Impact of Green Infrastructure on Nutrients Reduction, the case of Downtown Durham, North Carolina

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Introduction

Overland flow, often referred to as surface runoff, is the excess of stormwater on land surface when the rainfall intensity exceeds infiltration capacity of the land and soil (Horton, 1940). Severe runoff can bring flash floods and pollutants to downstream waterbodies (Taebi & Droste, 2004). The amount of runoff varies with storm intensity, soil architecture and land cover characteristics (Lin, Brooks, McDANIEL & Boll, 2006). By modifying the permeability of land cover, urbanization influences the infiltration of rainwater and increases surface runoff in flood season. The resulting landscape is referred to as 'urban karst' (Bonneau et al., 2017). Studies have proved that deforestation and urbanization are associated with both increased overall flood volume and increased "flushness" (increased peak volume and reduced response time) (Andréassian, 2004; Du et al., 2012; Miller et al., 2014). With more extreme weather events and increased rainfall brought by climate change (Carreiro, 2005), the synergistic effect of climate change and urbanization poses a serious threat to the public health and safety related to surface runoff (Stewart, 2013).

Green infrastructure, also referred to as Best Management Practice (BMP) or Stormwater Control Measures (SCM), is the urban blue-and-green network commonly used as climate impacts remediation and urban storm water management (Benedict & McMahon, 2002). As opposed to "gray infrastructure" with impervious surface, green infrastructure functions by modifying the land cover and increasing permeability. Previous studies have proved that green infrastructure can effectively reduce runoff volume and pollutants loads for parking lots, roadways, and buildings (Li, 2015). Commonly used green infrastructure types include downspout disconnection, rainwater harvesting, rain gardens, green roof, and permeable pavement (US EPA, 2019).

The Falls Lake was constructed during 1978-1981 by the U.S. Army Corps of Engineers, for purposes including flood control, drinking water supply, and water quality preservation for downstream waterbodies. The Falls Lake is the main drinking water supply for City of Raleigh, Town of Cary, and part of Durham County. However, it has been listed as impaired by many organizations. According to Falls Nutrient Strategy, Falls Lake was impaired by chlorophyll-*a* from 2002 to 2006. To restore its water quality, the Falls Lake Rules requires that the chlorophyll-*a* concentration must be reduced to 10% of its base level by 2030, which, according to a model that predicts chlorophyll-*a* standard exceedance rates in response to different Nitrogen and Phosphorus concentration (Figure 1; Lin & Li, 2011), is equivalent to 40% reduction in Nitrogen loads and 77% reduction of Phosphorus loads.

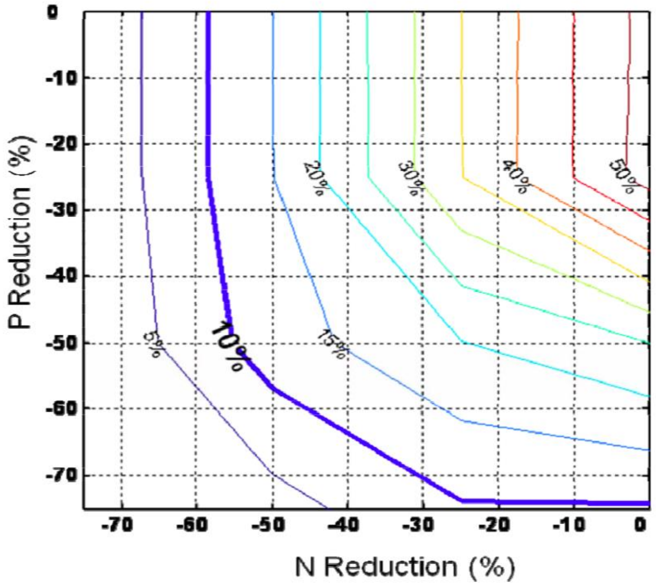

Figure 1. Chlorophyll-*a* exceedance rates in response to different combination of N and P reductions (Lin & Li, 2011)

Among the five sub-watersheds that drain into Falls Lake, Ellerbe Creek Watershed (EC) is the smallest in size (5%), but largest in Nitrogen delivery load (26%) and second largest in Phosphorus delivery load (27%) (Figure 2; NC DENR, 2009). Two main sources of pollutants from EC are point source sewage discharge and non-point source runoff from urban land use types. Approximately half of the watershed lies within the city of Durham, covering its highly impervious downtown area (Sub-basin 14). To reduce the runoff nutrients loads from downtown Durham will be crucial for the overall integrity of the Falls Lake. In 2010, the City of Durham Developed the Ellerbe Creek Watershed Improvement Plan, setting up goals for reducing total nitrogen, phosphorous, sediment and fecal coliform in the EC (City of Durham, 2010). To achieve the goal with minimum cost will be meaningful practically.

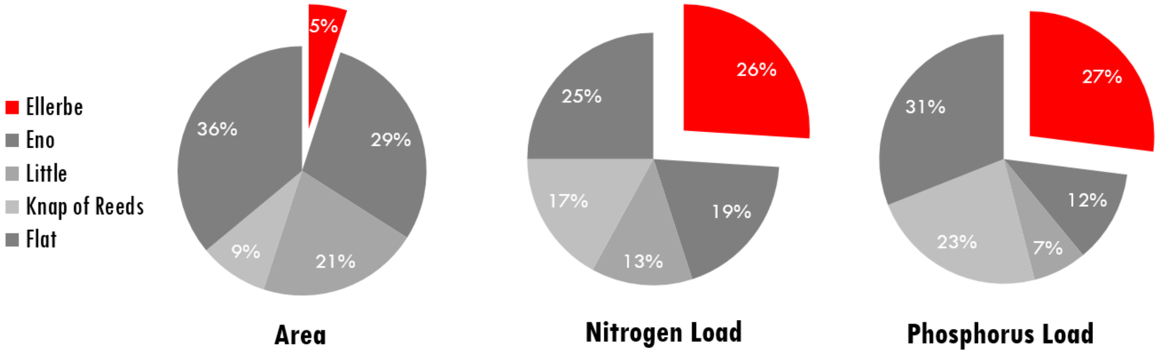

Figure 2. Comparisons among sub-watersheds in Falls Lake (NC DENR, 2009)

In order to mitigate the urban runoff impacts on Falls Lake, over 8,000 potential SCM sites have been proposed in the Ellerbe Creek Sub-watershed, and over 500 in Sub-basin 14 alone (Figure 3; Dreps, Hanson & Raabe, 2014).

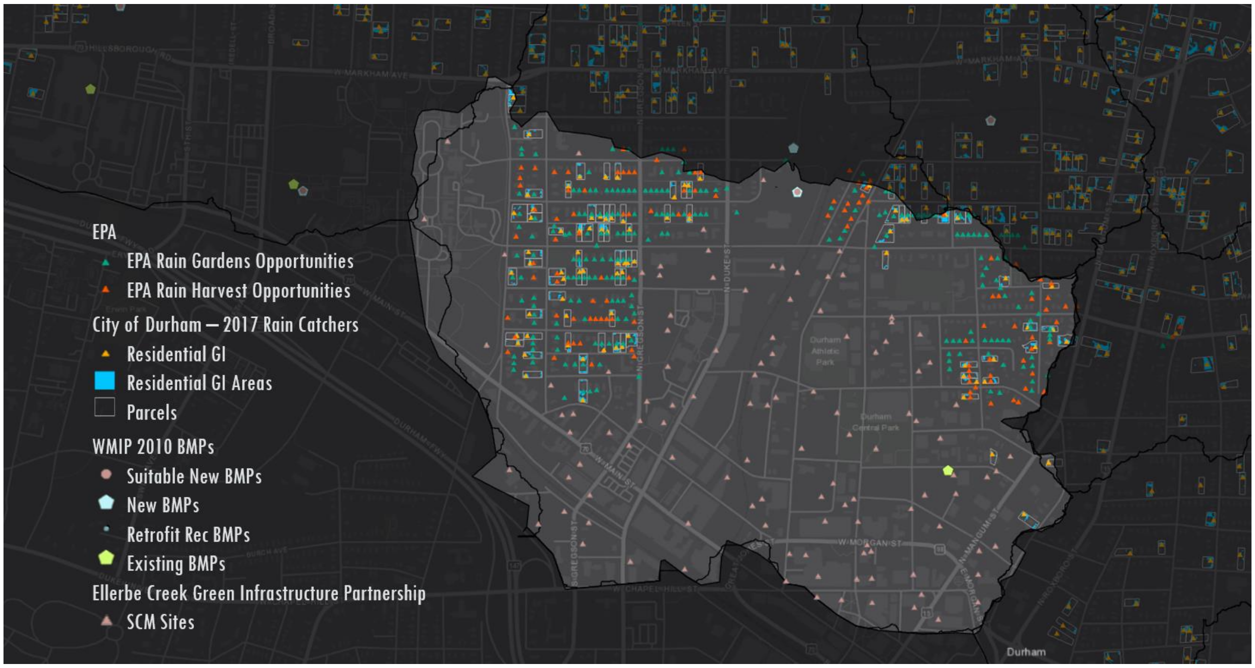

Figure 3. Existing proposals for Green Infrastructure locations in Sub-basin (Dreps, Hanson & Raabe, 2014)

After years of development, the concept of green infrastructure has been more widely recognized by decision makers and more deeply integrated in policies. However, a few components are still missing in the communication of information. First, there has not been an overall benchmarking scheme to evaluate proposed SCMs sites. Second, there is a lack of communication among the various proposals for SCMs from different organizations, making it hard for coordinated planning. At the current stage, a flexible SCM evaluation tool is both appropriate and necessary. For these reasons, the goal of this master's project is to assist the client, Ellerbe Creek Watershed Association, in developing a flexible SCMs assessment tool that responds to input of SCMs plans and provide real-time evaluation for the proposal.

