Ellerbe Creek Green Infrastructure Partnership Technical Report




A study presented by the Ellerbe Creek Green Infrastructure Partnership

Ellerbe Creek Watershed Association
Triangle J Council of Governments
American Rivers
City of Durham Stormwater Services
NC Cooperative Extension
Downtown Durham, Inc.

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1. Introduction/Background

Stormwater pollution is a pervasive and growing threat to the nation's eastern rivers, impairing water quality and endangering drinking water supplies. The Ellerbe Creek Watershed in Durham, North Carolina has the most urbanized watershed in the county, including 55,000[1] inhabitants and most of downtown Durham. Ellerbe Creek was dredged, straighten and channelized the U.S. Army Corps of Engineers in the 1950's to alleviate property damage caused by flooding. Ellerbe Creek is considered impaired by the NC Division of Water Quality (NC DENR 2012) because it doesn't meet habitat standards set under the US Clean Water Act. The most likely culprit for the stream's condition is urban stormwater runoff (NCDENR 2012). The City of Durham's regular creek monitoring found that seven of eleven water quality sites exhibited levels of bacteria that exceeded accepted standards (City of Durham 2011), while four out of five aquatic life monitoring stations exhibited poor aquatic life (City of Durham 2011). The high levels of bacteria and reported system overflows (City of Durham 2011) suggest leaks or overflows from sanitary sewer lines are also a problem for the creek. Despite its relatively small size, the Ellerbe Creek watershed is among the greatest contributors of nutrient pollutant to the impaired Falls Lake Reservoir, the drinking water for the City of Raleigh and other communities downstream.

The City of Durham has developed a Watershed Management Improvement Plan (WMIP) that provides guidance for reducing polluted stormwater runoff from existing development (Brown & Caldwell 2010). The plan recommends: 1) removing 85% of the watershed's sanitary sewer overflows and illicit connections to the stormwater system; 2) upgrading the North Durham Water Reclamation Facility to improve nutrient removal; 3) constructing and/or retrofitting 16 large-scale stormwater best management practices (BMP) in the South Ellerbe Creek and Goose Creek subwatersheds; 4) repairing and/or stabilizing 16 degraded stream reaches along South Ellerbe, Goose, and the main stem of Ellerbe Creek; 5) implementing a riparian management plan on publicly owned lands to improve the condition of riparian areas; and 6) acquiring and/or protecting 324 parcels identified as critical to the protection of water quality (Brown & Caldwell 2010).

In 2011, the State of North Carolina adopted the Falls Lake Nutrient Management Strategy (NMS), which requires the reduction of nutrients from both new and existing development in the 771 square-mile base that includes Ellerbe Creek. The Falls Lake NMS requires reductions of 77% and 40%, respectively, of the current in-lake levels phosphorous and nitrogen. Ellerbe Creek is among the largest contributors of phosphorous and nitrogen to Falls Lake, and the loading reductions required from existing development is an important component of the Falls NMS rules that Durham must implement.

[1] US Census Bureau 2010 Census Tract data for Durham Tracts 1.01, 1.02, 2, 3.01, 3.02, 4.01, 4.02, 9, 10.01, 10.02, 11, 17.05, 17.07, 18.01, and 22 collected on the US Census Bureau American Fact Finder webpage, http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml .

The Ellerbe Creek WMIP's recommended management scenario is expected to cost an estimated $169 Million, with $49 Million of the estimated expenses for the implementation of the 16 stormwater BMPs and 16 stream repairs (Brown & Caldwell 2010). Implementation of the plan is not expected to meet nitrogen, phosphorous, sediment, and fecal coliform water quality goals; however, the cost estimates of those scenarios range up to $430 Million (Brown & Caldwell 2010).

Watershed-wide implementation of the type of large-scale stormwater BMP's and stream repair projects recommended in the WMIP are expected to account for minor reductions in nitrogen (8%) and fecal coliform (3%) compared to current conditions; however, these practices are expected to result in more significant reductions in sediment (24%) and phosphorous (13%) loading to Ellerbe Creek (Brown & Caldwell 2010). The WMIP does not present any analysis of potential reductions in overall stormwater volume. The Ellerbe Creek Green Infrastructure Partners pose the question, "What further pollutant and stormwater volume reductions, could be achieved with the implementation of multiple, dispersed Green Infrastructure (GI) practices throughout the watershed?"

Ellerbe Creek's impairment is most likely due to many factors, chief among them are hydrologic modification from dredging/channelization combined with the major hydrologic alterations of streamflow accompanied by high levels of urban development (NCDENR 2012). It is well understood that impervious surfaces and stormwater drainage systems short circuit the natural hydrologic processes in watersheds, increasing the magnitude and frequency of storm flows into streams (National Research Council 2008). These flow changes result in channel widening and deepening, increased channel erosion, reduced flooding, covering of stream bed locations with sediment, the introduction into the stream of a host of pollutants, and other effects that contribute to "Urban Stream Syndrome" (Walsh et. al 2005).

