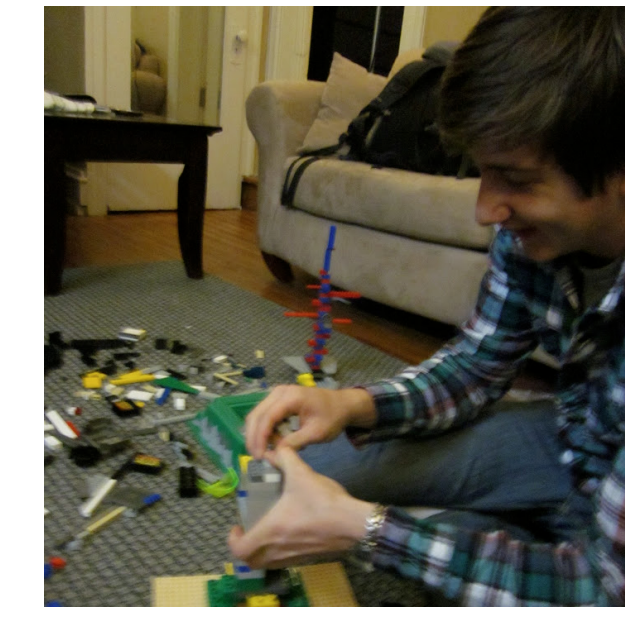


Quantifying urban green stormwater infrastructure performance with hydrologic abstractions

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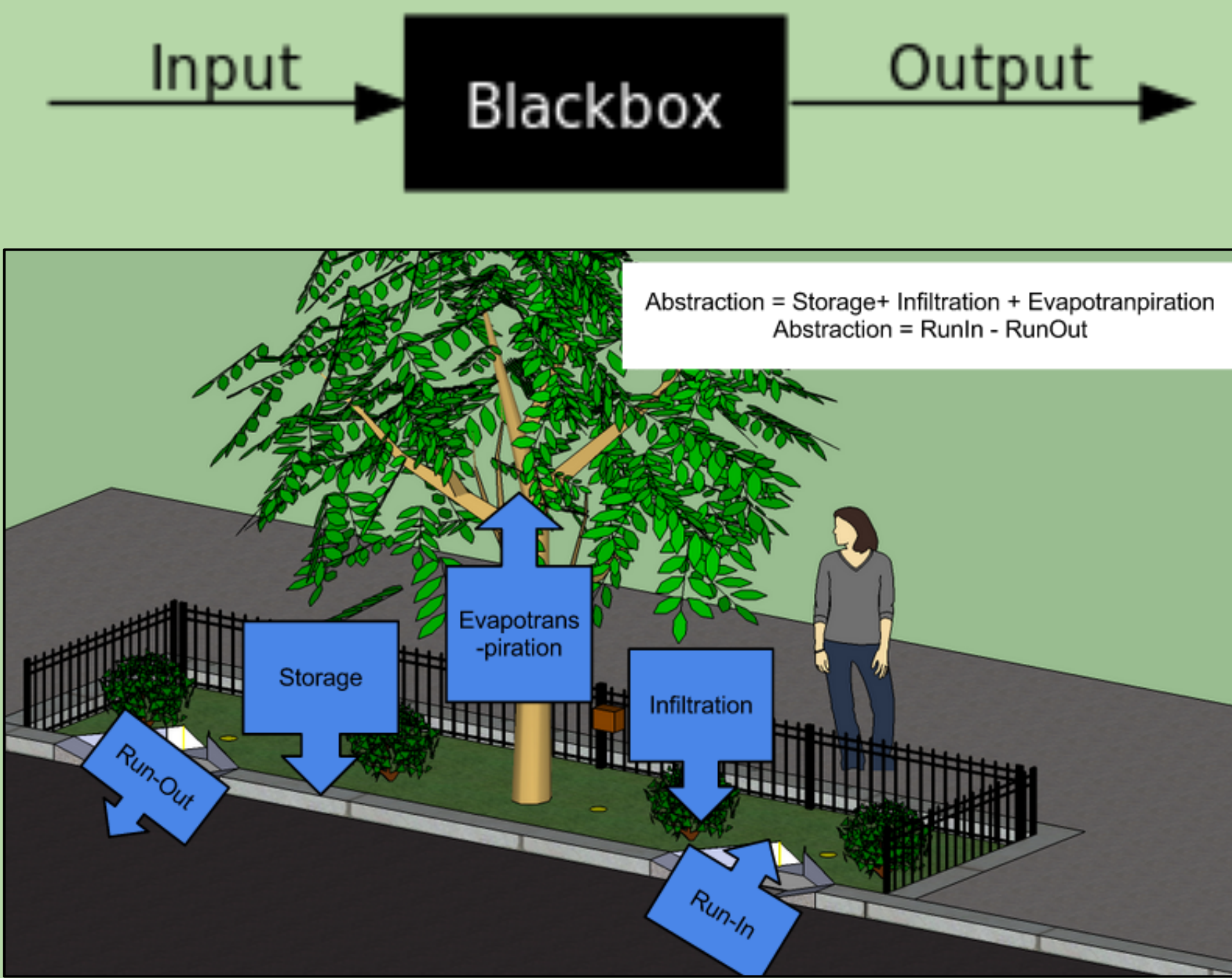
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Key Question

Will green infrastructure work to reduce stormwater runoff?