Methods

Literature Review on Green Infrastructure Effectiveness

The first part of the project is an investigation of the general green infrastructure effectiveness in runoff nutrients reduction. I conducted a meta-analysis on 219 samples from 21 different studies about green roofs, permeable pavements, and rain gardens (Appendix 1). The selection of studies follows a few criteria. First, the study is a case analysis about certain SCM project. Second, the study is either published in peer-reviewed journal article, or a rigorously written technical report. Third, the study reports empirical findings on at least one of the following measurements:

1. Precipitation (mm)
2. Runoff volume (runoff coefficient)
3. Ammonia Nitrogen Concentration (mg/L)
4. Nitrite Nitrogen Concentration (mg/L)
5. Total Kjeldahl Nitrogen (mg/L)
6. Organic Nitrogen Concentration (mg/L)
7. Total Nitrogen Concentration (mg/L)
8. Total Phosphorus Concentration (mg/L).

For this study, nutrients measurement in quantity (nutrients load) is more useful practically than measurement in concentration. However, most cases from literature review report empirical measurement in concentration. Figure 4 shows the locations of the selected studies.

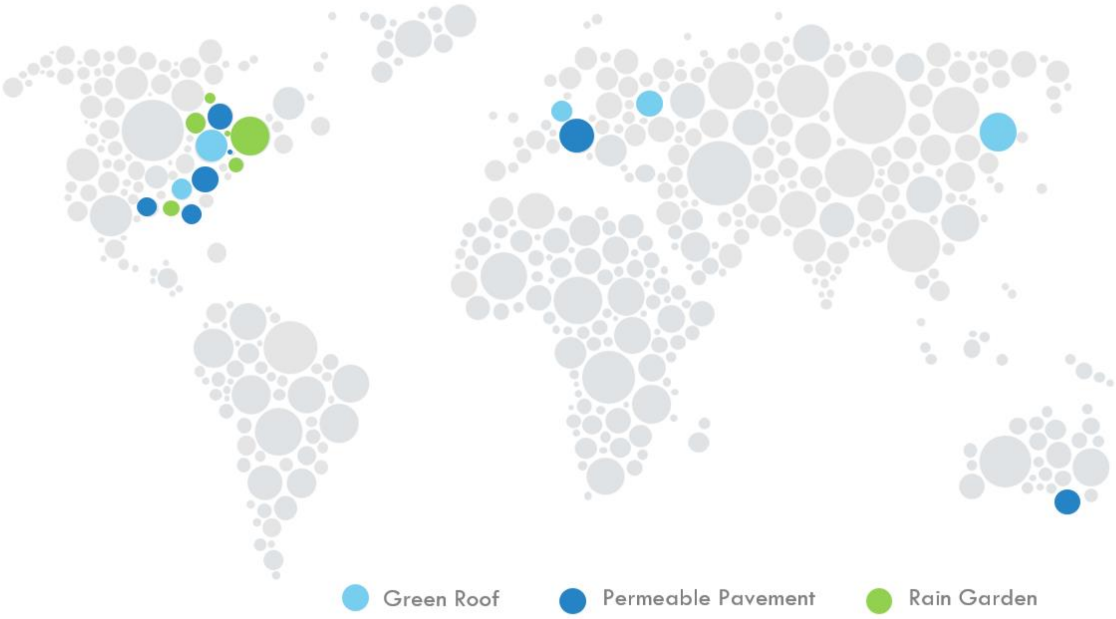

Figure 4. Locations of the studies for meta-analysis

The samples were collected and analyzed using Microsoft Excel and R. All measurements were converted into percent change between inflow and outflow of the SCM installation. After that, I conducted two-part analysis based on the standardized measurements. First, I compared the percent change in runoff volume and nutrients concentration among three types of SCM. Second, I explored features specific to each SCM type and identified more desirable SCM characteristics for nutrients reduction purposes. Due to small sample size and inconsistency among experimental conditions across different studies, only simple analyses like boxplot and scatterplot were applied in this section. The results were revealed in visual examination rather than statistical significance.

Evaluating SCMs in Downtown Durham, NC

In this section, I constructed a model and evaluated the runoff nutrients reduction effectiveness of SCM sites proposed in downtown Durham, NC. Figure 5 provides an overview of the evaluation methods.

The study area covers places bounded by sub-basin 14 in Ellerbe Creek Sub-watershed. As is shown in Figure 6, the southern part of the study area is mainly occupied by high-rise commercial buildings, while the Northern side is mainly low-rise residential.

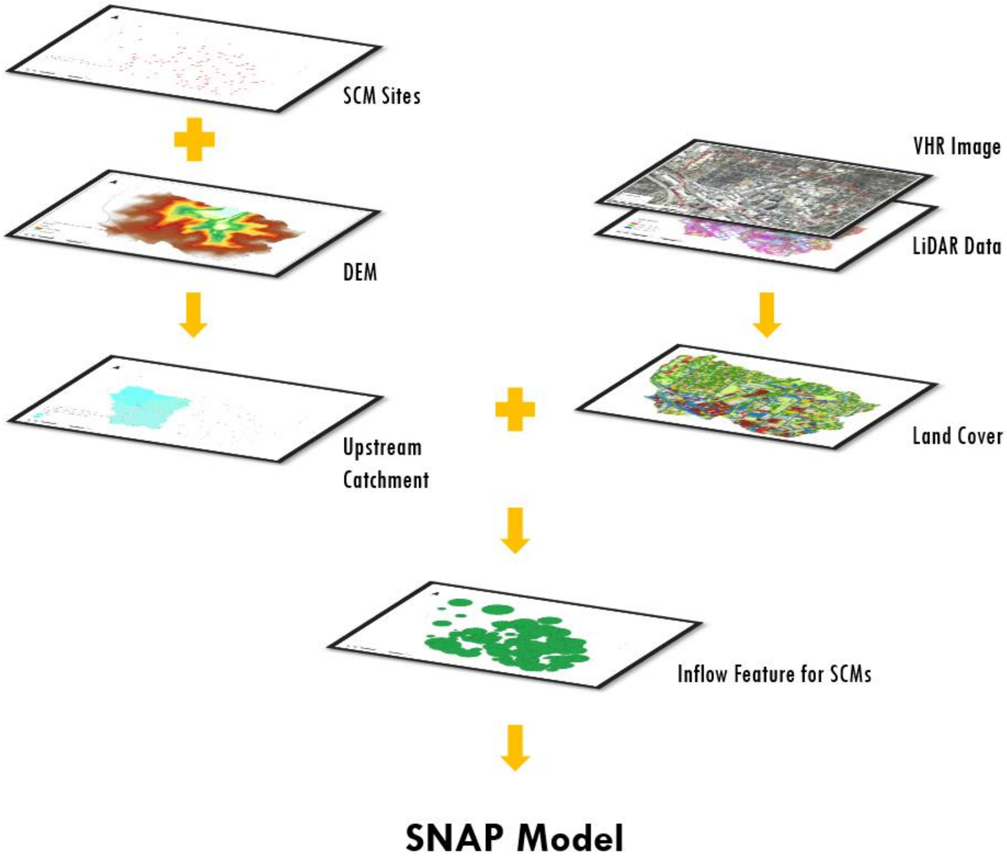

Figure 5. Conceptual diagram for SCMs evaluation process

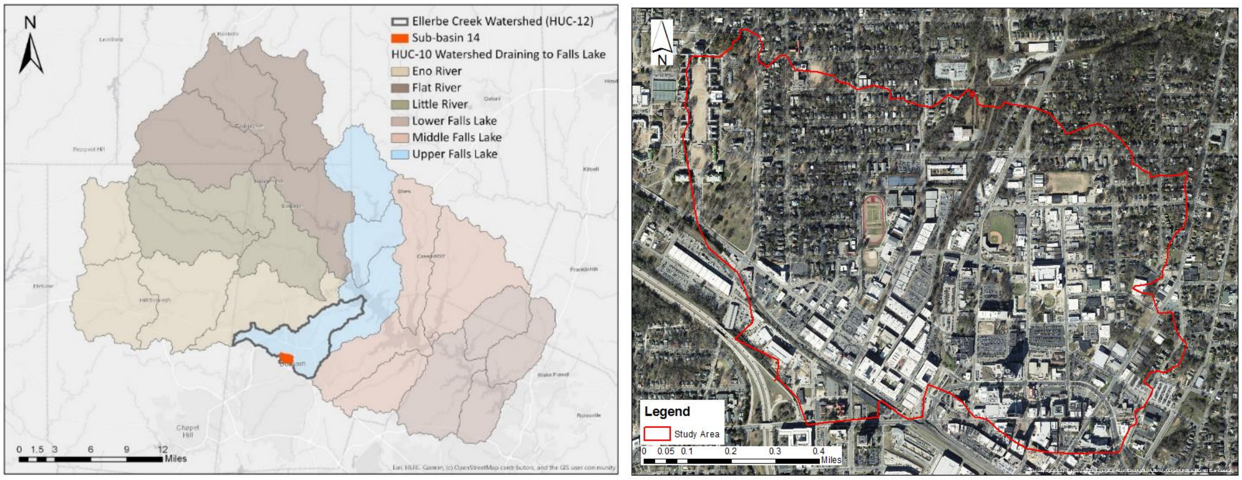

Figure 6. Study area (**left**: regional perspective of the location of sub-basin 14; **right**: land cover in the study area)

Among the various projects that propose SCM sites for runoff nutrients reduction, I chose to analyze four projects, namely the EPA Rain Gardens Opportunities (EPA-RG), EPA Rain Harvest Opportunities (EPA-RH), City of Durham Rain Catchers Residential Green Infrastructure (CoD-RG), and Ellerbe Creek Green Infrastructure Partnership (ECWA-GI). All four projects identified at least 50 potential SCM sites. Altogether, the evaluation covered 594 proposed SCM sites. Except from the ECWA-GI, whose sites distributed nearly evenly across the entire sub-basin 14, all projects focus on the residential area at the North of the study area (Figure 3).

