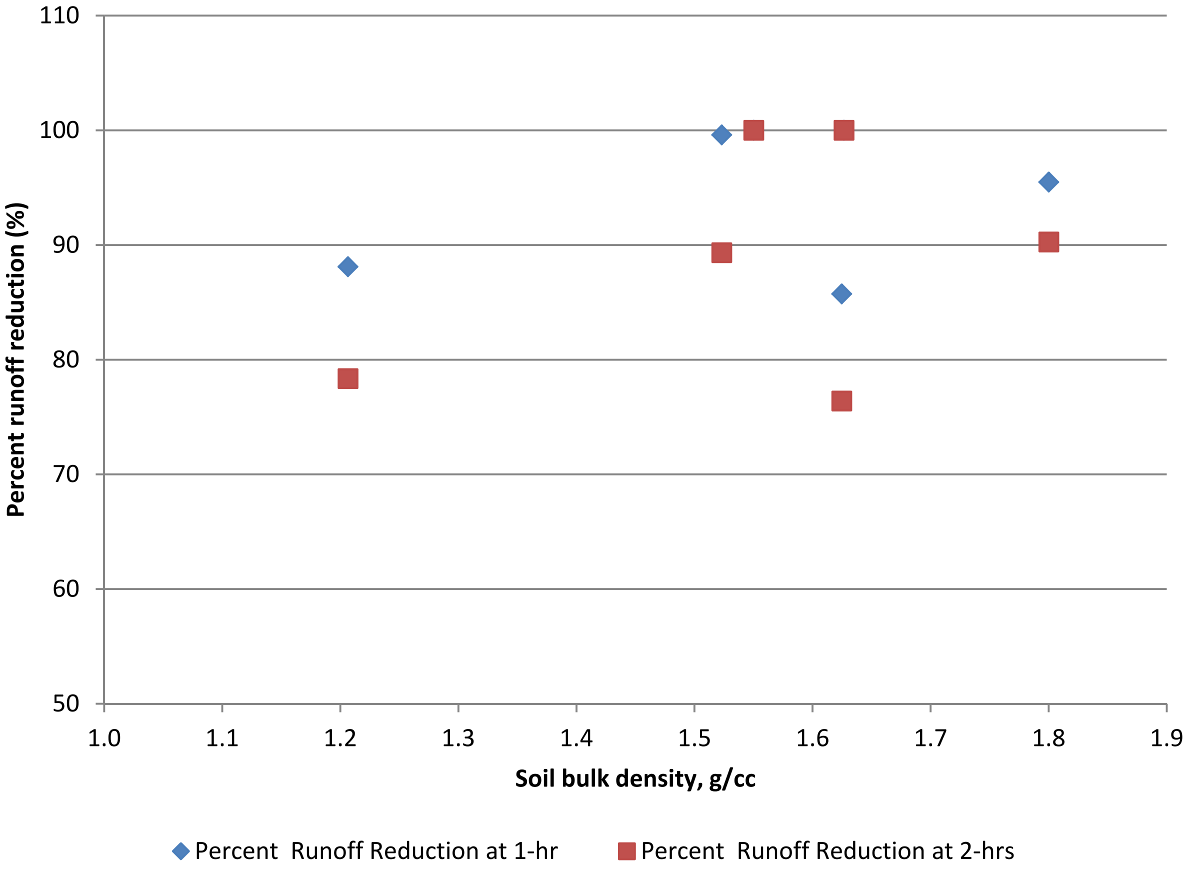
Table 4. Minimum infiltration rates for different soil types (source Dunne and Leopold 1987)

Soil Group	Infiltration rate (mm/hr)
A	8-12
B	4-8
C	1-4
D	0-1

Soil characteristics may also affect the runoff reduction. The soil characterization completed for this study found a range in soil bulk densities (1.2 – 1.8 g/cc), similar soil type/texture, and a range in pebble content (10.3 to 44%). A general trend is shown, where soils with higher bulk densities had lower runoff reduction (Figure 3). The two sites with the lowest soil bulk densities and higher pebble content did not produce any measurable runoff throughout the experiments. The bulk densities along with soil texture suggest that the study sites had C soils (Dunne and Leopold 1987). It is likely soils at Site 1 were compacted given its higher bulk density of 1.8 g/cc Soils are considered compacted when bulk densities are greater than 1.6 g/cc. Reported infiltration rates for different soil types (e.g. A, B, C, D) suggest that runoff reduction may be reduced for soils with lower infiltration rates (e.g. D soils) (Table 4), as well as compacted soils. Additional evaluation of soils in urban residential lawns in Baltimore would be recommended to ensure the runoff reduction values obtained through this study are characteristic, or may vary based on other soil characteristics.