This Technical Report addresses the question of the potential effects of implementing GI practices in Ellerbe Creek. Several partners including the Ellerbe Creek Watershed Association, the City of Durham, American Rivers, Downtown Durham, Inc., Triangle J Council of Governments, and NC Cooperative Extension proposed and were subsequently awarded a US Environmental Protection Agency (EPA) Urban Waters grant to conduct a study and model to build upon the Ellerbe Creek WMIP by identifying GI retrofits in the most urban areas of the city. Because of the small, dispersed nature of GI practices and the need to consider a vast number of these, the study and plan focus on a limited area of the watershed. The project will quantify the pollution reductions that could be achieved by implementing these low-cost, dispersed retrofits. The project partners will present these findings in both technical and public documents and in community workshops.

2. Technical Report

This Technical Report compiles information from meetings and discussions of the Ellerbe Creek GI Partners with written documents; the December 2012 "Technical Memo: Desktop Analysis for identification of possible stormwater sewer retrofit locations in subwatersheds 14 and 18 of Ellerbe Creek Watershed," and the January 2013

" Ellerbe Creek Green Infrastructure Partnership Semi-annual Report, May 30-December 31, 2012." The Technical Report presents the analysis methodologies and results of the study area identification, GIS analysis, fieldwork, and modeling completed by project partners.

The Ellerbe GI project Partners agreed upon the following goals for the project:

- Provide field work and analysis to show how stormwater control measures (SCMs) can reduce water quality pollutants, specifically nutrients, entering Ellerbe Creek;
- Provide field work and analysis to show how to improve Ellerbe Creek hydrology by reducing stormwater volumes and increasing evaporation, plant transpiration, infiltration, and water storage in the watershed; and
- Maximize the number of best management practices in the watershed.

3. Study Area

The study area is a 467-acre catchment within the Ellerbe Creek Watershed shown in Figure 1. This document refers to this area as the “downtown Ellerbe Creek catchment.”