All proposed sites were recorded as point features. The analysis of runoff was based on upstream catchment units delineated for each point feature in ArcGIS. A catchment is an area in which all water drains to a same point. It is a natural boundary commonly used for hydrologic analysis. For catchment delineation, I used Digital Elevation Model from North Carolina Floodplain Mapping Programs, USFWS. This data has a resolution of 20 feet, fine enough to capture urban features like roadways, but not the structural details that would bias the analysis.

The feature of runoff inflow is computed using land cover composition in each delineated catchment area.

For the purpose of this study, the input land cover data has to satisfy two criteria. First, the spatial resolution has to be sufficiently fine to account for small urban features like driveways and sidewalks. Second, the categories need to be distinguished in detail to separate urban structures that have different permeability. For example, parking lot and rooftop have different runoff behaviors. Therefore, lumping the two categories into one will bring down the accuracy of the model. In this project, I conducted a land classification to address both criteria, using two input datasets, a Very High Resolution Image (0.1 resolution) obtained from Google Earth on May 2nd, 2017, and a LiDAR dataset (0.3048 point spacing) from Phase two (2016-2017) of the North Carolina QL2/QL1 LiDAR Collection Mission. Using object-oriented classification written in random forest algorithm, the classification results in a 1m resolution 10-category land cover map for sub-basin 14 (Forest, Grassland, Bare land, Surface garage, Rooftop garden, Building garage, Low-rise residential buildings, Mid-rise buildings, High-rise commercial buildings, and Roads). Codes for land classification can be found in Appendix 2.

By tabulating the land cover data with upstream catchment information, I obtained the upstream land cover composition for each SCM site. This information is used as input for nutrient accounting. In this project, I used the Stormwater Nitrogen and Phosphorus (SNAP) tool for nutrient accounting (NCDEQ, 2018). The SNAP tool is a Microsoft Excel-based tool developed by North Carolina Department of Environmental Quality, for project-level storm water nitrogen and phosphorus accounting. The SNAP model is an empirical model based on the assumption of the Simple Method. The Simple Method estimates the runoff volume and nutrients load from an urban catchment by calculating runoff coefficient as proportional to fractional impervious cover, runoff volume proportional to rainfall through runoff coefficient, and pollutant loads proportion to runoff volume through an event mean concentration of pollutant. Despite the risk of oversimplification in the SNAP model, it has three main advantages over all the other tools:

1. SNAP tool is an empirical model calibrated for North Carolina, specifically for Falls Lake nutrients control.
2. For reason 1, the SNAP tool is well known and widely recognized by professionals and policy makers.
3. The simple algorithm of the SNAP tool makes it possible to largely shorten processing time compared to other more sophisticated models.

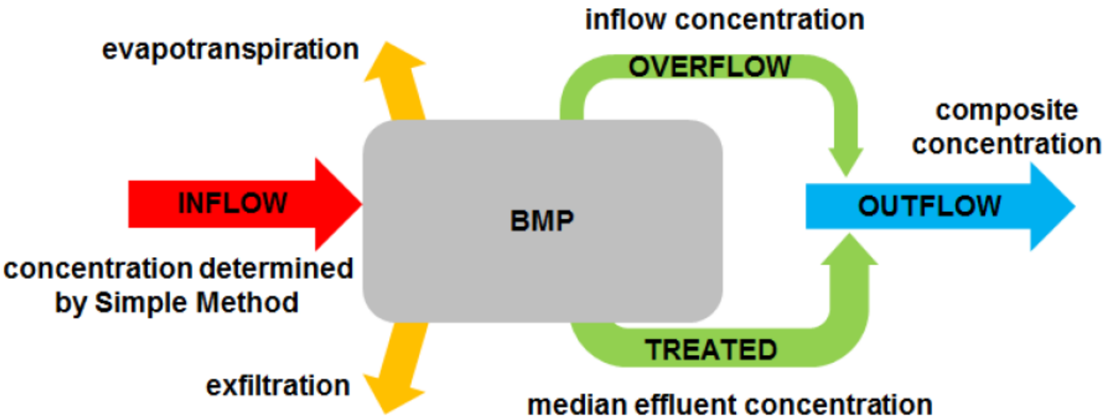

Figure 7. SNAP tool runoff partitioning

SNAP tool takes input land cover composition and SCM type, which were used to estimate runoff volume, nitrogen and phosphorus loads for runoff inflow into the SCM. It then partitions inflow into evapotranspiration/exfiltration, overflow, and treated effluents, and produces estimates of outflow runoff volume, nitrogen and phosphorus loads for each SCM (Figure 7). In this project, I compared inflow and outflow characteristics in each SCM site, and recorded the following eight measurements as baseline of SCM effectiveness comparison:

1. Upstream catchment area (ft^2)
2. Upstream catchment imperviousness (coefficient)
3. Percent change in runoff volume (%)
4. Absolute change in runoff volume (L)
5. Percent change in nitrogen loads (%)
6. Absolute change in nitrogen loads (lb)
7. Percent change in phosphorus loads (%)
8. Absolute change in phosphorus loads (lb)

The entire evaluation section (except from land classification) was compiled into a Python script (Appendix 3).

Web Application Development

To enable more efficient communication about SCM effectiveness in runoff nutrients reduction, I developed a web application based on analysis output from previous section. I used MongoDB database to store attributes of each SCM site, including geographic location, type, project name, and the eight analysis output measurements. MongoDB is an object-oriented database designed for applications. It has good performance in cloud environment (Chodorow, 2010). The server for this web application was built with Node.js, a javascript runtime for creating HTTP server and APIs (Tilkov & Vinoski, 2010). I used Mapbox[1] for user interface.

Chodorow, C. (2010). Introduction to mongodb. In *Free and Open Source Software Developers European Meeting (FOSDEM)*.

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[1] https://docs.mapbox.com/help/tutorials/building-a-store-locator/#initialize-the-map

Results

Literature Review

Literature review included three types of SCMs, Green Roofs (GR), Permeable Pavements (PP) and Rain Gardens (RG). Figure 8 shows the overall change in runoff volume and pollutants concentration for the three types of SCMs. Overall, PP exhibits the best performance in recorded cases, with an average runoff volume reduction of over 95% and reduction in nutrients concentration for almost all types of nutrients. While on average GR reduces runoff volume by around 60%, previous studies found that RG only change runoff volume mildly. For RG, concentrations of all nutrient types dropped after treatment, with an average reduction rate of 20-30% (Figure 8).

Almost all case studies about GR found it increase the concentration of Ammonia Nitrogen and Total Phosphorus, at levels of 700% - 10,000% of the original concentration. Despite the reduction in overall runoff volume, in these cases the total load of the Ammonia Nitrogen and Total Phosphorus will likely increase after GR treatment.