The results are encouraging and suggest that downspout disconnection may reduce a significant percentage of rooftop runoff. However, general conclusions from the data on specific site

Figure 3. Runoff reduction (as percent) as a function of soil bulk density (g/cc).



requirements for downspout disconnection are limited given the small sample size. For example, despite the general trend, there is not a strong relationship between bulk density and runoff reduction, as soils with a bulk density of 1.6 g/cc had variable runoff response ranging from 86% to 100% for the simulated 1” rainfall - all relatively high (Figure 3) and all soils were characteristic of clay or clay loam soils. Specific site and soil characteristics may have affected runoff response. For example, the monitoring set up for Site 2 was adjacent to a large tree where roots deeper in the soil could have facilitated infiltration, even though roots were not encountered during the experiment (e.g. during set up or soil sampling). Further, soil moisture may have affected runoff response. It was determined that 48 hours would be sufficient time between experiments to allow the water from the previous experiment to infiltrate into the soil. It is likely that this may have impacted the runoff reduction for the subsequent experiments as there was a consistent trend of reduced runoff reduction behavior at all sites as the experiment was repeated, with the exception of Sites 2 and 5 that did not produce any runoff.

Develop a working set of standards to estimate overall stormwater reduction from downspout disconnection, or a way to quantify DD as a utility discount

While the small sample size included in this study may preclude definitive conclusions, it is clear that the experimental set-up employed (1:1 rooftop to receiving area ratio, 13’-20’ flow path) was sufficient to eliminate the majority of expected runoff from a 1” storm. If applied conservatively, this information can be used as the basis for a working set of standards for downspout disconnection. CWP recommends that the following criteria be used to assess the appropriateness of downspout disconnection projects:

- A minimum flow path of 15’ of pervious cover from the downspout is available.
- The drainage area for the downspout is less than 500 ft^2.
- The pervious cover has a mild slope (less than 5%)
- The pervious cover is well-vegetated with minimal bare spots.
- Soil bulk density less than 1.6 g/cc or soils that are not compacted
- Opportunities for flow channelization or inadvertent reconnection to impervious surfaces (i.e., an adjacent driveway too close to the downspout) are negligible.

The 15’ flow path and 500 ft^2 are the current rules for the State of Maryland and do not warrant modifications to these two standards at this time for residential properties in the City of Baltimore. Results of the study suggest that smaller receiving areas are adequate and can be accommodated in a variety of residential settings in the city.

If these criteria are met, then it may be assumed that the annual runoff reduction achieved will be:

- 90% for a 1:1 rooftop to receiving area ratio.
- 45% for a 2:1 rooftop to receiving area ratio.

The 90% runoff reduction for annual rainfall is based on the Maryland stormwater guidance for water quality volume treatment and the typical rainfall frequency spectrum for the mid-Atlantic region. In general, the Maryland Stormwater Design Manual states that capture and treatment of the 1” storm equates to90% of the average annual runoff. This is because the rainfall analysis for the mid-Atlantic finds that the majority of rainfall events (i.e., 90%) are one inch in depth or less (DeBlander et al., 2008).

The study results suggest that a 1:1 ratio for small rooftop areas (e.g. less than 500 square ft) may reduce 95% of a 1” storm event and 90% on average for 2” of rain. Given that the 1” per hour rainfall simulated for this study was delivered over a shorter time period compared to the design 1” in 24-hour storm, it may be assumed that similar runoff reduction may be achieved and conservatively estimated at 90%. Using this rationale and the study results, it is suggested that the 1:1 ratio would adequately reduce 90% of the runoff generated from the annual rainfall and that a 2:1 ratio may treat 45% of the runoff. As the ratio of rooftop to receiving area increases, the validity of this study in predicting runoff response in the receiving area becomes less. More study may be beneficial to assess the effects of different rooftop to receiving area ratios to verify the response in these situations.