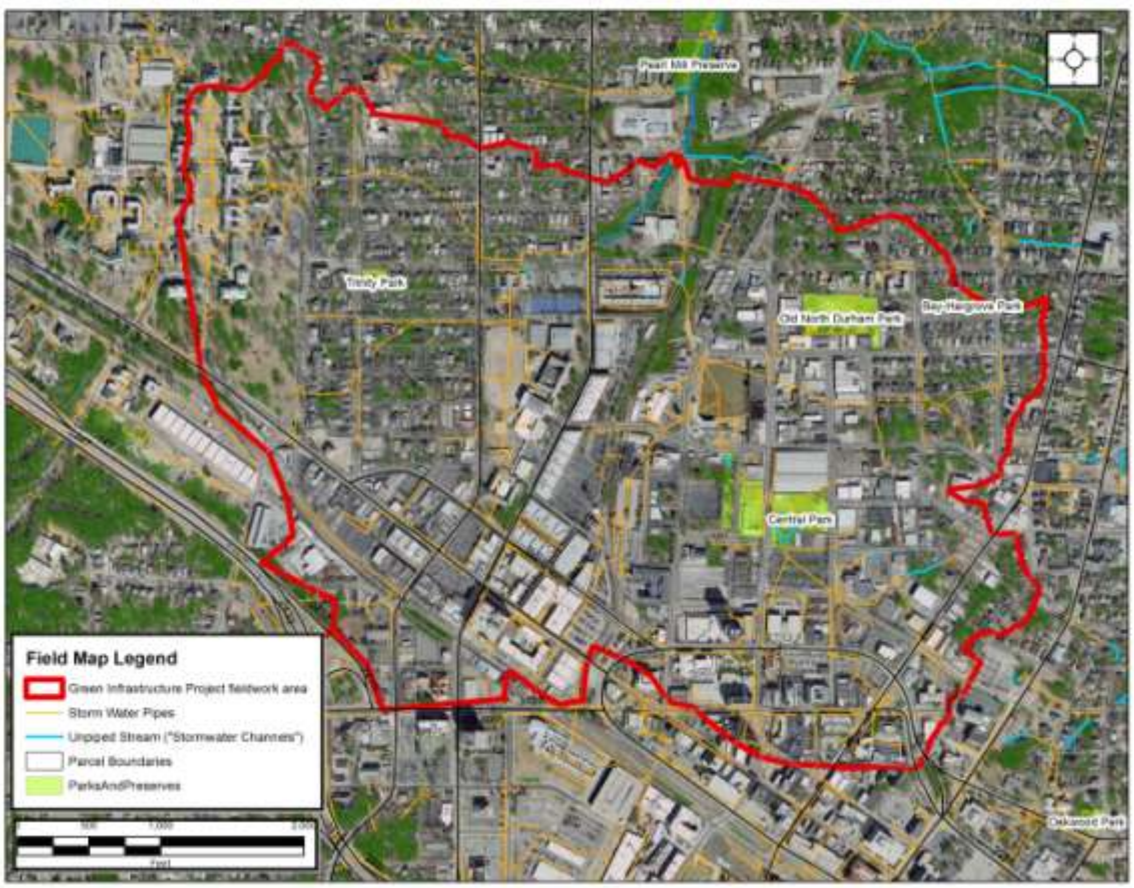


Figure 1. Ellerbe Creek downtown catchment (Catchment #14 from Ellerbe Creek Watershed Management Improvement Plan)

Ellerbe Creek's watershed lies within the Durham Triassic Basin, a geologically unique area located on top of 200 Million year-old sedimentary deposits that filled an even more ancient rift valley (Bain and Harvey 1977). The sedimentary geology is distinct from crystalline and metamorphic geology to the northwest (in most of the Eno River) and southeast (in lower Falls Lake and Wake County) (Bain and Harvey 1977). Triassic Basin geology is relatively flat, forms soils dominated by shrink-swell clays, and has relatively little rockiness within stream beds, except for areas where streams intersect more recent diabase (magma) intrusions (Bain and Harvey 1977).

The catchment is the most impervious, 42.6% total impervious area, of the 33 similarly sized catchments identified in the Ellerbe Creek WMIP (Brown & Caldwell 2010). The catchment's land use is 31% un-built parcels (includes surface parking), 28% commercial, 16% detached residential, and 2% publicly-owned land.

Not only is the catchment the most impervious of all the Ellerbe Creek headwaters, but it has the highest density of stormwater inlets (1.5 inlets/acre), and the great majority of the stream has been piped (shown in orange in Figure 1), with very little of the stream open to daylight (shown in blue). These conditions combine to create an unnaturally high volume of runoff that reaches South Ellerbe Creek very rapidly, even during small summer storms. Thus, South Ellerbe Creek is exposed to regular, highly-erosive flows carrying pollutants from downtown.

Since the downtown Ellerbe Creek catchment has very few opportunities to improve water quality within the stream, a GI-based approach to stormwater management should be an integral part of efforts to improve water quality and hydrology of the catchment.

4. Analysis Methodologies

The following section describes the methodologies used to select the areas of focus for the Ellerbe Creek Green Infrastructure analysis and to conduct the desktop analysis, field analysis, and post fieldwork pollutant reduction modeling of immediate and long-term scenarios. Figure 2 illustrates the fieldwork and modeling steps and the results for each of three different types of analyses completed; 1) the Site Retrofit analysis; 2) the Residential Retrofit Analysis; and 3) the Street Retrofit Analysis. For all three of these analyses, initial scoping and information gathering was completed using GIS. The Field Analysis section of this report (Section 4.3) explains how the field teams conducted all fieldwork, and the Post-Field Work Assessment section (Section 4.4) explains two separate modeling scenarios, an Immediate Opportunities and a long-term "Full Green" scenario, and details how the modeling steps and assumptions for each of these scenarios. The Results section (Section 5) presents flow and nutrient reductions calculated in the JFSNLAT for both the Immediate Opportunities and Full Green Scenarios.

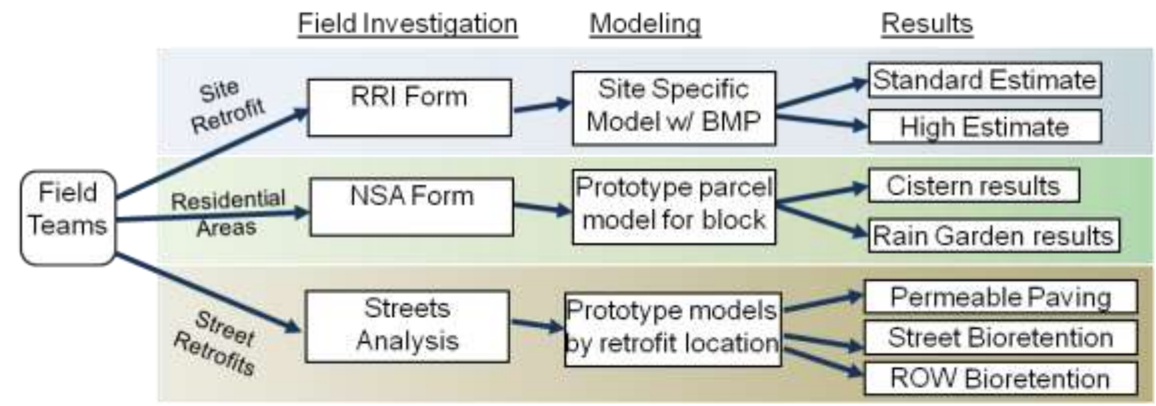


Figure 2. Field Investigation and Modeling process for the three types of investigations