Conceptual Framework



hydrologic abstraction: the collective term given to the various processes which act to remove water from the incoming precipitation before it leaves the watershed as runoff. These processes are evaporation, transpiration, interception, infiltration, depression storage and detention storage. (Marsh, 1984)

$$Abstraction = inflow - outflow$$

$$Abstraction = \int_0^t (Q_{in}(t) - Q_{out}(t)) dt$$

where:

$$Abstraction = volume\ retained$$

$$Q_{in} = inflow\ rate$$

$$Q_{out} = outflow\ rate$$

$$t = total\ time\ of\ flow$$

When designing a stormwater management plan, it is important to know how well the green infrastructure will perform. One way to quantify this performance is by its hydrologic abstraction, or the water volume the system will retain through processes such as infiltration, evapotranspiration, and storage capacity. The hydrologic abstraction can be determined using empirical methods by measuring inflow and outflow through the facility. In this study, hydrologic abstractions are determined for three different green infrastructure pilot facilities in New York City and Philadelphia using empirical methods in order to determine the stormwater capture potential of each facility. While hydrologic abstractions vary with each storm as a result of varying antecedent conditions, it is recommended that the abstractions be presented as a box-plot in order to accommodate for inherent intra-storm variability.

Research Sites

ABC Carpet Warehouse constructed wetland



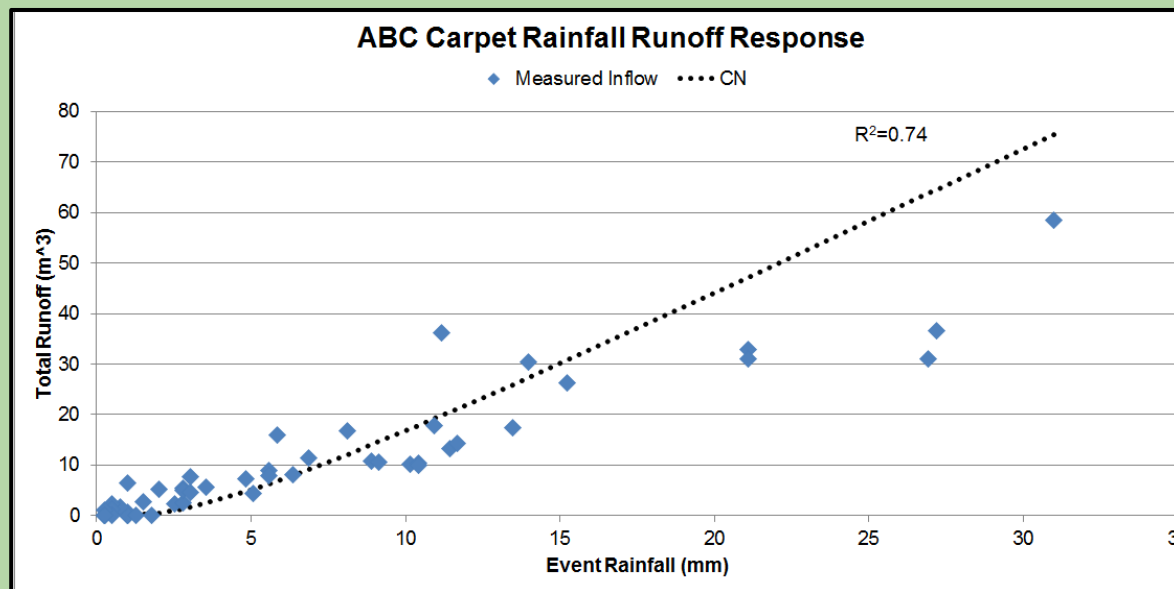
Site Description

The ABC Carpet wetland captures and purifies runoff from the factory parking lot

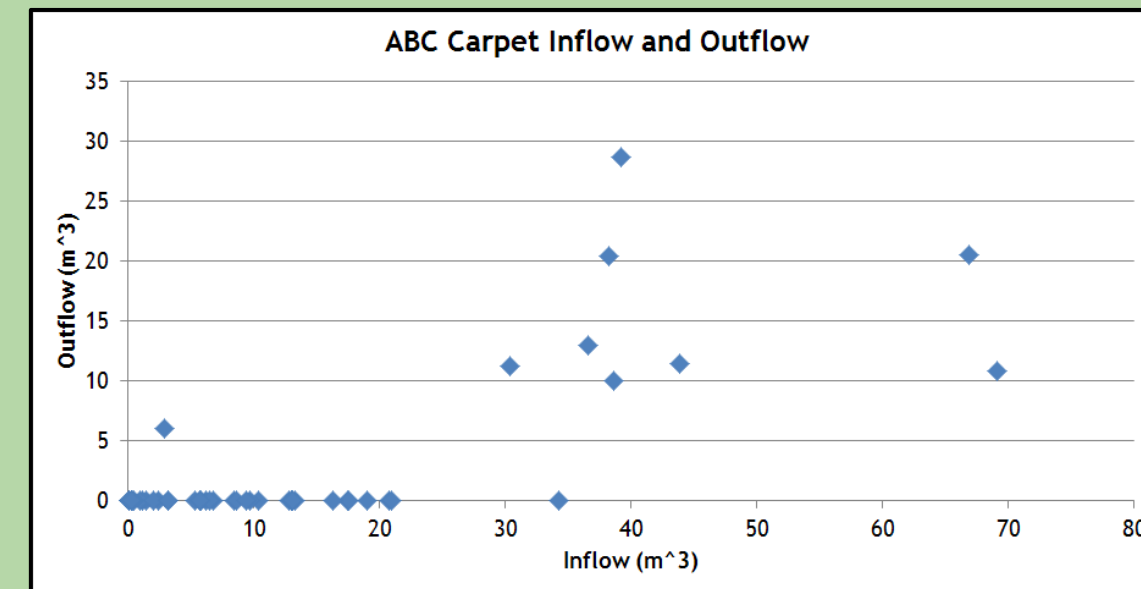
The ABC Carpet wetland project converted the riparian buffer between the Bronx River and the ABC Carpet Warehouse from an unkempt and under-used space to an artificial wetland. Runoff from the factory parking lot is pumped into the wetland to purify the water before entering into the Bronx River while decreasing the direct runoff on the factory. Stormwater runoff is monitored from the parking lot of the ABC Carpet warehouse located at 1055 Bronx River Ave, Bronx, NY 10472. The 0.3 hectare parking lot is all impervious cover and is sloped downward towards a catchbasin that collects runoff from the entire parking lot catchment. Monitoring at ABC Carpet includes: measuring direct stormwater inflow from the parking lot using a trapezoidal flume and direct rainfall using two Campbell Scientific tipping bucket rain gages. Trapezoidal flumes are water channels that measure flow rate by relating water level to flow rate. The flume is calibrated so that the flow rate through the pipe will result in a particular water level of that flow. As water level rises in the pipe, so does the flow rate. In this regard, monitoring the flow then can be done by monitoring the water level. This was done using a Campbell Scientific pressure transducer placed in a stilling well attached to the flume. All sensors were logged at 15 minute interval using a Campbell Scientific CR1000 data logger.