Conclusions and Recommendations for Further Study

An assessment of the potential benefit from DD was evaluated to determine the benefits of this practice on small lot sizes and soil characteristics that limit infiltration, or a combination of both. The percent runoff reduction measured by the difference between the amount of rainfall and measured runoff was used to evaluate the benefit from DD. Of the six study sites, the average runoff reduction was 95% for the 1” rainfall and 90% for the 2”. Two of the sites had 100% runoff reduction. The results are based on an average of three experiments at each site, where the pattern, rate and volume of runoff varied for each experiment likely due to soil characteristics, micro-topography and soil moisture conditions.

A 1:1 ratio between rooftop area and receiving area was to evaluate the effectiveness of DD for rooftop areas 300 ft^2 in area. The area was selected based on the target 1” rainfall that was simulated and translated to a flow rate for experimental purposes (e.g. 3.12 gpm). The 20% rule, or receiving area of 20% of the impervious drainage area, for rain gardens and infiltrating practices does not apply to downspout disconnection as there is no modification of the soil to facilitate infiltration or volume excavated for storage.

The study results suggest that DD can be a successful practice on small residential lots in the City of Baltimore, where a specific set of criteria are met. Although the study represents a small sample size that limit broader application of the results, results consistently showed that the experimental set-up employed (1:1 rooftop to receiving area ratio, 13’-20’ flow path) was sufficient to eliminate the majority of expected runoff from a 1” storm. If applied conservatively, this information can be used as the basis for a working set of standards for downspout disconnection based on the physical characteristics of the site and land cover as well as soil characteristics.

Overall, the study provided promising results for the broader application of the DD in the City of Baltimore and the following recommendations are made to more fully investigate the benefits of this practice.

1. Evaluate the effect of larger ratios of rooftop to receiving area (e.g. 2:1, 4:1) and control for additional parameters such as soil moisture and soil types.
2. Increase the participation level in the study to statistically evaluate the results that would include varied soil types and levels of compaction. The bulk density tests completed for this study found that most sites were not compacted, with the exception of Site 1. A soil is considered compacted if it has bulk density greater than 1.6 g/cc, or penetrometer readings greater than 2,068 kPa (300 psi) (Craul 1999; Pitt et al. 1999).
3. Use a penetrometer to differentiate between compacted and non-compacted soils along with infiltration testing on the urban residential lawns. The soil testing for this study suggests that the study sites were C-soils that could significantly reduce runoff volumes from the 1” rainfall.

Special thanks to Ian Yesilonis from the USDA Forest Serve, Northern Research Station for use and assistance with soil sampling equipment, Andy Miller, Suzanne Braunschweig, Chris Swan from the University the University of Maryland Baltimore County Department of Geography and Environmental Systems for use of the lab to process soil samples.

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APPENDIX A

MONITORING STUDY DESIGN

Study Design to Monitor Runoff Reduction

Using Simple Downspout Disconnection

1.0 Background

Downspout disconnection (DD) is a simple, low cost and maintenance stormwater practice to reduce the amount of runoff and pollutants entering streams and eventually, the Chesapeake Bay. DD is an example of a low impact development, or LID, technique that may be readily adopted by homeowners. Although general practice guidelines and, or criteria for stormwater practices (e.g. Best Management Practices, BMP and Low Impact Development, LID) are developed by the State and adopted by local jurisdiction, refinement or modifications to them to address local watershed characteristics may be needed. In the City of Baltimore, an assessment of the potential benefit from DD is evaluated where the benefits of this practice may be questioned due to either, small lot sizes and soil characteristics that limit infiltration, or a combination of both.

1.1 Purpose of Monitoring Study and Monitoring Objectives

The data generated from the monitoring project will be used to evaluate and refine the following:

- Develop a working set of standards to estimate overall stormwater reduction from DD, or a way to quantify DD as a utility discount
- Determine limits to the 20% rule and setbacks as related to storm size
- Determine site requirements needed to capture a 1” storm in Baltimore City and surrounding suburbs

1.2 Study Site Description

Site Selection

Six sites were identified by Blue Water Baltimore using a contact database based on the following criteria:

- Receiving area of 300 ft^2 with approximate dimensions of a pervious flow path of at least 20 feet and width 15ft.
- Receiving area has uniform slope and is less than 5%
- Receiving area has 100% turf cover (no bare spots) and is free of obstructions (trees, walkways, etc)
- Lawn age two years or greater

Initial site visits to identify potential sites based on physical site characteristics above. Based on this assessment, Blue Water Baltimore will contact the homeowners to determine their interest to participate in the study. Once an agreement between the homeowner and BWB is met, soil tests to determine the infiltration and/or bulk density of the soil will be made to classify the sites as “A” or “B”. Ideally, the objective is to have 3 to 4 sites in each category.