4.1 Focus Catchment Selection

Project partners selected the Center for Watershed Protection's Urban Stormwater Retrofit Practices (Schueler et. al 2007) to guide the GIS analysis to identify potential Green Infrastructure (GI) retrofit opportunities. ECWA staff collected and organized all the GIS data during July-October and ranked the most urbanized catchments for analysis using the criteria shown in Table 1.

Table 1. Criteria used for ranking Ellerbe Creek Catchments

	Catchment								
	8	11	12	13	14	18	19	20	22
Area (acres)	494	269	190	387	467	534	377	718	435
Impervious cover	32.0%	19.6%	15.2%	20.8%	42.6%	32.2%	27.2%	24.7%	23.1%
Percentage of unbuilt parcels	27%	17%	5%	13%	31%	15%	15%	18%	14%
Percentage of publicly-owned lands	1%	41%	14%	1%	2%	3%	2%	1%	3%
Percentage of detached residential land	37%	27%	62%	62%	16%	33%	43%	38%	46%
Percentage of industrial land	0%	0%	0%	0%	0%	4%	3%	3%	0%
Percentage of commercial land	18%	22%	2%	4%	28%	20%	14%	23%	26%
Catchment upstream of non-mainstem WQ station*	Yes**	No	No	Yes	Yes	Yes	No	No	No
BMP's recommended in ECWMIP*	2	2	0	0	1***	3	0	2	1
Stormwater outlets*	55	42	28	293	15	65	57	133	95
Stormwater outlet density (per acre)	0.111	0.156	0.147	0.757	0.032	0.122	0.151	0.185	0.218
Stormwater inlets*	585	176	99	212	679	706	374	499	311
Stormwater inlet density (per acre)	1.184	0.654	0.521	0.548	1.454	1.322	0.992	0.695	0.715

* Source = Ellerbe Creek Wat. Imp. Plan
**RainCatchers mon. in addition to City wq site
***DDFC project also recommended in SW #14

The partners decided that selecting priority catchments would allow the team to focus on effectively achieving the GIS and field-based analysis that is outlined in the Center for Watershed Protection guidance (Schueler et al. 2007) for the most urbanized catchments in Ellerbe Creek. Subsequent to this decision by the partners, project partners from Ellerbe Creek Watershed Association, Triangle J Council of Governments, and American Rivers decided to further narrow the GIS analysis to the two most urbanized catchments, catchments 14 and 18.

ECWA staff ran a subwatershed-scale GIS analysis to identify potential GI retrofit opportunities in catchments 14 and 18 based on Center for Watershed Protection (Schueler et al. 2007) guidance. This analysis is described in detail in "Technical Memo: Desktop Analysis for identification of possible stormwater sewer retrofit locations in subwatersheds 14 and 18 of Ellerbe Creek Watershed" (Welch 2012). ECWA staff, Triangle J Council of Governments (TJCOG) staff, and City of Durham Stormwater Services (Durham) staff reviewed the initial analysis results, and the results are mapped locations and spreadsheets of the categories of potential storage (SR) and on-site (OS) retrofit opportunities in Table 2.

Table 2 describes two different categories of retrofit practices, storage retrofits (SR) and on-site retrofits (OS). Storage retrofit opportunities are locations where stormwater from areas of 5-500 acres can be treated (Schueler et al 2007), so these are usually areas where stormwater from areas uphill concentrate into one area where there is potential for storage and treatment. By contrast, on-site retrofits are smaller (0-5 acres) locations closer to where the rain falls.

Table 2. GIS guidelines followed for identifying potential storage (SR) and on-site (OS) retrofit opportunities