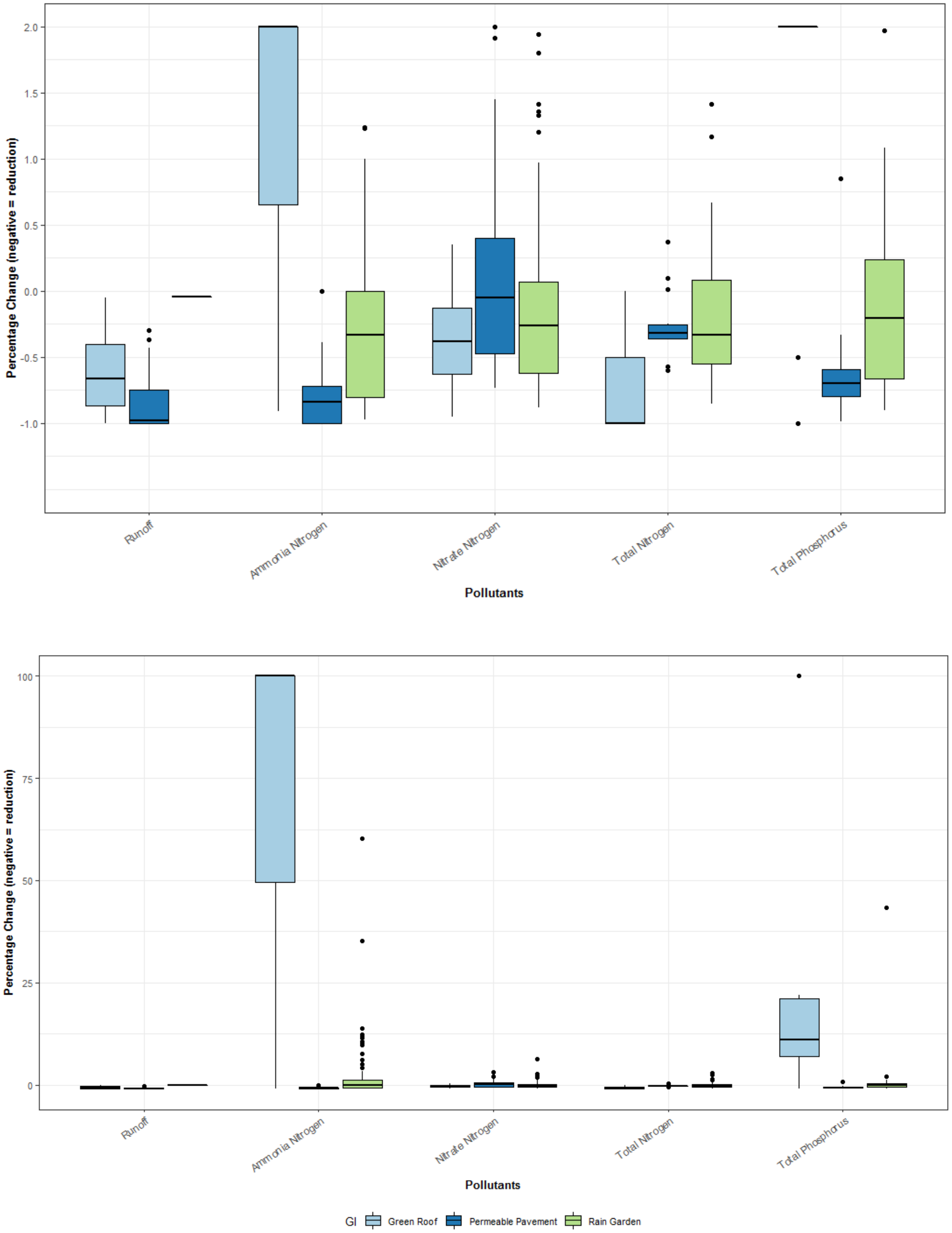


Figure 8. Runoff concentration and pollutants concentration change of GR, PP and RG (**top**: all values adjusted to below 200%; **below**: no adjustment)

By comparing observations from cases under heavy and light precipitation events (cutoff set at 50mm/24hr), this meta-analysis found that both PP and GR perform better at light rainfall events than heavy ones. For PP and GR, the runoff reduction capacity drops from 99% to 55%, and from 70% to 40%, respectively (Figure 9). The performance of PP is also influenced by the initial nutrient concentration in the runoff, with higher initial concentration associated with better nutrients reduction performance (Figure 10).

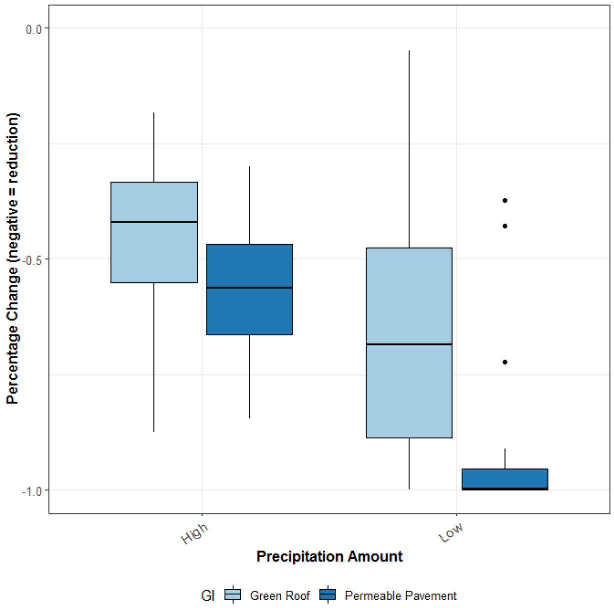


Figure 9. Runoff reduction performance under light and heavy rainfall

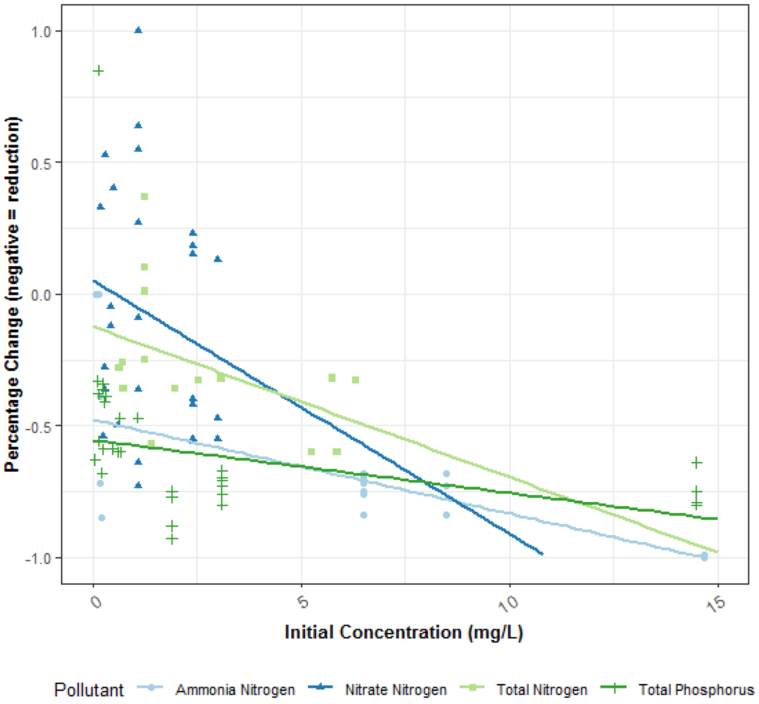


Figure 10. Nutrients removal performance (PP) in response of initial concentration

Most case studies about GR studied the effectiveness of extensive green roofs, except from Berndtsson, Bengtsson & Jinno (2009) who also included intensive green roofs. Typically, extensive green roofs have a height of 6-20 cm, weight 60-150 kg/m^2, and planted with mosses, sedums, herbs and grasses. In comparison, intensive green roofs are usually 15-100 cm high, with a weight of 180-500 kg/m^2 and common vegetation types of lawn, perennials, shrubs and small trees. The cost and maintenance demand are both higher for intensive green roofs than for extensive ones (Fernandez-Cañero, Emilsson, Fernandez-Barba & Machuca, 2013). Interestingly, in this methe only reduction in Ammonia Nitrogen and Total Phophorus concentration was reported by Berndtsson, Bengtsson & Jinno (2009). In their study, Berndtsson, Bengtsson & Jinno (2009) found that intensive green roof has significant better performance in reducing total nitrogen

(Tot-N), phosphate phosphorus (PO_4-P), total phosphorus (Tot-P), and dissolved organic carbon (DOC).

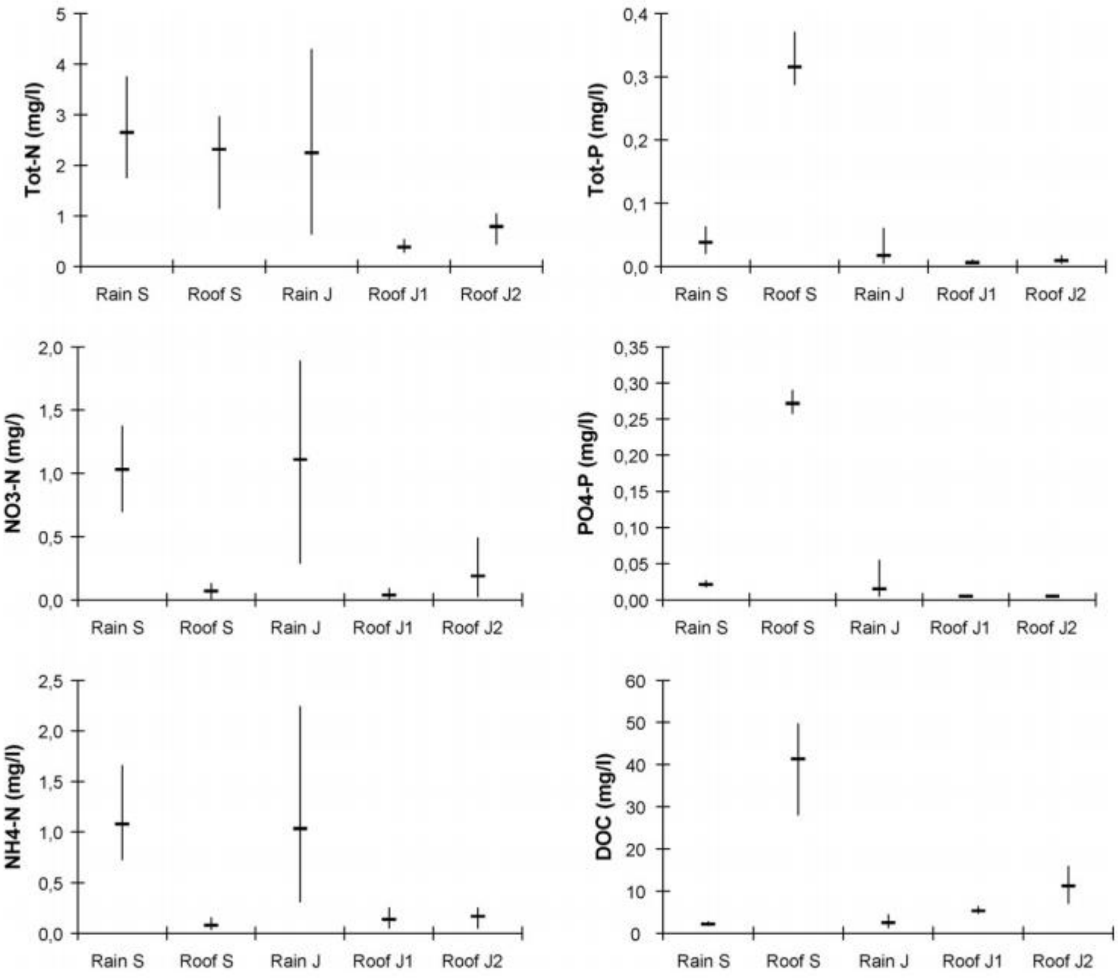


Figure 11. Nutrients concentration results in Berndtsson, Bengtsson & Jinno (2009) (**S**: extensive green roof in Sweden; **J**: intensive green roof in Japan)

The influence of vegetation in GR effectiveness were further elaborated by Dunnett et al., (2008). In their study, they found that the outflow runoff volume from GR installation decreases with increased mean height and dry root weight of the GR vegetation (Figure 12).