2.0 Monitoring Approach

The monitoring study will generate data to estimate the amount of runoff reduction that may be achieved through downspout disconnection on residential properties in Baltimore City.

2.1 Monitoring Set-up

The monitoring set-up was designed to simulate both rooftop runoff discharged through a downspout and rainfall falling on the lawn. Figure 1 illustrates the experimental set-up. Rainfall will be simulated through a downspout and a sprinkler at each site for the established flow rate. Two garden hoses are to be run from spigots at the residential homes to a constructed downspout and a sprinkler. Each hose will be connected to a flow meter to regulate the flow coming from the spigots. The receiving area for the rooftop runoff was delineated based on the identification of the low point in the lawn and an area measuring up to 300 square feet. The 300 square feet is selected to be representative of the area draining one downspout in a typical downtown Baltimore single family residence. This area was also selected to accommodate the generally small lawn areas and the targeted rainfall intensity for this study of 1 inch per hour.

Figure 1. Experimental site set-up.

Install a graduated 2- gallon bucket at the low point in the lawn as the natural overflow point. The lip of the bucket is located slightly below the ground surface and sealed with plumber's putty to prevent water from flowing behind the bucket and to prevent the loss of any runoff. Twenty feet is measured from the collection bucket which determines the location of the simulated downspout setup. Landscape edging is installed from the collection bucket to the simulated downspout, maintaining a width of 15' for the drainage area. The purpose of the lawn edging is to help contain and direct runoff to the collection bucket. The lawn edging should be placed so that the side with the lip is facing the interior of the receiving drainage area. This will convey water that hits the edging directly into the collection bucket thus preventing the loss of any runoff as a result of lateral flow outside of the collection area. Soil remaining from the excavation of the ground bucket should be used to backfill along the outside of the edging trench in order to "seal" it to prevent loss of potential runoff underneath the edging. A hand trowel should prove to be particularly helpful in this task of backfilling.

Once the receiving drainage area has been delineated, the total amount of square footage is used to determine the target flow rate (Section 2.2). Flow meters should be field tested and calibrated if necessary at the beginning of each simulation. For each simulation, an antecedent dry period of 48 hours is targeted based on the estimated infiltration capacity of D soils (e.g. 1mm/hr from Dunne and Leopold 1987). A simple garden soil moisture probe will be used to provide relative soil moisture levels at each site prior to and after the completion of the experiment. Measurements will be taken at both 3" and 6" depths to evaluate the effect of infiltration and subsurface flow.

2.2 Methods: Empirical and Sampling Techniques

I. Precipitation Analysis and Target Flow Rate

Precipitation Analysis

Precipitation Data for the site location Baltimore WSO City, MD was obtained from NOAA's National Weather Service Precipitation Frequency Data Server. Precipitation depth and intensity data for the 1 year frequency storm event are as follows:

1 year, 24 hour duration =	2.67 in, 0.11 in/hr
1 year, 1 hour duration =	1.18 in, 1.18 in/hr
1 year, 30 min duration =	0.95 in, 1.89 in/hr

Given the expected design of the monitoring study it will not be feasible or cost-effective to adjust the simulated flow rate over time nor run the test for a duration exceeding 2 hours. Based on this information and the precipitation record, it is recommended that the study target a simulated fixed rainfall intensity (i) at1 in/hr for a 2 hour duration. Figure 2 depicts the recurrence interval curves for intensity versus storm duration. Table 1 outlines the effect of this simulation over the study duration. By simulating a fixed intensity over the 2-hour time span, the average recurrence interval associated with this intensity will increase. After 30 minutes, the intensity simulated will be representative of a high probability storm (more frequent than the 1-year storm). The sustained 1 in/hr intensity for a 2 hour period approaches a recurrence interval of 5-years event. Therefore, the 1 in/hr intensity is viewed as typical for the Baltimore area, and is representative of a range of storms up to the 5-year reoccurrence interval.