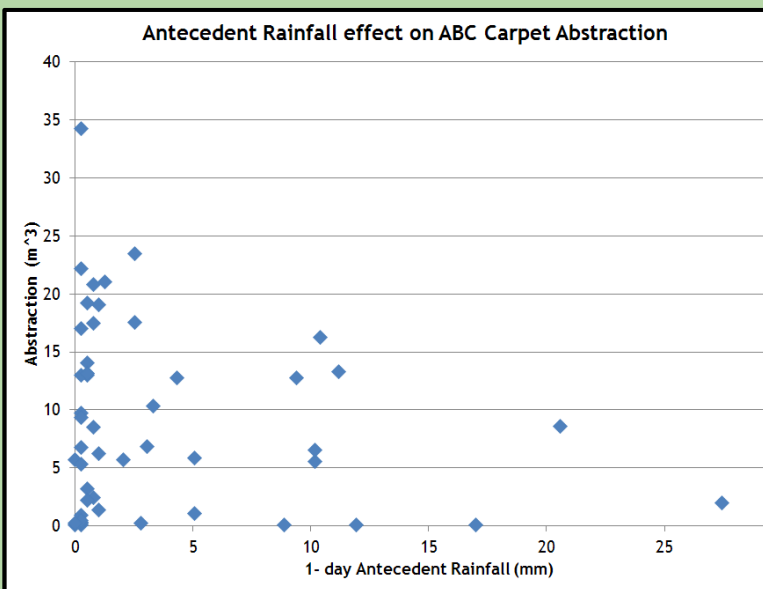
Water is pumped to the wetland through a trapezoidal flume to measure inflow.



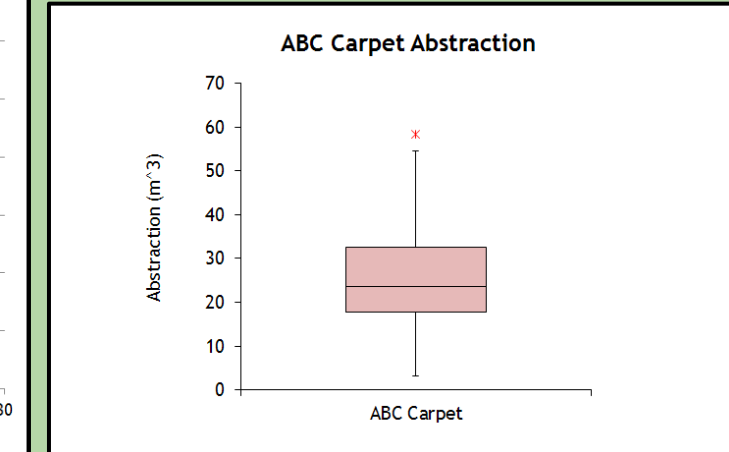
Rainfall-runoff response of the highly impervious catchment area shows a close fit to the curve number model.



Little runoff occurs from the wetland until ~ 30 m³. This point represents the initial abstraction of the wetland.



The variability in the abstractions is due primarily to the antecedent moisture conditions



To illustrate this variability, the abstraction of the wetland can be displayed as a box-plot.