Retrofit location	**Guidelines**
SR-1 Existing Pond	Evaluate stormwater layer to find existing stormwater ponds with a contributing drainage area greater than 5 acres *or* Superimpose topography, drainage layers and aerial photos to identify low points in the drainage network where dry ponds may exist.
SR-2 Roadway Culvert	Superimpose topography and headwater stream layers (zero, first and second order) over the local and state road network to identify road crossings.
SR-3 Below Outfall	Superimpose publicly-owned stream corridor land parcels at least two acres in area with storm drain outfalls with a diameter greater than 12 inches and less than 60 inches.
SR-4 Conveyance System	Superimpose ditch lines, zero-order streams, conveyance easements or open channels with open land adjacent to the drainage network
SR-5 Transport Right of Way	Compare local, state or federal highway right-of-way layers against the stream or drainage network to identify open spaces one acre or greater *or* review highway agency GIS for existing stormwater infrastructure or treatment practices suitable for retrofitting.
SR-6 Large Parking lot	Match large contiguous parking areas/rooftops greater than 5 acres in size with adjacent open land in public or institutional ownership, or owned by the same landowner.
OS-8 Small Parking lot	Search for parking lots less than five acres in size that are municipally or institutionally owned.
OS-9 Individual St	Screen for streets that meet street retrofit feasibility criteria, such as slope, right-of-way width, open section drainage, presence/absence of sidewalks and parking lanes.
OS-10 Individual Rooftop	Superimpose property ownership layers with aerial photos or impervious land cover data to locate large (>0.25 acres) municipal, institutional, commercial or industrial buildings that may be assessed for demonstration rooftop retrofits *or* look for clusters of building permit data that indicates areas experiencing active redevelopment
OS-11 Little Retrofit	A desktop search is not helpful in finding specific locations for little retrofits, although a GIS can help find tax reverted vacant lots and publicly owned parcels, such as parks, schools, recreation centers to investigate in the field.

ECWA staff mapped the locations of storage and on-site retrofit opportunities using GIS ArcGIS version 10. Before starting the analysis, it was understood that very few existing stormwater ponds (SR-1), storage opportunities in transportation rights-of-way (SR-5), or opportunities near large parking lots over 5 acres (SR-6) were likely to be identified in the downtown catchment. In addition, GIS analysis of potential on-site possibilities was limited to individual parking lots (OS-8) and rooftops (OS-10), and individual streets (OS-9) and little retrofits (OS-11) were identified primarily as a part of the field verification process.

4.2 Work Areas Selection

Prior to starting fieldwork, ECWA and TJCOG staff divided the area of the Downtown Ellerbe Creek catchment into 7 contiguous "work areas" to ensure that multiple field teams could work simultaneously without overlap, and to more easily track which areas of the watershed had been assessed. The following criteria were used in delineating the subareas:

- Contiguous Area
- Minimum number of major road and rail crossings for field teams
- Consistent land use within the work area
- Efficiency of assessment (efficient walking paths)

Figure 3shows the Work Areas used by the field teams. Work area 1 is dominated by Duke's East Campus. The dividing line between Work Area 4 and Work Areas 5, 6, and 7 is a railroad right-of-way.

Work Areas 2 and 5 are characterized as primarily residential areas. This distinction is important as field teams in these areas used a different field assessment methodology for the most part than field teams in the rest of the Work Areas.