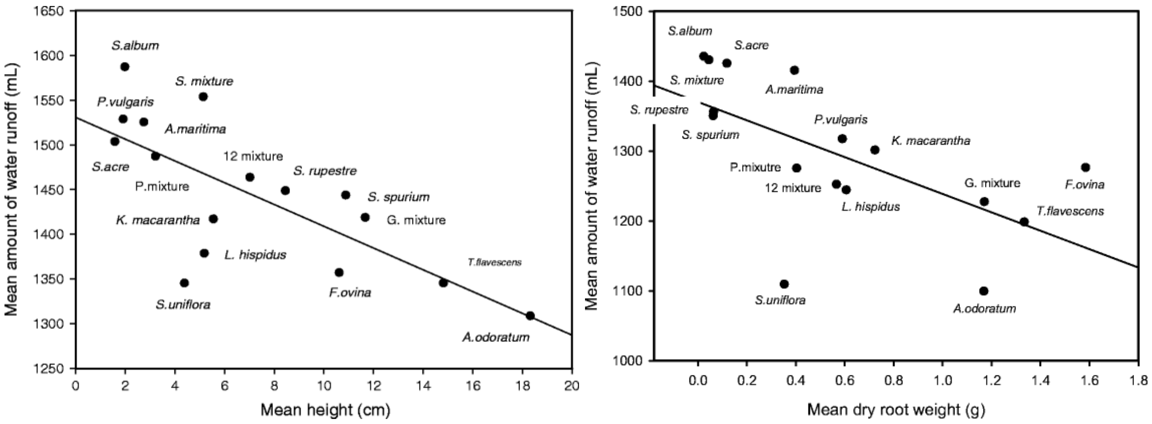


Figure 12. Correlation between amount of runoff and mean height (left)/mean dry root weight (right) (Dunnett et al., 2008)

Evaluating SCMs in Downtown Durham, NC

Table 1 summarizes the number and type of SCM sites in each project. I did a comparison of nutrient removal effectiveness for SCM types with at least 5 sample sites (Figure 13). The comparison was based on percent reduction in nutrient load. Overall, rainwater harvesting and infiltration system yield the highest percent reduction in nutrient load for both nitrogen and phosphorus. While for most nutrient types, the distributions of percent reduction are unimodal, the percent reductions in phosphorus load for bioretention, permeable pavement, rain garden, and swales exhibit a bi-modal pattern. Both rain gardens and bioretention have relatively large sample sizes, so the bi-modal pattern is more likely to be an actual pattern in data than a dispersed result of small sample size.

Table 1. Number of SCM sites in each project

	EPA-RG	*EPA-RH*	*CoD-RG*	*ECWA-GI*	***Total***

Bioretention				27	**27**
Constructed Wetlands				2	**2**
Downspout Disconnection				2	**2**
Dry Pond				1	**1**
Green Roof				34	**34**
Infiltration System				5	**5**
Permeable Pavement				7	**7**
Rain Garden	196		81	4	**281**
Rainwater Harvesting		217		11	**228**
Swales				7	**7**
Total	**196**	**217**	**81**	**100**	**594**

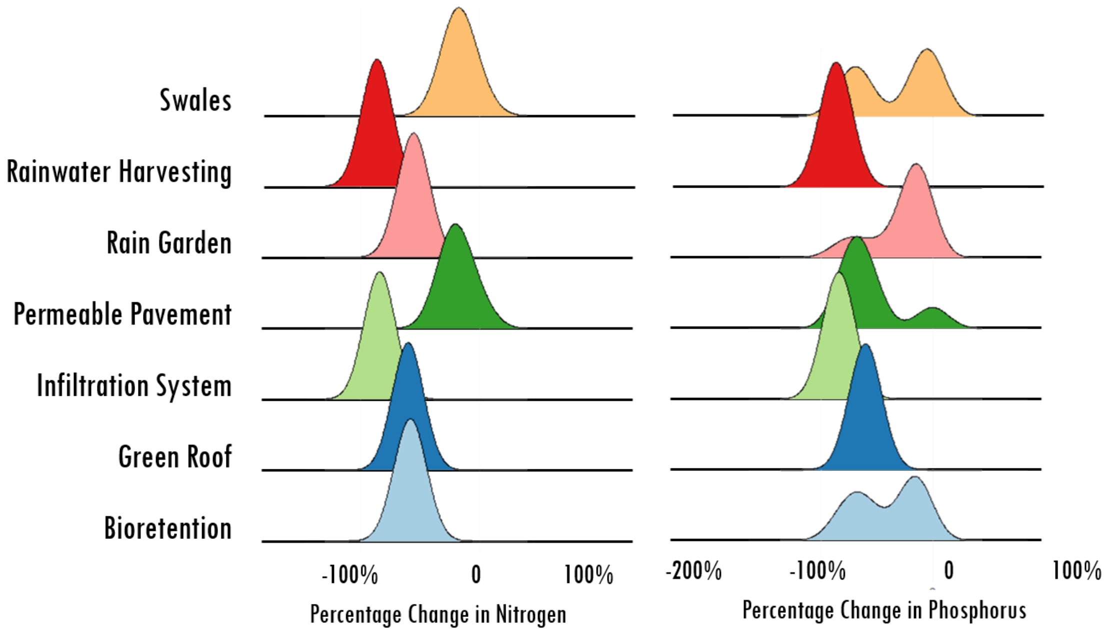


Figure 13. Comparison of nutrient removal effectiveness among SCM types

Total number of SCM sites in each project ranges from 81 to 217. Sites proposed by ECWA-GI consist of 10 different SCM types, while the other three projects focus on only one type of SCM (Rain Garden for EPA-RG and CoD-RG, and Rainwater Harvesting for EPA-RH) (Table 1). As is mentioned in Methods section, ECWA-GI sites cover both high-rise commercial area in the South and low-rise residential area in the North of the study area. In contrast, EPA-RG, EPA-RH, and CoD-RG designate sites only in the residential Northern part (Figure 3).

The results of existing sites evaluation show that for all projects, the majority of proposed SCM sites have very small upstream catchment area (less than 3,000 ft^2 or 0.07 acre) on which the SCM leverage influence (Figure 14).

Land cover composition varies significantly among projects. Forest (tree) is the dominant land cover type for EPA-RG (47.40%), EPA-RH (42.38%), and CoD-RG (50.35%). For ECWA-GI, the dominant land cover type is High-rise commercial buildings (23.26%). CoD-RG also has higher percentage of Grassland than any other project (34.58%). However, the presence of Low-rise residential building in CoD-RG (5.08%) is not as strong as EPA-RG (24.99%) or EPA-RH (22.45%), though the percentage is still higher than ECWA-GI (0.50%). ECWA-GI has significantly higher average percent of Bare land (13.06%), Surface garage (10.12%), and Roads (14.44%) than the other three projects.

In terms of imperviousness, the distribution of imperviousness measure for all four projects show a bi-modal pattern. Note that the imperviousness measure in this study is the percent imperviousness calculated based on runoff coefficient in SNAP tool. It can be interpreted in a similar manner as the more commonly used percent imperviousness in land area, but it is scaled differently so values outside of 0-1 can exist. EPA-RG, EPA-RH and CoD-RG has more sites in the lower imperviousness mode, while ECWA-GI has a dominant peak in higher imperviousness (Figure 14).