Fieldston School green roof



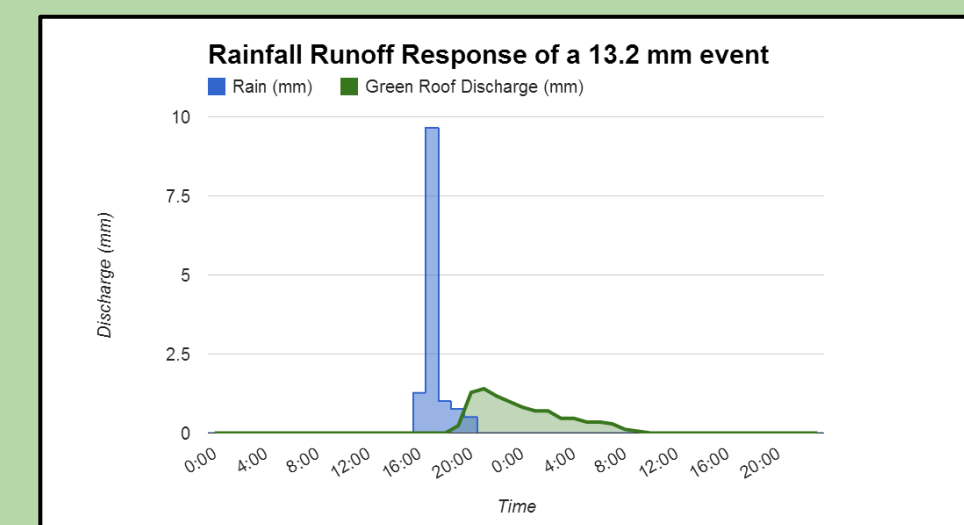
Site Description

The Fieldston green roof is a typical extensive green roof

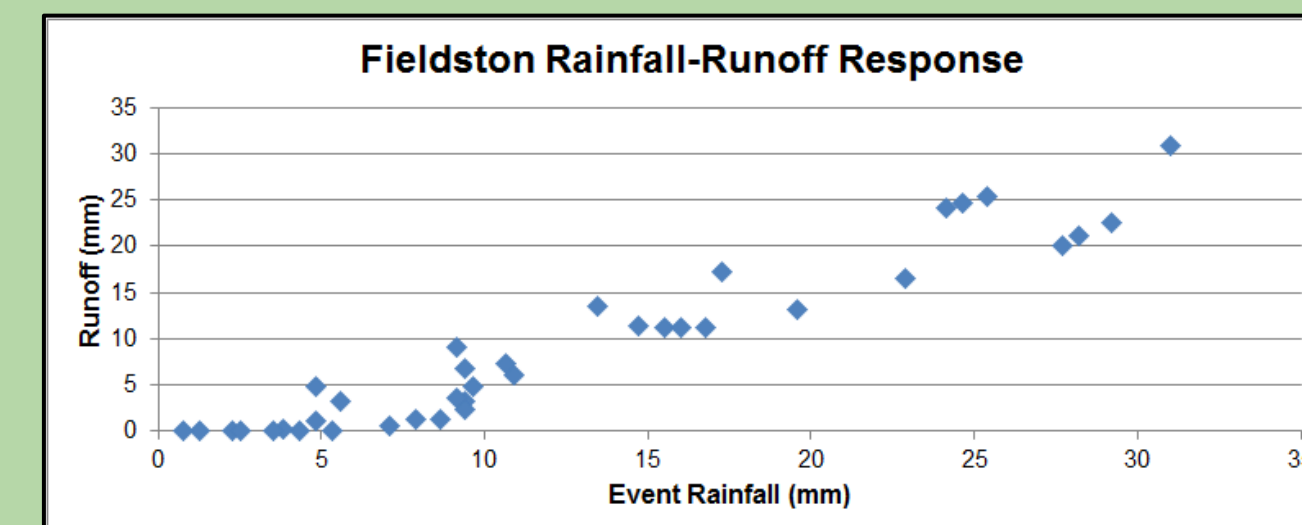
The green roof on the Ethical Culture Fieldston School located at 3901 Fieldston Rd, Bronx, NY 10463 is a 500 m² extensive type green roof consisting of a roof membrane with root barrier, insulation layer, filter fabric, drainage layer, media layer, and vegetative layer. The media layer is 10 cm thick and made up of 85% expanded shale and 15% organic matter. Six different species of *Sedum* were planted from plug to make up the vegetative layer of the rooftop (*Sedum album*, *S. saxangulaire*, *S. reflexum*, *S. floriferum*, *S. hybridum*, and *S. spurium*). The data set used for the Fieldston analysis was from June to January 2009. Runoff from the green roof was measured using a tipping bucket rain gage (accurate to 0.25 mm) that collected runoff from a weighing lysimeter (shown in the image) positioned on the roof. Rainfall on the green roof was measured using another tipping bucket rain gage attached to a climate station mounted on the roof. In this setup, the initial abstraction was determined as the number of rain gage tips previous to any lysimeter discharge.



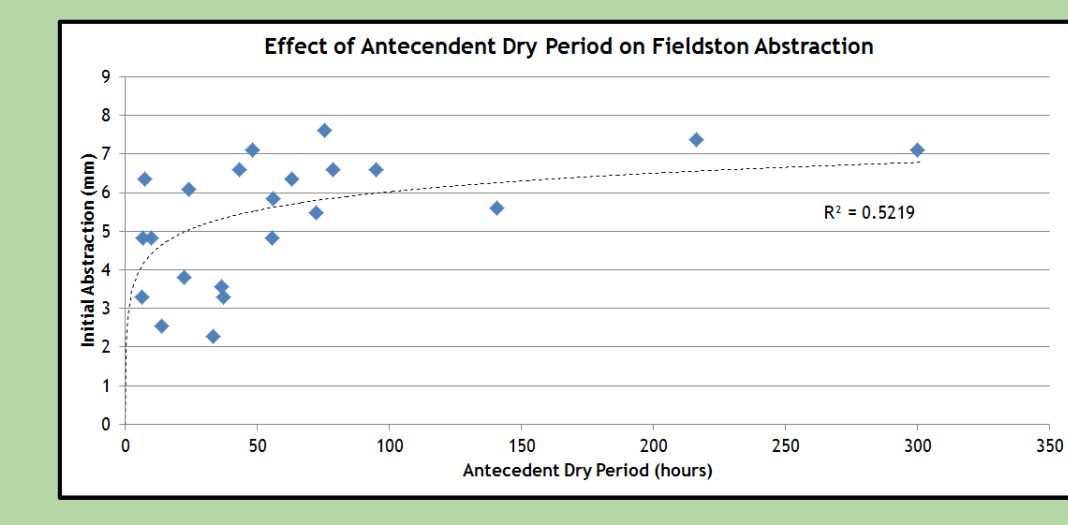
Drainage from the lysimeter is measured using a tipping bucket rain gage



The green roof delays runoff. The amount of rainfall captured before runoff is the green roof initial abstraction



The rainfall-runoff response of the green roof shows little runoff until the initial abstraction point of ~ 7 mm.