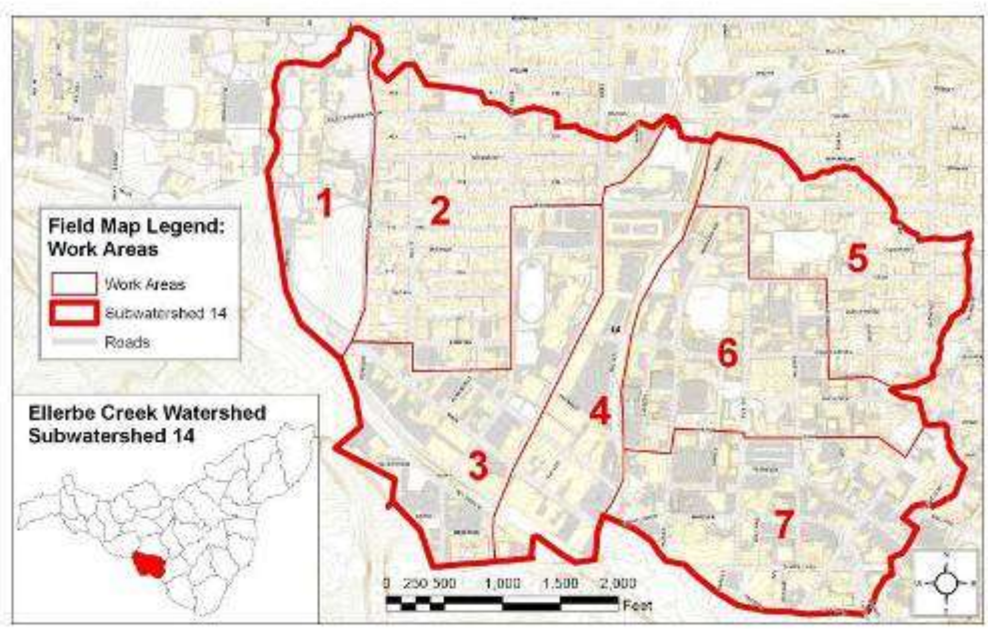


Figure 3. Work Areas for Field Work in Subwatershed 14

Work Areas 3, 4, 6, and 7 are characterized by mixed use commercial and institutional land uses. Work Area 3 is characterized by schools and churches in the north section, and shopping, dining, and large parking areas in the southern section. Work Area 4 is comprised of generally larger buildings and warehouses, with some significant parking areas. Work Area 6 includes Durham Central Park and the Durham Athletic Park, and mixed offices, dining, retail, and small industrial (garages, plumbing companies) uses. Work Area 7 is a significant portion of Durham's core downtown area with offices, street side retail and restaurants, and generally dense development.

4.3 Field Analysis – Identifying Retrofit Opportunities

Results from the initial GIS analysis were used to identify areas with high numbers of potential retrofit practices. Budgetary considerations were used to further narrow the area of focus to one downtown Ellerbe Creek catchment area, Catchment 14 (described in Section 3 above). Project partners conducted field work in Catchment 14 during the week of December 3-7, 2012.

Field teams consisted of two individuals per team and included staff from Durham Stormwater Services, Triangle J Council of Governments, NC Cooperative Extension, and Ellerbe Creek Watershed Association. Two to three field teams investigated potential retrofits sites identified in the GIS analysis. Teams also noted and investigated additional feasible locations discovered in the field. One field team was assigned to a Work Area each day to ensure efficient coverage and to avoid duplication of survey efforts.

The Retrofit Reconnaissance Investigation forms and methodology (Schueler et al. 2007) were used to evaluate potential site retrofit locations in Work Areas 1, 3, 4, 6, and 7). The

Neighborhood Source Assessment forms and methodology (Wright et al. 2005) were used for neighborhood field assessments in Work Areas 2 and 5, except in cases where individual site retrofits required the use of Retrofit Reconnaissance Investigation methods.

Two-person teams were equipped with a field notebook and a tablet computer device. Team members were required to wear a high-visibility vest and identification, and appropriate footwear and clothing for the conditions. Generally, one person utilized the field notebook and the other person used the tablet.

The field notebook contained reference materials such as maps and documents, specifically:

- maps and datasheets of retrofit opportunities;
- mapping with hydrology, utilities, and infrastructure such as roads, stormwater, water, and sewer networks;
- a retrofit guide describing BMP guidance such as sizing considerations and constraints;
- a paper version of the Retrofit Reconnaissance Investigation field form (adapted from Schueler et al 2007);
- a paper version of the Neighborhood Site Assessment (NSA) form for analysis of retrofit potential in residential areas (adapted from Wright et al. 2005);
- an authorization letter;
- contact information for relevant local and state government entities;
- a photo log form to record photo ID number and subject;
- a comment form to note field observations not evident from the GIS analysis; and
- reference materials described in Schueler et al. (2007).

The tablet devices were preconfigured for the field work by TJCOG and were either an iPad or Android tablet. Each device was used as a multifunction platform to capture and record pertinent field information about potential retrofits, including photos, retrofit locations, site data, calculations, and distances and areas. A project-specific Google account was established to store and receive field data. Electronic versions of the RRI and NSA field forms were developed using Google-based document tools (Google Forms) and accessible through the tablet web browser (below and Appendix 2). Data from the following forms were uploaded directly into spreadsheets for later analysis.

- Retrofit Reconnaissance Investigation (RRI) form developed by the Center for Watershed Protection (Schueler et al., 2007) for the identification, siting, and preliminary sizing of retrofit opportunities in the watershed. This form was revised to exclude fields not applicable the downtown area (e.g. soils information) and to capture additional detail about land cover and the site-specific work area.
- Neighborhood Source Assessment (NSA) form developed by the Center for Watershed Protection (Wright et al., 2005) for characterizing neighborhoods' watershed quality and potential for residential area retrofits. This form was revised to specify neighborhood names instead of using generic terms (e.g. "Work

Area") and to capture additional detail about land cover. Several fields not applicable were excluded, such as trash and index of infill and redevelopment.

Various tablet applications and tools were obtained or developed by TJCOG for the field work. It was discovered during the field work that the tablet operating system platform affected application functionality. Several applications functioned better on the iPads but would malfunction on the Android-based devices. The standard camera application was used to capture photos and location-marking of retrofits was recorded in real-time using My Maps Editor application. My Maps Editor was configured to display relevant GIS information, such as retrofit locations and work area boundaries. A stormwater flow estimator was developed by TJCOG using a Google-based spreadsheet, allowing for field calculation of runoff based on land area, impervious cover, and volume of rain. The application Where Am I At was used to copy the spatial coordinates of the user into the electronic RRI form. An ESRI-based ArcGIS application allowed the user to delineate distance and area measurement of the current location.