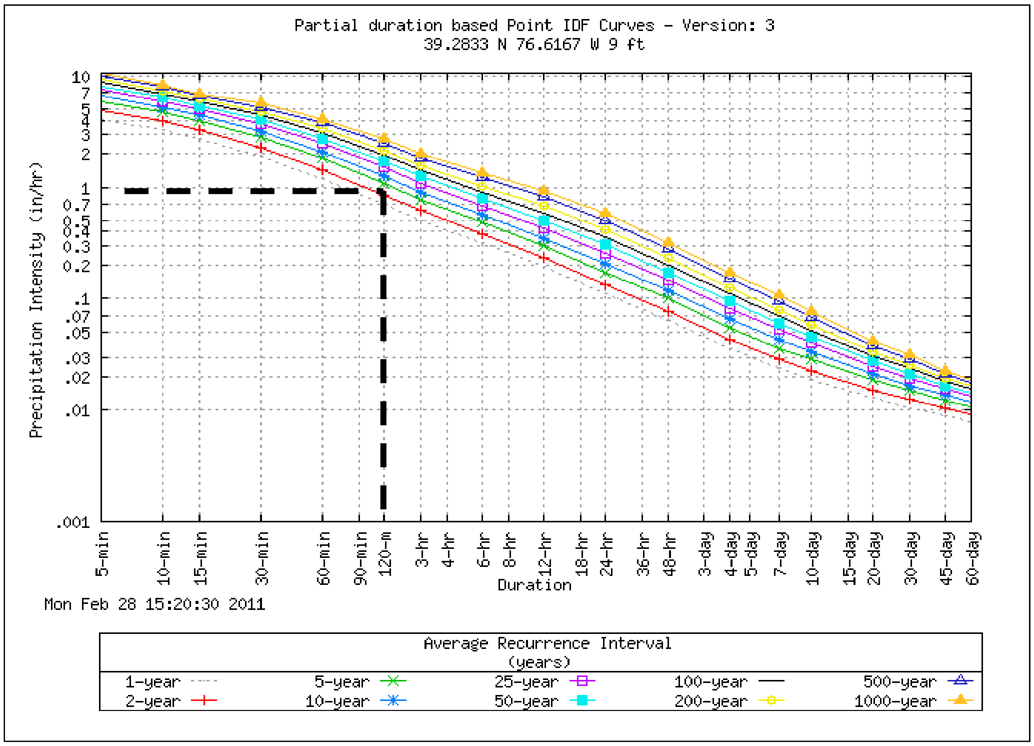


Figure 2. Recurrence interval curves for precipitation intensity for Baltimore City, MD. (Source: NOAA)

Table 1. Simulated Rainfall Characteristics over the study Duration				
Time	**30 min**	**60 min**	**90 min**	**120 min**
Cumulative Rainfall	0.5 in	1 in	1.5 in	2 in
Intensity	1 in/hr	1 in/hr	1 in/hr	1 in/hr
Approx. Avg. Recurrence Interval	<<1-year	<1-year	2-year	5-year

Target Flow Rate

In order to determine an appropriate flow rate for the simulation of a 1 in/hr storm event, the following assumptions were made:

- The space available for the downspout disconnection simulation is at least 15’ deep by 20’ wide.
- The runoff simulation will assume a 1:1 drainage area to receiving area ratio.
- The effect of downspout change in elevation is negligible. A several foot drop in downspout elevation would result in the formation of faster travelling water droplets. These droplets would likely disburse upon hitting the bottom of the downspout and be distributed across the lawn as a constant flow rate. Since the overall flow rate of runoff would not increase nor decrease it is assumed that the difference due to the change in elevation is negligible.
- The effect of the simulated rainfall falling simultaneously on the lawn will be simulated through the use of a hose and sprinkler set-up which will deliver water onto the lawn at the same flow rate

Disconnection Area = 300 square feet (15’ length x 20’width),
1:1 drainage area to receiving area ratio = 300 SF rooftop area

$$300\ ft^2 \times \frac{1\ in}{hr} \times \frac{1\ hr}{60\ min} \times \frac{7.48\ gal}{ft^3} = 3.12\ gal/min$$

Therefore, a flow rate of approximately 3.12 gal/min should be used. However in the cases where it was not possible to meet the 300 square foot receiving area requirement, the flow rate was reduced proportionally to maintain simulation of the 1:1 relationship.

II. Runoff Reduction

The day prior to the experiment, the receiving area is identified and the lawn edging installed. The turfgrass should be mowed to a height of 2” as needed at this time. The downspout and sprinkler are to be set-up for each experiment.