Abstraction potential varies based upon antecedent conditions. If it recently rain, the soil will have little room to capture more water. It takes ~3 days to dry.

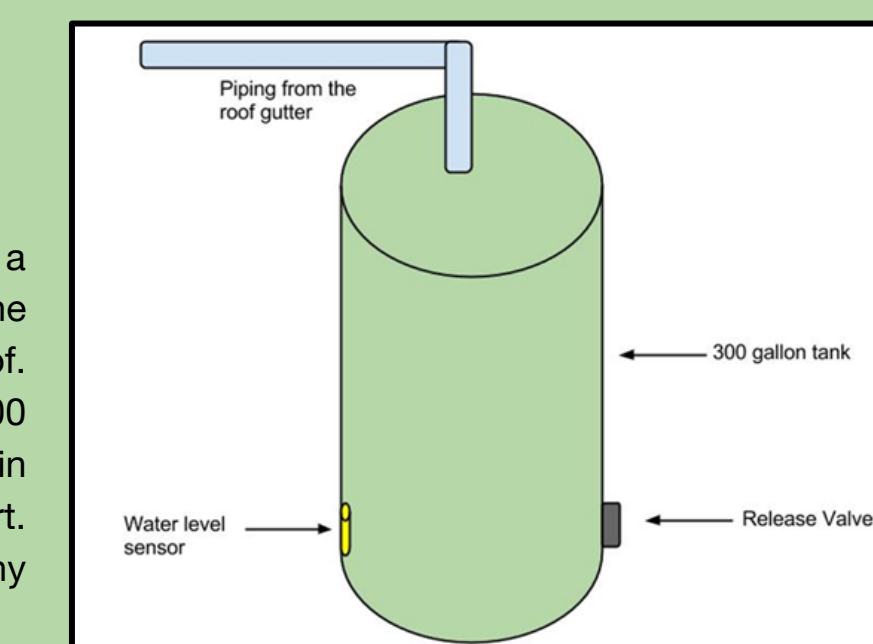
Powelton Rowhome green roof



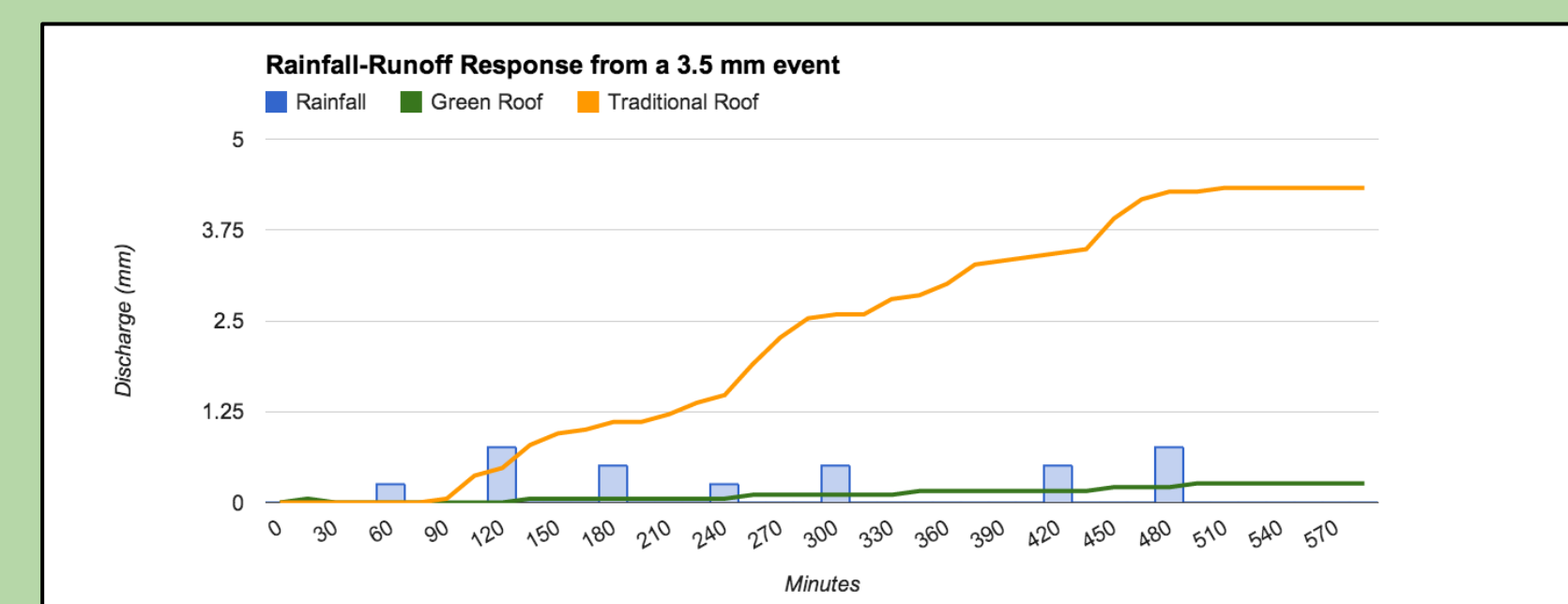
Site Description

The Powelton green roof was made from recycled building material

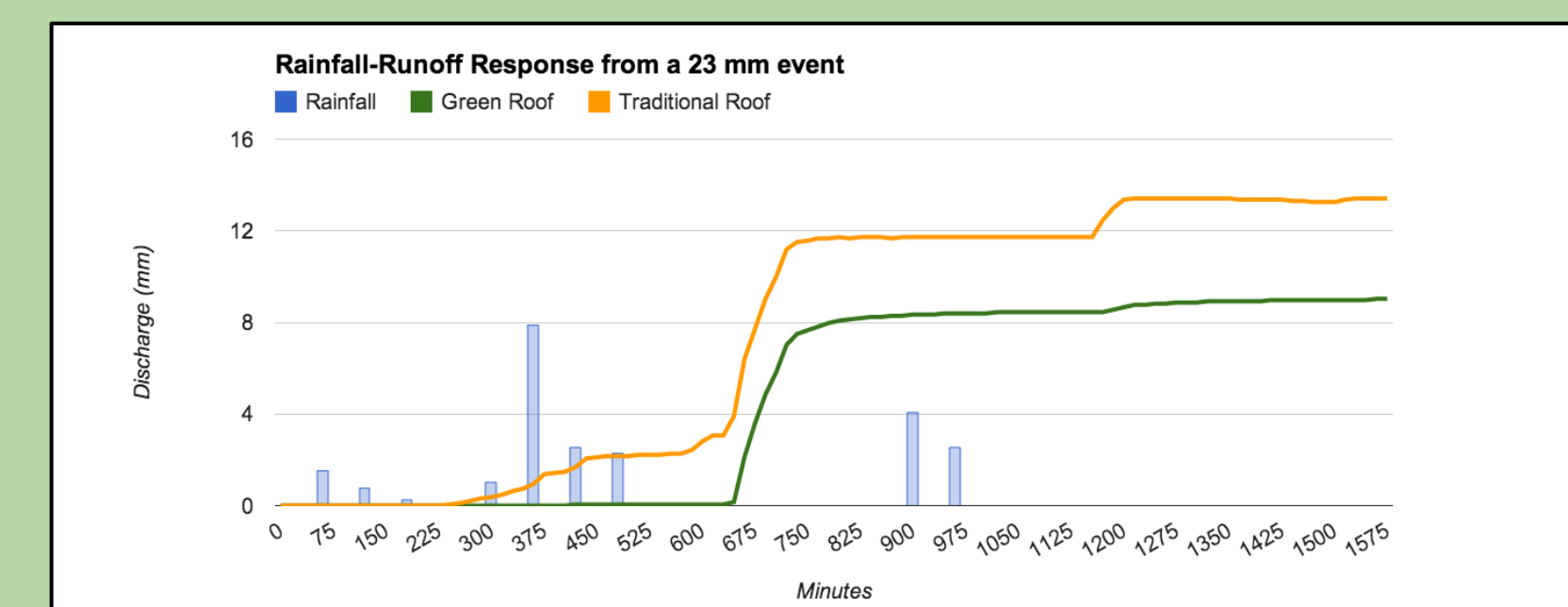
The Powelton green roof is located on the 300 Block of Holly Street in West Philadelphia located in a residential block lined with row houses typical of Philadelphia. As part of this study, baseline stormwater runoff conditions were measured from a traditional roof adjacent to the green roof. Stormwater from the gutters were rerouted to