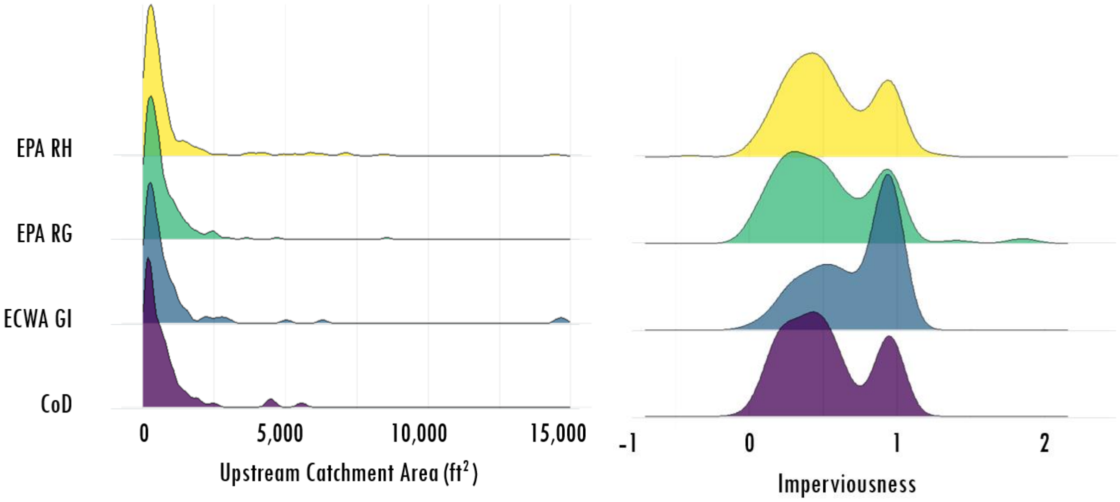


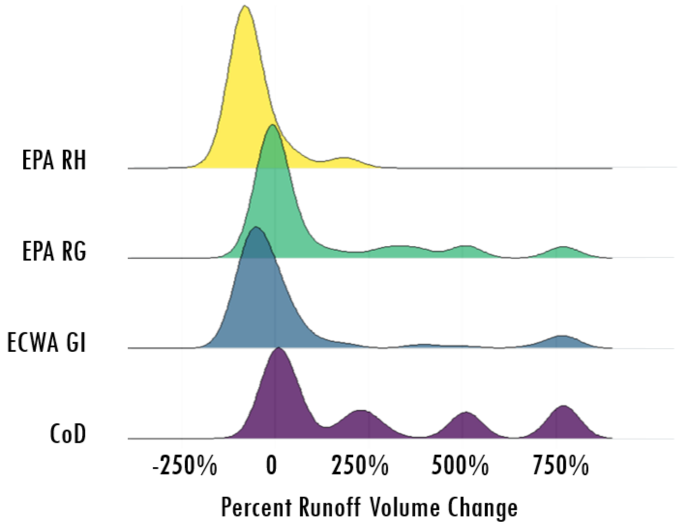
Figure 14. Characteristics of upstream catchment for each project

Table 2. Comparison of upstream land cover composition for projects

	EPA-RG	*EPA-RH*	*CoD-RG*	*ECWA-GI*
Grassland	12.80%	14.84%	34.58%	19.84%
Forest	47.40%	42.38%	50.35%	17.74%
Bare land	6.38%	6.83%	5.01%	13.06%
Rooftop garden	0.00%	0.00%	0.00%	0.04%
Surface garage	1.46%	3.53%	1.32%	10.12%
Building garage	0.00%	0.00%	0.00%	0.00%
Low-rise residential buildings	24.99%	22.45%	5.08%	1.00%
Mid-rise buildings	0.51%	0.01%	0.00%	0.50%
High-rise commercial buildings	3.46%	4.62%	2.54%	23.26%
Roads	3.01%	5.35%	1.11%	14.44%

The majority of sites in EPA-RH and ECWA-GI contributes to a reduction of percent runoff volume. For EPA-RG and CoD-RG, some sites help reduce percent runoff volume, while other result in an increase. For these two projects, the results of runoff volume reduction is also significantly more variable than EPA-RH or ECWA-GI (Figure 15).

EPA-RH seems to have the highest effectiveness in percent reduction of both nitrogen and phosphorus loads, followed by ECWA-GI. The effectiveness in percent nutrient load reduction for ECWA-GI sites is very dispersed. While for nitrogen load reduction, most sites satisfy the 40% reduction target set by Falls Lake Nutrient Strategy Rules, for phosphorus load reduction, majority of project sites failed to hit the 77% reduction target, except from EPA-RH (Figure 15).



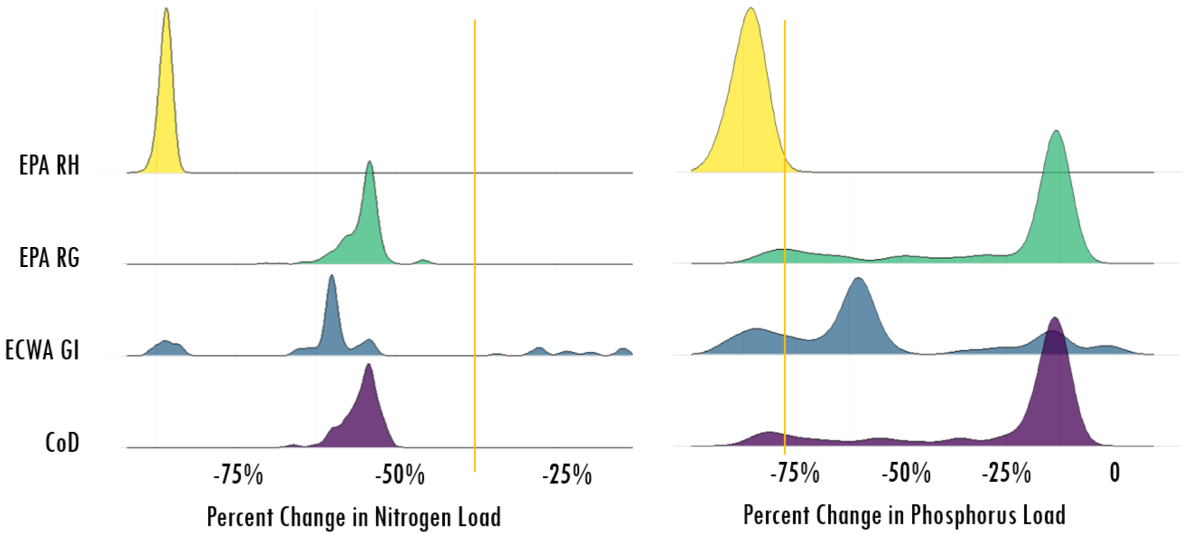


Figure 15. Comparison of nutrient removal effectiveness in percentage (orange vertical line: reduction target set by Falls Lake Nutrient Strategy Rules)

Although we observe a considerable amount of nutrient reduction in percentage sense, the nutrient reduction in absolute amount (lb.) tells another story. Figure 16 is a boxplot of nutrient reduction in pounds (lb.) for both nitrogen and phosphorus for all sites included in this project. The average nutrient reduction for both nitrogen and phosphorus are both close to 0. Effectiveness in percentage sense does not imply cost effectiveness in practice, especially when the investment will result only in negligible amount of impacts.

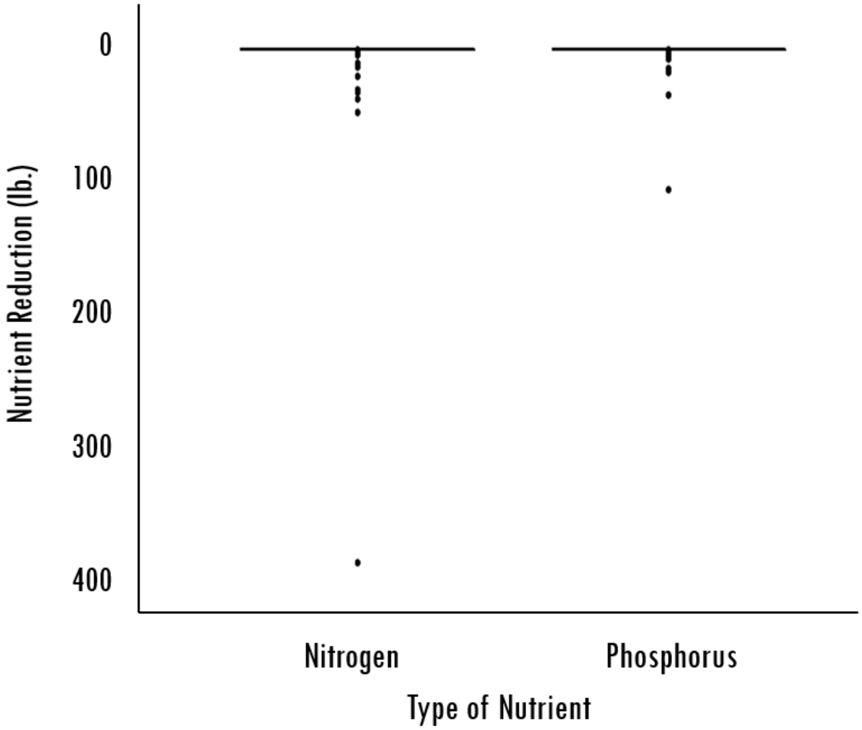
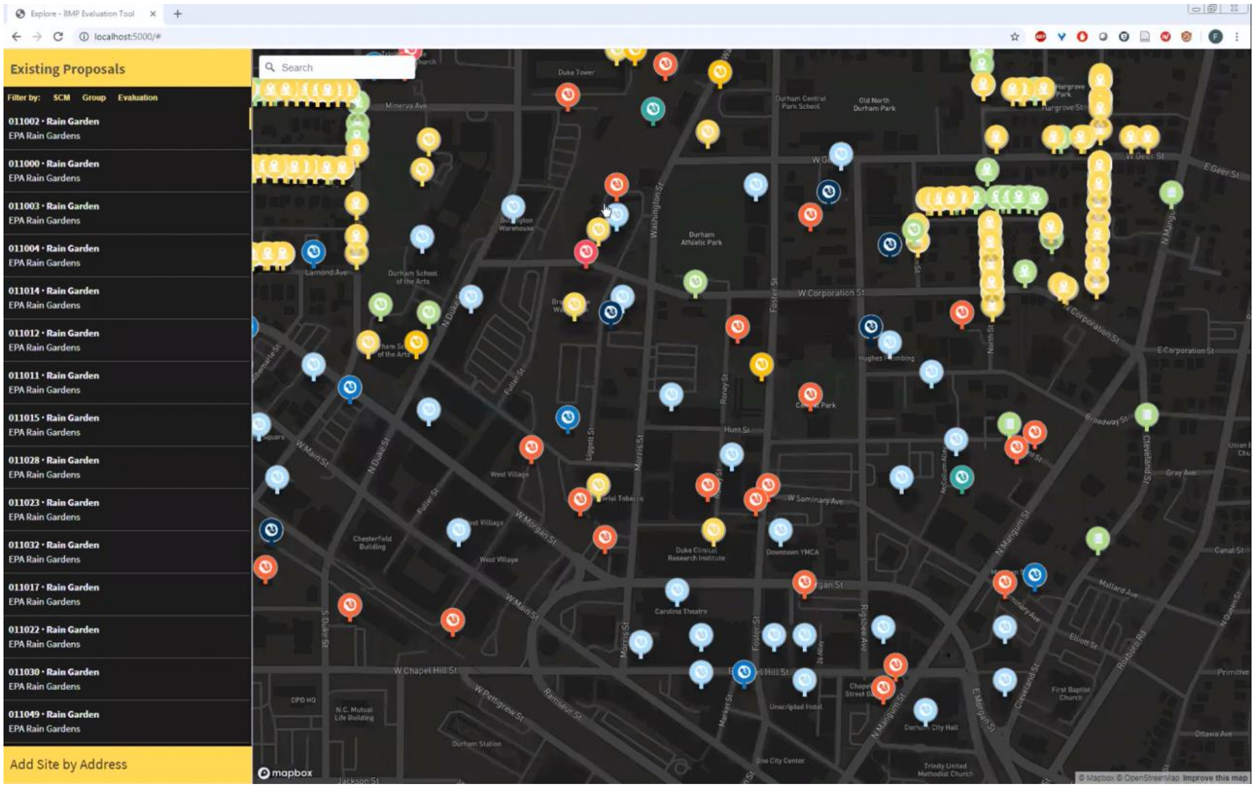