4.3.1 The Search for Larger Site Retrofit Opportunities – Retrofit Reconnaissance Investigation

The teams following the RRI methodology were looking for individual site retrofits on predominantly non-residential sites. For each potential retrofit, teams were instructed to take a photo(s) and precisely mark the retrofit location on the My Maps Editor application (NextBusinessSystem Co. 2012). A screenshot of the application being used to mark a retrofit location is shown in Figure 4. After these tasks were completed, the field teams could begin using the online RRI forms to document site conditions and describe the proposed retrofit. For redundancy, field teams were asked to input the site location's latitude and longitude, a process made easier by the Where Am I At? application (MacDonald 2012). The most important site conditions were determined to be drainage area to the site, estimated percent impervious, land cover type, and available area for retrofit. Additionally, the field team would match the site to previously-identified retrofit opportunities, and document constraints, conflicts, and other notes. (The full RRI questionnaire is available in Appendix 1A.)

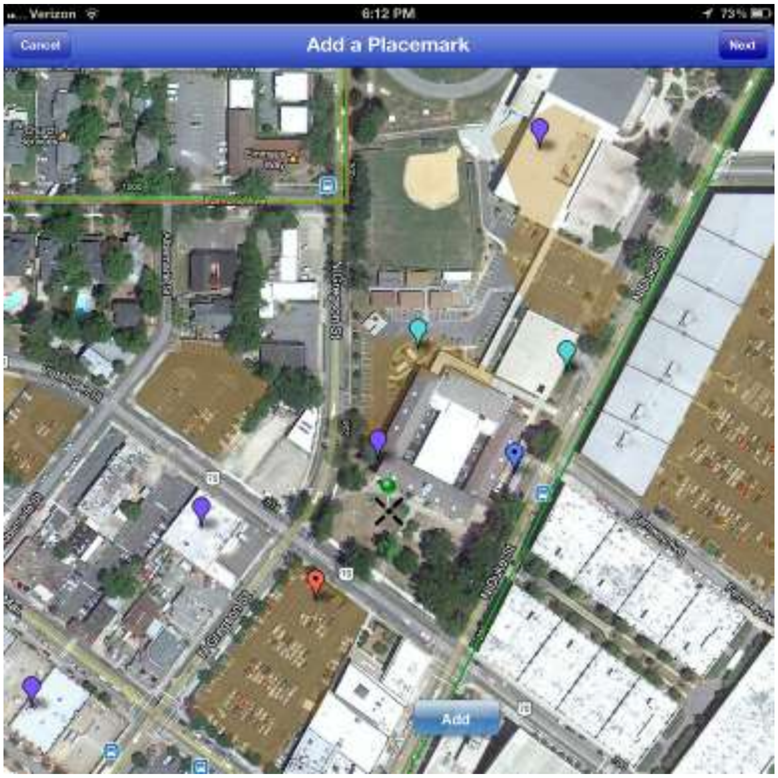


Figure 4. The MyMapsEditor Application being used to precisely mark a retrofit location (at the x).

Teams reviewed potential storage retrofits at roadway culverts (SR-2), below outfalls (SR-3), or within open conveyance channels (SR-4) and potential onsite storage opportunities at small parking lots (OS-8) or on individual rooftops (OS-10). In addition to reviewing the opportunities identified by the GIS analysis, field teams identified other locations with the potential for stormwater retrofitting. Field teams did not limit their recommendations to the size constraints used in the GIS analysis, and therefore they considered additional small parking lots, rooftops, or other locations.

Like the GIS Analysis, which used the Urban Stormwater Retrofit Practices (Schueler et al. 2007) definitions for watershed areas (see Table 2), the field teams used the same document's definitions for Stormwater Retrofit Types found in Table 3. The codes for each retrofit type (e.g. ST-6, RR-2) are used throughout the document. Two of the retrofit types in the guidance, rain barrels and French drains, were excluded from this project due to limited application potential and overlap with other retrofit types.

Table 3. Stormwater Retrofit Types. (Adapted from Schueler et al., 2007.)

Retrofit Type	Description
ST-1 **Extended Detention**	This option relies on 12 to 24 hour detention of stormwater runoff after each rain event within a pond, with portions of the pond drying out in between storm events. Extended detention (ED) allows pollutants to settle out, and if enough storage is available, can also provide downstream channel protection.