rain barrels and equipped with Global Water WL900 pressure transducer sensors to measure changes in water volume resulting from each storm. Rain gage data was taken from a nearby climate station located at the Philadelphia International Airport. Initial abstractions were determined as the amount of runoff from the traditional runoff before any discharge was detected from the green roof.



Rain Barrel Runoff Monitoring System



During a small 3.5 mm event, the green roof capture nearly all of the storm.

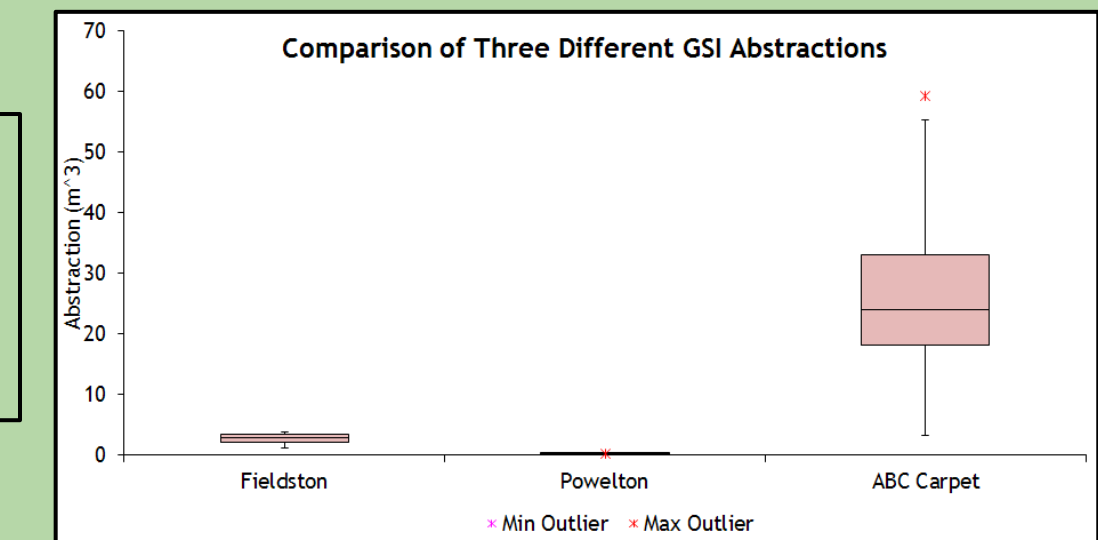


During a larger 23 mm storm, the green roof captures ~ 4 mm. This is the green roof abstraction for this storm. Also notice that initial abstraction is equivalent to the total abstraction.