Figure 16. Nutrient removal effectiveness in absolute amount (lb.)

Web Application

The web application development produces an interactive HTML web page (Figure 17). The sidebar to the left of the website page shows listings of all available SCM sites, and the map to the right marks sites as location markers on the study area, with colors indicating types of SCM and logo pattern showing projects. The listing of SCM sites are colored using the same rule as location markers, but the website only shows the color when the site is activated.



Explore - BMP Evaluation Tool

localhost:5000/#

Existing Proposals

Filter by: SCM Group Evaluation

011002 · Rain Garden
EPA Rain Gardens

011000 · Rain Garden
EPA Rain Gardens

011003 · Rain Garden
EPA Rain Gardens

011004 · Rain Garden
EPA Rain Gardens

011014 · Rain Garden
EPA Rain Gardens

011012 · Rain Garden
EPA Rain Gardens

011011 · Rain Garden
EPA Rain Gardens

011015 · Rain Garden
EPA Rain Gardens

011028 · Rain Garden
EPA Rain Gardens

011023 · Rain Garden
EPA Rain Gardens

011032 · Rain Garden
EPA Rain Gardens

011017 · Rain Garden
EPA Rain Gardens

011022 · Rain Garden
EPA Rain Gardens

011030 · Rain Garden
EPA Rain Gardens

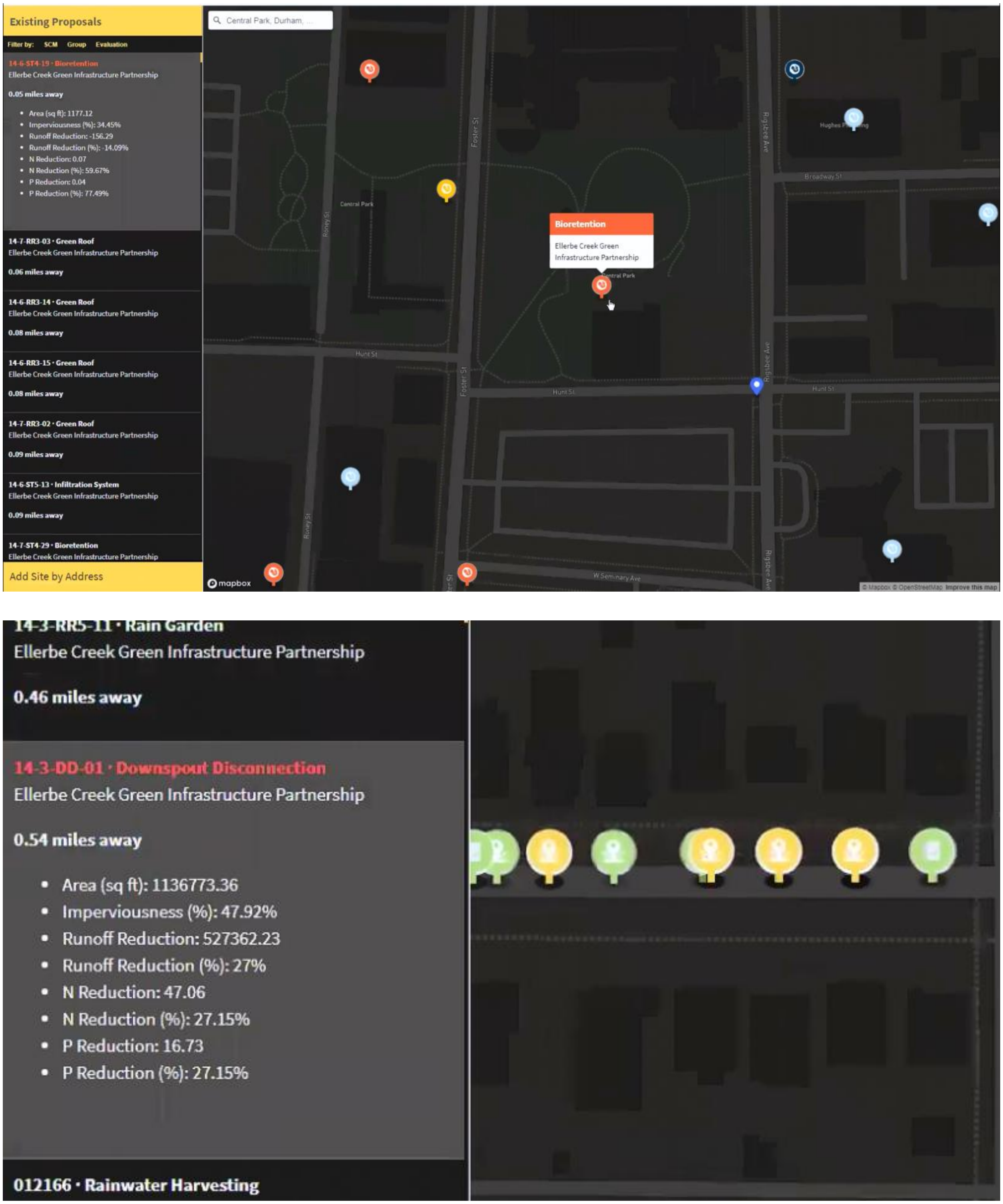
011049 · Rain Garden
EPA Rain Gardens

Add Site by Address

Figure 17. The HTML web page overview

Figure 18. Examples of the location markers (left to right: EPA Rainwater Harvesting, ECWA Green Roof, City of Durham Rain Garden)

Users can activate a site by clicking either on the site name or on the location marker. Once activated, the map will zoom to the location of the site, a pop-up window will appear on top of the location marker, and evaluation statistics will expand below the listing (Figure 19). The evaluation statistics include the eight measurements calculated for each site.



Existing Proposals

Filter by: SCM Group Evaluation

14-6-ST4-19 · Bioretention
Ellerbe Creek Green Infrastructure Partnership

0.05 miles away

- Area (sq ft): 1177.12
- Imperviousness (%): 34.45%
- Runoff Reduction: -156.29
- Runoff Reduction (%): -14.09%
- N Reduction: 0.07
- N Reduction (%): 59.67%
- P Reduction: 0.04
- P Reduction (%): 77.49%

14-7-RR3-03 · Green Roof
Ellerbe Creek Green Infrastructure Partnership

0.06 miles away

14-6-RR3-14 · Green Roof
Ellerbe Creek Green Infrastructure Partnership

0.08 miles away

14-6-RR3-15 · Green Roof
Ellerbe Creek Green Infrastructure Partnership

0.08 miles away

14-7-RR3-02 · Green Roof
Ellerbe Creek Green Infrastructure Partnership

0.09 miles away

14-6-ST5-13 · Infiltration System
Ellerbe Creek Green Infrastructure Partnership

0.09 miles away

14-7-ST4-29 · Bioretention
Ellerbe Creek Green Infrastructure Partnership

Add Site by Address

14-3-RR5-11 · Rain Garden
Ellerbe Creek Green Infrastructure Partnership

0.46 miles away

14-3-DD-01 · Downspout Disconnection
Ellerbe Creek Green Infrastructure Partnership