Runoff Collection

The volume of runoff generated is estimated based on the runoff collected in the 2-gallon bucket. The size of the bucket was determined based on the need to disturb the homeowner’s lawn to the minimal extent as practical for experimental purposes. The collection bucket will be graduated with 1” marks. Once the water in the bucket reaches the 7” depth, water will be rapidly bailed with a 28 oz graduated “bailing bucket”. The volume of the runoff is estimated based on the following details recorded on the field sheets provided in Appendix A-1 with the following information:

- The start bailing time
- End bailing time to determine the rate of runoff
- The ending depth of the water in inches in the collection bucket
- The number of buckets bailed as well as the volume bailed

Total amounts of runoff collected will be recorded in a runoff collection data sheet. The experiment will be terminated prior to the 2 hour duration when the water that is being bailed is equal to 50% of the water being put onto the lawn. This is due to the practical ability to empty the runoff collection bucket (e.g. 6 quarts in approximately 30 seconds based on a flow rate of 3.12gpm).

$$6\ qts \times \frac{1}{x\ gpm} \times \frac{1\ gal}{4\ qts} \times \frac{60\ sec}{1\ min}$$

Where x gpm is the flow rate of one flow meter.

Repeat the simulation 3 times at each site with a minimum of 48 hours in between each test and less than one half inch of rainfall in the interim. The data generated from the experiment will be entered into a database to evaluate the relationship of surface runoff volume to rainfall depth.

To understand the behavior of the runoff throughout the duration of the experiment, the extent of the overland drainage will be determined and recorded at 20 minute “delineation intervals”. At these times the drainage area will be inspected for “saturation” as indicated by surface ponding and the boundaries marked by surveyor flags. The areas will then be measured for their length and width and recorded on a data collection sheet (Appendix A-1) so that different drainage patterns over the course of the experiment can be analyzed.

IV. Soil Characteristics

Each site is to be classified based on the physical texture characteristics of the soil through a simple field assessment technique (see Field Sheets for method in Appendix A-1). Soil samples are to be taken from the lawn where the experiment was conducted and 3 soil samples, approximately 6” in length taken using a soil corer. The volume of the samples recorded and samples dried at 105 degrees Fahrenheit for 24 hours and weighed. Soil cores with pebble or gravel-like content involves an extra step where the sample is sieved using a 2mm sieve after being oven dried. The volume of the rock is estimated dividing the bulk density of quartz (2.65 g/cc) by the rock mass. The soil bulk density is based on the soil mass and the revised volume (I. Yesilonis, USDA Forest Service, pers. comm.)

2.3 Equipment and Supply Needs

- Access to homeowner water supply
- Shovels for digging
- Plastic Garden Edging (8-12” high)
- 3 gallon collection bucket graduated with 1” marks
- Plumbers putty
- Graduated water bailer
- Two 50’ heavy duty kink free hoses
- Two 1-10 gpm flow meters
- Constructed downspout
- Sawhorse
- Zip ties
- Downspout splash pad
- Hand-held Soil Moisture Probe
- Marking flags to delineate inundation area
- Hand trowel
- 50’ tape Measure
- Clipboards
- Stopwatches
- Calculator

2.4 Monitoring Study Timeline

Sampling is to begin in June 2011 and be completed by the end of September 2011.

2.5 Data QA/QC

A project team member should be identified to be responsible for the oversight of QA/QC development and implementation. The major elements to be included in a QA/QC plan for the field monitoring and the data analysis are listed below.

Field

- Study site set-up
- Flow meter verification

At each site a project team member will verify that the study site has been set-up according to the prescribed criteria. This includes checking that the lawn edging has been installed correctly, with the lip side facing in toward the receiving area, and that the edging is packed firmly into place without any gaps that would result in the loss of runoff. Additionally, confirming that the collection bucket was placed in the lowest point of the receiving area and that the total square footage of the receiving area is 300 ft^2. In the case where the 300 ft^2 area was not able to be met, the flow rate would need to be adjusted accordingly (see Section 2.2). Prior to the start of each experiment the flow meters are to be tested to ensure they are working properly. This is done by setting the flow to the predetermined flow rate and timing the amount of time it takes to fill a bucket a known volume.

An example field form is provided to record the date, time, site characteristics and experimental observations (Appendix A-1). These field forms are kept in a project binder or entered into an electronic database. This information helps to ‘red flag’ unusual conditions or samples that may need further evaluation.