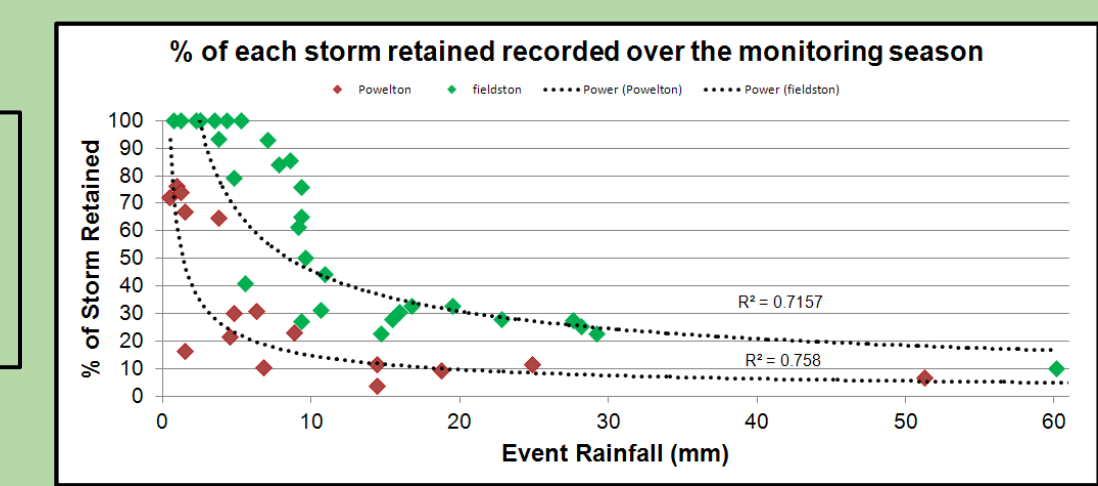
Findings

1. Abstractions enable comparing green infrastructure stormwater capture performance to one another

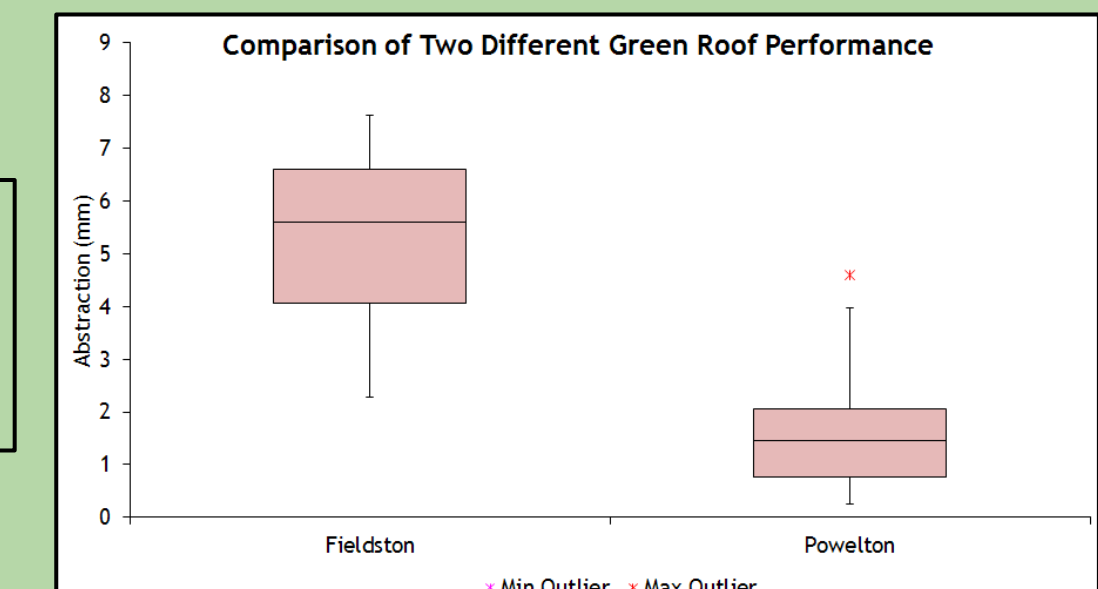
Shown is this graphical comparison of volumetric green infrastructure stormwater capture, the constructed wetland captures much more water than the green roofs. This is because the wetland has a much greater storage depth than the green roofs.



While the event rainfall of a storm is less than the initial abstraction, all of the rainfall will be captured by the green roof. After the initial abstraction depth is past, runoff will occur. Illustrated here, the two roofs follow this same trend.