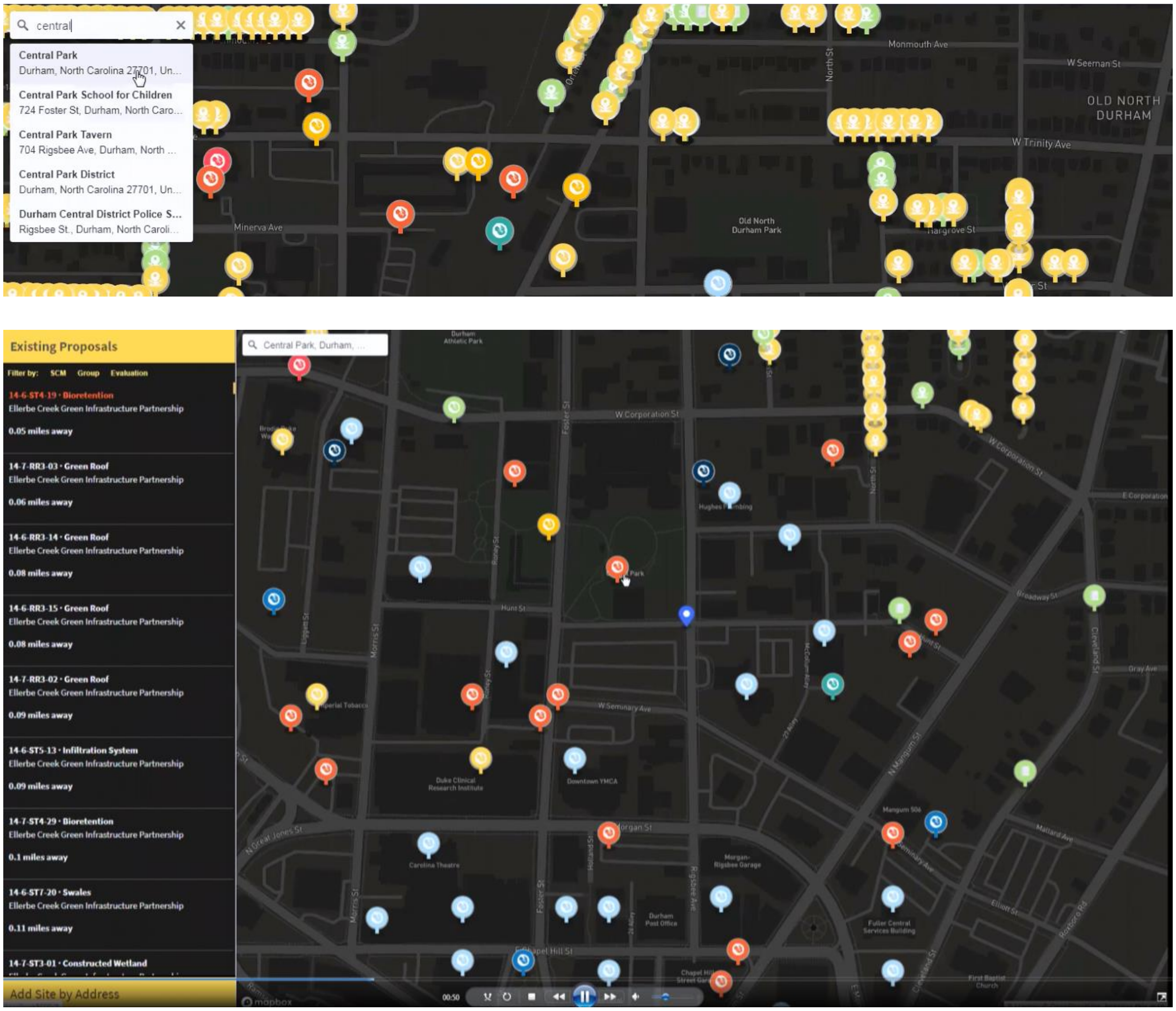
0.54 miles away

- Area (sq ft): 1136773.36
- Imperviousness (%): 47.92%
- Runoff Reduction: 527362.23
- Runoff Reduction (%): 27%
- N Reduction: 47.06
- N Reduction (%): 27.15%
- P Reduction: 16.73
- P Reduction (%): 27.15%

012166 · Rainwater Harvesting

Figure 19. Site activated

If a user is interested in knowing about proposed SCM sites around a certain location, the user can find that location by typing it in to the location search button at the top left side of the map. Once the map identifies the user input location, a marker will appear on that specific location and the map will zoom to that marker. A distance field will be added to each site listing, and the order of the listing adjusted based on distance (shortest to furthest) to the specified location.



central

Central Park
Durham, North Carolina 27701, Un...

Central Park School for Children
724 Foster St, Durham, North Caro...

Central Park Tavern
704 Rigsbee Ave, Durham, North ...

Central Park District
Durham, North Carolina 27701, Un...

Durham Central District Police S...
Rigsbee St., Durham, North Caroli...

Central Park, Durham, ...

Existing Proposals

Filter by: SCM Group Evaluation

14-6-ST4-19 · Bioretention
Ellerbe Creek Green Infrastructure Partnership
0.05 miles away

14-7-RR3-03 · Green Roof
Ellerbe Creek Green Infrastructure Partnership
0.06 miles away

14-6-RR3-14 · Green Roof
Ellerbe Creek Green Infrastructure Partnership
0.08 miles away

14-6-RR3-15 · Green Roof
Ellerbe Creek Green Infrastructure Partnership
0.08 miles away

14-7-RR3-02 · Green Roof
Ellerbe Creek Green Infrastructure Partnership
0.09 miles away

14-6-ST5-13 · Infiltration System
Ellerbe Creek Green Infrastructure Partnership
0.09 miles away

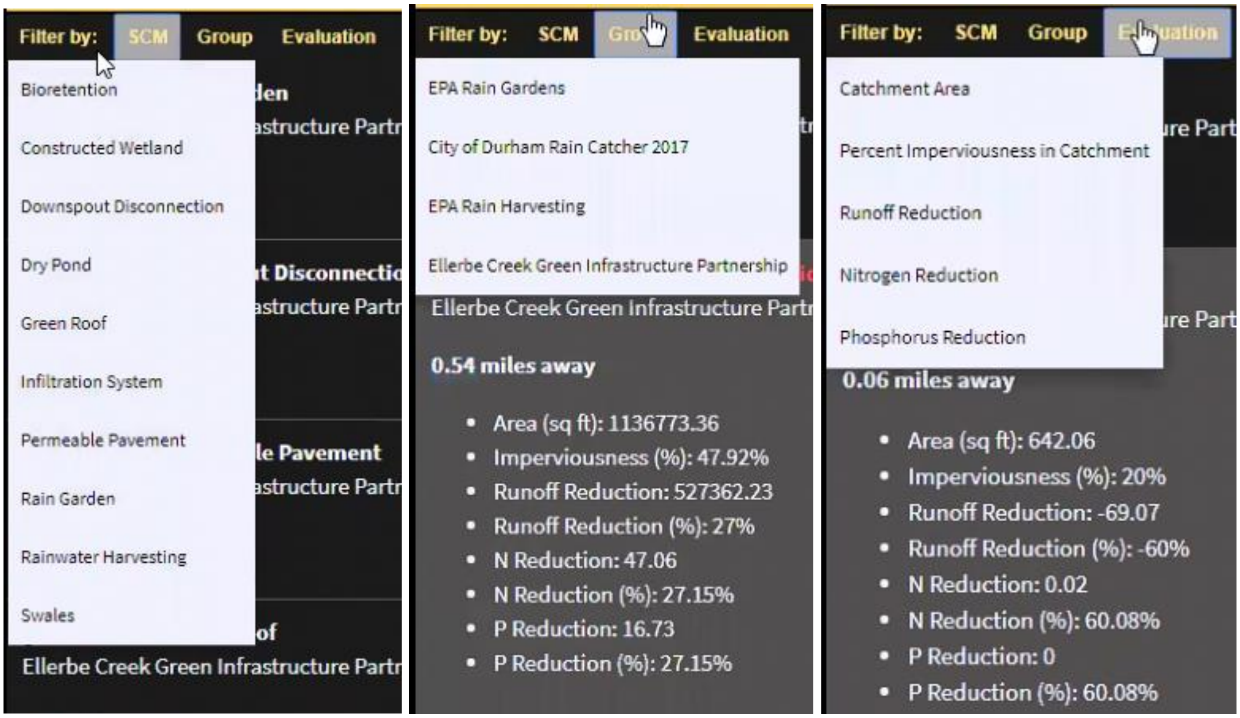
14-7-ST4-29 · Bioretention
Ellerbe Creek Green Infrastructure Partnership
0.1 miles away

14-6-ST7-20 · Swales
Ellerbe Creek Green Infrastructure Partnership
0.11 miles away

14-7-ST3-01 · Constructed Wetland

Figure 20. Calculate distance from certain location

Users also have the option to filter and sort the listings using the “Filter by:” tab at the top of the sidebar. This function allows user to display only certain types (“SCM”) of SCM, or SCM sites from certain project (“Group”). Users can also find the best-performing SCM sites (“Evaluation”) by ranking the SCMs in their designated way.



0.54 miles away

- Area (sq ft): 1136773.36
- Imperviousness (%): 47.92%
- Runoff Reduction: 527362.23
- Runoff Reduction (%): 27%
- N Reduction: 47.06
- N Reduction (%): 27.15%
- P Reduction: 16.73
- P Reduction (%): 27.15%

0.06 miles away

- Area (sq ft): 642.06
- Imperviousness (%): 20%
- Runoff Reduction: -69.07
- Runoff Reduction (%): -60%
- N Reduction: 0.02
- N Reduction (%): 60.08%
- P Reduction: 0
- P Reduction (%): 60.08%

Figure 21. Filter and sort function

A demonstration video is available through this link:

https://www.youtube.com/watch?v=dHDuxq7G1zA&feature=youtu.be

Discussion

The results of this report imply: (1). GI is not universally effective. In many cases, GI may have an adverse effect on nutrients removal. The effectiveness of GI varies widely among different types and locations of the installation; (2). A trade-off exists among nutrients control, other ecosystem services, and budgets; (3). Most GI sites proposed in Durham are effective but not cost-effective. Science-based planning is crucial for cost-effective investment; and (4). The interactive web-application tool developed in this project facilitates the communication of quantitative analysis results with stakeholders.

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