Data Management

Data management requires the continuous review of data collected to ‘red flag’ any suspicious data. It is recommended that data QA/QC be performed after each experiment. The data QA/QC process of this project will require a review of the results database and comparison between runoff measurements and “rainfall” depth. Notes for each experiment are to be included in the database to identify specific issues encountered at each site for each experiment.

APPENDIX A-1

FIELD FORMS

DOWNSPOUT DISCONNECTION

DD

SITE ID:	**DATE: __/__/____**	**ASSESSED BY:**

SITE CHARACTERISTICS

Property Address:

Soil Compaction: ☐ Group A – High Compaction ☐ Group B – Low Compaction

Soil Texture Characterization: *(using the directions on back)*

☐ Sand ☐ Loam ☐ Silt Loam ☐ Clay Loam ☐ Clay

Take 6-10 measurements at 3” and 6” at various points in the study area at beginning and ending of experiment.

Beginning Soil Moisture:

3”	6”	3”	6”

please note if taken in kPa or psi, relative

Ending Soil Moisture

3”	6”	3”	6”

please note if taken in kPa or psi, relative

SITE PREPARATION

Pretest flow rate of spigot at house days in advance? ☐ Yes ☐ No

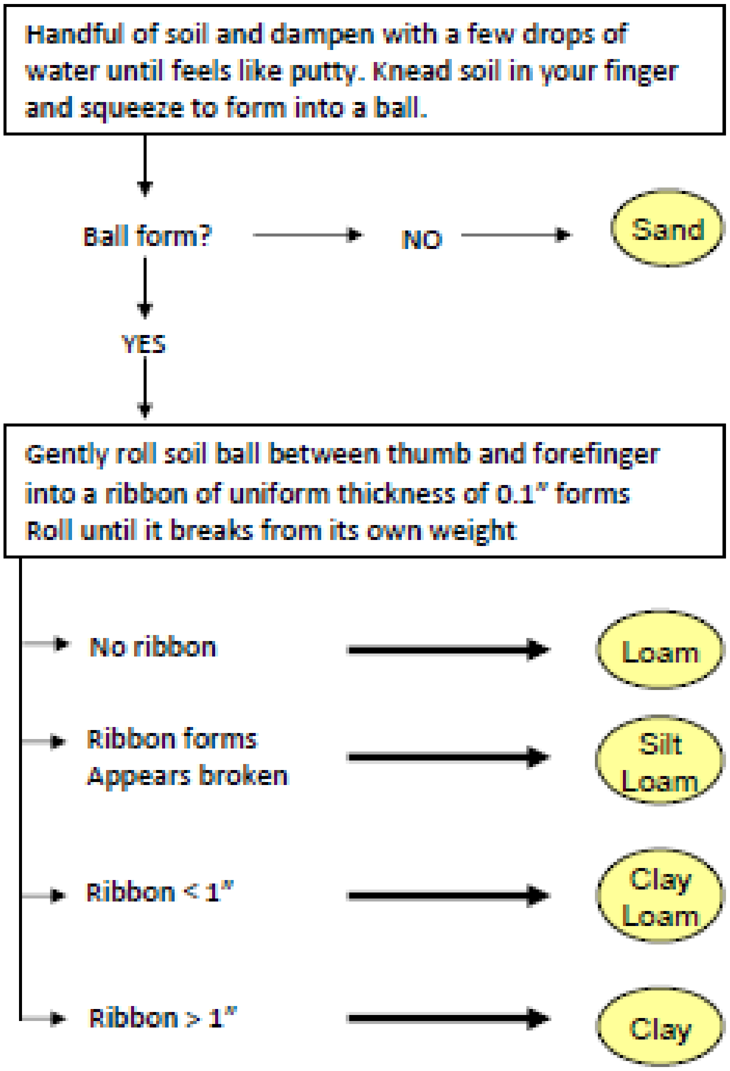
Field verification of flow rate? ☐ Yes ☐ No *To be performed **3** times prior to experiment*

Flow Rate (gpm):		Time to fill (sec):		Flow Rate Check: *(see below)*	
D	**S**	**D**	**S**	**D**	**S**
1.		1.		1.	
2.		2.		2.	
3.		3.		3.	

Flow Rate Conversion Calculations:

$$\frac{80\ ounces}{x\ secs\ to\ fill} \times \frac{60\ sec}{1\ min} \times \frac{1\ gal}{128\ oz} = gallons\ per\ minute$$

D	S
1.	1.
2.	2.
3.	3.