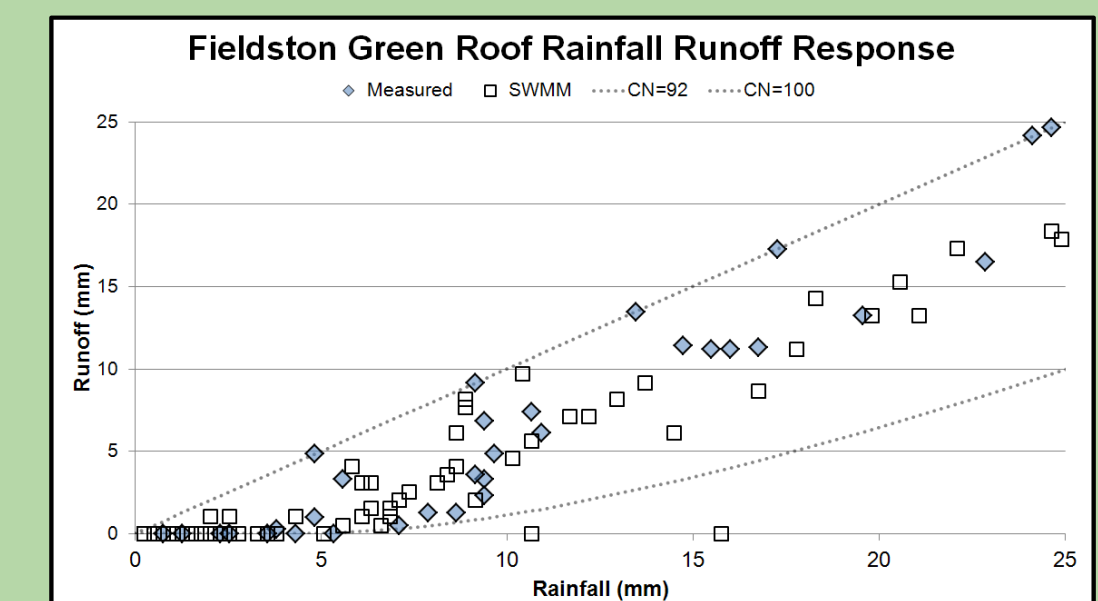


When comparing the green roofs side-by-side, the Fieldston green roof captures significantly more water than Powelton. This is the result of the larger soil depth of Fieldston and the slope of the Powelton roof.

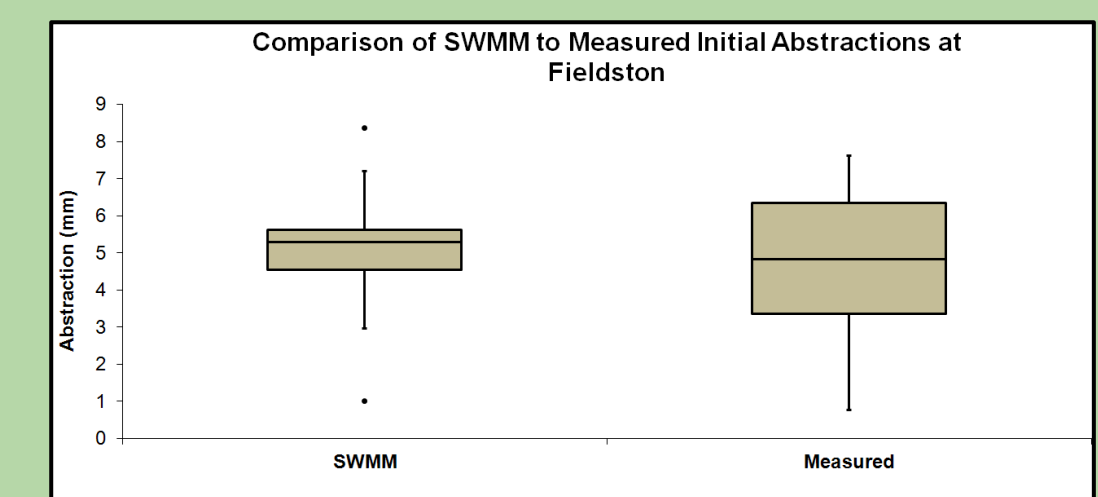


2. Abstractions can be used for modeling

The performance of Fieldston green roof was successfully modeled using EPA SWMM illustrating the potential of SWMM for green roof performance modeling. Also note that the curve number method is not successful at modeling a green roof.



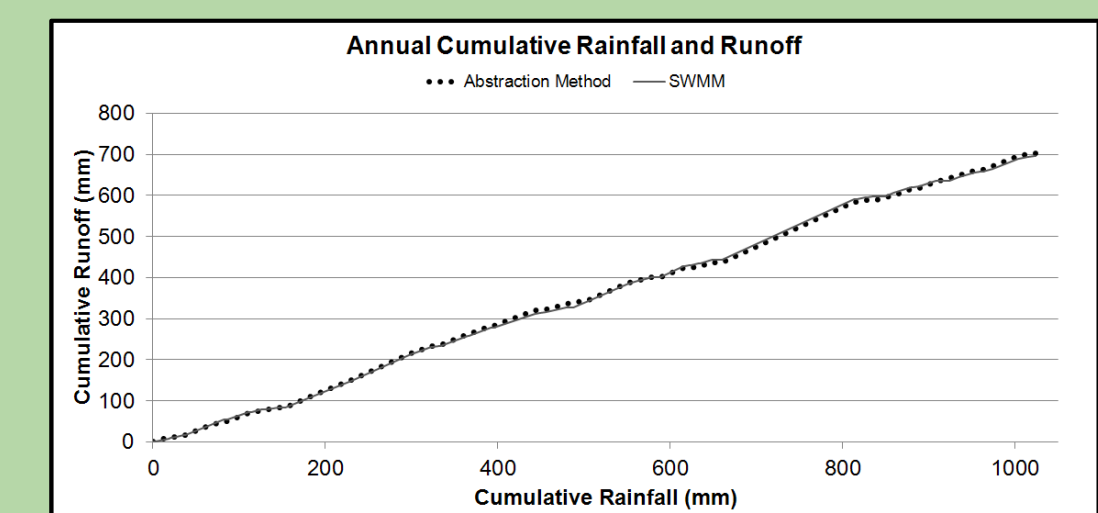
There was little difference between the modeled abstractions and measured abstractions



$$\begin{aligned} \text{if } Precipitation > abstraction & \quad Runoff = Precipitation - Abstraction \\ \text{if } Precipitation \leq abstraction & \quad Runoff = 0 \end{aligned}$$

$$Annual\ Runoff = \sum Runoff\ for\ each\ storm$$

Modeling annual rainfall and runoff using abstractions and comparing it to SWMM shows identical predictions. In the case of Fieldston green roof, the annual reductions in stormwater runoff amount to 70%



Research Partners