Circle factors found in field.

Sand = gritty; Silt = smooth like flour; Clay = shiny, sticky

Factor	Sand	Loam	Silt Loam	Clay Loam	Clay
Grains visible	Yes	Some	Some	No	No
Ball form	No	Moderate	Yes	Yes	Yes
Ribbon	No	No	Broken appearance	Yes Will break	Yes Stable, very long

RUNOFF OBSERVATION SHEET		
SITE ID:	**DATE: __/__/____**	**ASSESSED BY:**
Runoff observed?	☐ Yes → Time: ☐ No	☐ Surface Flow ☐ Subsurface Flow _*If possible to determine_

GROUND BUCKET NOTES – *note the level of water in ground bucket every 5 minutes until begin to get runoff then move onto Bailing Section*

Time	Level (inches)	Time	Level (inches)
0:5:00		1:05:00	
0:10:00		1:10:00	
0:15:00		1:15:00	
0:20:00		1:20:00	
0:25:00		1:25:00	
0:30:00		1:30:00	
0:35:00		1:35:00	
0:40:00		1:40:00	
0:45:00		1:45:00	
0:50:00		1:50:00	
0:55:00		1:55:00	
1:00:00		2:00:00	

BAILING NOTES –*Begin bailing when water reaches 7” in the bucket;*
Use the following equation to determine when to stop bailing:

$$6\,qts \times \frac{1}{x\,gpm} \times \frac{1\,gal}{4\,qts} \times \frac{60\,sec}{1\,min}$$

	Begin Bailing Time (**min:sec**)	End Bailing Time (**min:sec**)	# of buckets bailed	Volume Bailed + **units**	Ending Depth in Ground Bucket (**inches**)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

	Begin Bailing Time (**min:sec**)	End Bailing Time (**min:sec**)	# of buckets bailed	Volume Bailed + **units**	Ending Depth in Ground Bucket (**inches**)
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					

DOWNSPOUT DISCONNECTION **DD**

	Begin Bailing Time (**min:sec**)	End Bailing Time (**min:sec**)	# of buckets bailed	Volume Bailed + **units**	Ending Depth in Ground Bucket (**inches**)
44					
45					
46					
47					
48					
49					
50					
51					
52					
53					
54					
55					
56					
57					
58					
59					
60					
61					
62					
63					
64					
65					
66					

Unique Site ID:_______

	Begin Bailing Time (**min:sec**)	End Bailing Time (**min:sec**)	# of buckets bailed	Volume Bailed + **units**	Ending Depth in Ground Bucket (**inches**)
67					
68					
69					
70					
71					
72					
73					
74					
75					
76					
77					
78					
79					
80					
81					
82					
83					
84					
85					
86					
87					
88					

FLOW RATE CHECK SHEET						
SITE ID:			**DATE:__/__/____**			**ASSESSED BY:**
Time (min)	Flow rate (gallons/min) *If varying by +/- 0.1 adjust flow accordingly.*		Adjusted flow?			Notes (note when runoff begins & surface/subsurface flow)
	Downspout	Sprinkler	Y/N	New Flow Rate		
				Downspout	Sprinkler	
0:0:00						
0:5:00						
0:10:00						
0:15:00						
0:20:00						
0:25:00						
0:30:00						
0:35:00						
0:40:00						
0:45:00						
0:50:00						
0:55:00						
1:00:00						
1:05:00						
1:10:00						
1:15:00						
1:20:00						
1:25:00						
1:30:00						
1:35:00						
1:40:00						
1:45:00						
1:50:00						
1:55:00						
2:00:00						
Bold times indicates time to delineate drainage area						

SKETCH – 20 MINUTE DELINEATION		
SITE ID:	**DATE: __/__/____**	**ASSESSED BY:**

SKETCH – 40 MINUTE DELINEATION		
SITE ID:	**DATE: __/__/____**	**ASSESSED BY:**

SKETCH – 60 MINUTE DELINEATION		
SITE ID:	**DATE: __/__/____**	**ASSESSED BY:**

SKETCH – 120 MINUTE DELINEATION		
SITE ID:	**DATE: __/__/____**	**ASSESSED BY:**

SKETCH – 140 MINUTE DELINEATION		
SITE ID:	**DATE: __/__/____**	**ASSESSED BY:**

SKETCH – 2 HOUR DELINEATION		
SITE ID:	**DATE: __/__/____**	**ASSESSED BY:**