ST-2 **Wet Ponds**	Wet ponds consist of a permanent pool of standing water. Runoff from each new storm enters the pond and partially displaces pool water from previous storms. The pool also acts as a barrier to re-suspension of sediments and other pollutants removed during prior storms.
ST-3 **Constructed Wetlands**	Constructed wetlands are shallow depressions that receive stormwater for treatment. Runoff from each new storm displaces runoff from previous storms, and the residence time of several days to weeks allows multiple pollutant removal processes to operate.
ST-4 **Bioretention**	Bioretention is an innovative urban stormwater practice that uses native forest ecosystems and landscape processes to enhance stormwater quality. Bioretention areas capture sheet flow from impervious areas and treat the stormwater using a combination of microbial soil processes, infiltration, evapotranspiration, and plants.
ST-5 **Filtering Practices**	Filter practices function by filtering runoff through an engineered media and collecting treated runoff in an underdrain. The media may consist of sand, soil, compost, or a combination of these.
ST-6 **Infiltration Practices**	An infiltration trench is a rock-filled chamber with no outlet that receives stormwater runoff. Stormwater runoff passes through some combination of pretreatment measures, such as a swale or sediment basin, before entering the trench where it infiltrates into the soil.
ST-7 **Swales**	Swales are a series of engineered, vegetated, open channel practices that are designed to treat and attenuate stormwater runoff for a specified water quality volume.
RR-1 **Stormwater Planters**	These are on-site retrofits that consist of planters that store and infiltrate runoff through a soil bed to reduce runoff volume and pollutant loading. They generally treat rooftop runoff, and act similarly to bioretention, or in some cases, infiltration BMPs.
RR-2 **Water Harvesting (Cisterns)**	Rainwater harvesting cisterns can be used in a non-residential application to collect runoff from rooftops, and store and use it for non-potable purposes. Water should be released (gradually) if not used.
RR-3 **Green Roofs**	Green roofs are used to store and treat rooftop runoff, and consist of a layer of vegetation and soil installed on top of an existing roof.
RR-5 **Rain Gardens**	Rain gardens are a form of bioretention that captures, filters and infiltrate rooftop runoff. Generally used for residential properties, but they can be used in non-residential applications where site conditions permit. Although Hydrologic D soils dominate in the Ellerbe watershed, it was assumed for the purposes of this analysis, and based on field observation of existing practices, that rain gardens can be effective treatment practices in residential and in some nonresidential locations.
RR-7- **Permeable Paving**	Permeable paving systems help reduce parking lot runoff by using a porous or semi-porous material to allow water to trickle through the paved area and into a shallow storage area (like a gravel bed), from which it can infiltrate into the soil.
LCC – **Land Cover Change**	One possible retrofit option is simply to replace one type of land cover with another land cover type that is less impervious or has lower nutrient export. This is generally applicable to sites like abandoned parking areas.

The team would select the Treatment Type and the form would automatically display items specific to each retrofit type selected. For instance, a storage retrofit (dry pond, wetland, or bioretention) requires inputs for available treatment area, average storage depth, target storage, and available storage. Green roofs require input of total green roof area selection of extensive or intensive type roofs. A large text field allowed for additional comments for each specific retrofit.

Figure 5. Team leader from Triangle J Council of Governments demonstrates the on-line field form to Durham Stormwater Services Staff

Field teams were instructed to limit proposed retrofits based on only on physical site conditions. The retrofit opportunities previously identified in the GIS analysis were intended to serve as a starting point for field analysis. Field teams were encouraged to consider other opportunities identified in the field. Detailed assessments of all potential utility-related site constraints, such as underground cables, were not conducted. It is important to note that all proposed sites should be further evaluated for feasibility prior to implementation.

4.3.2 Residential Retrofits Search—the Neighborhood Source Analysis

Initial fieldwork conducted in the residential work areas focused on evaluation of parcel site conditions as well as for rain garden and water harvesting retrofit potential. Commercial and other non-residential zoned parcels were included in this assessment if they were located in a residential area. Detailed assessments of all potential utility-related site constraints, such as underground cables, were not conducted. It is important to note that all proposed sites should be further evaluated for feasibility prior to implementation.

The Neighborhood Source Assessment was conducted by grouping neighborhoods into "blocks" with similar site characteristics. Specifically, Work Areas 2 and 5 were divided into neighborhood blocks based on map evaluations and visual observations from field reconnaissance. Neighborhood blocks were considered as an efficient methodology for these areas due similarity in landscape and construction. Additionally, there would be a high potential for error and considerable difficulty in designing and modeling over 400 individual practices on a site-specific level.

Field forms for these areas (Neighborhood Source Assessment – see Appendix 1B) were completed for each of the 10 distinct blocks with one form per block. Field teams were asked to envision the typical parcel for the block and to estimate the amount (percentage) of lawn, driveway, building, managed pervious, forest, etc. Figure 6 shows a map of the blocks.

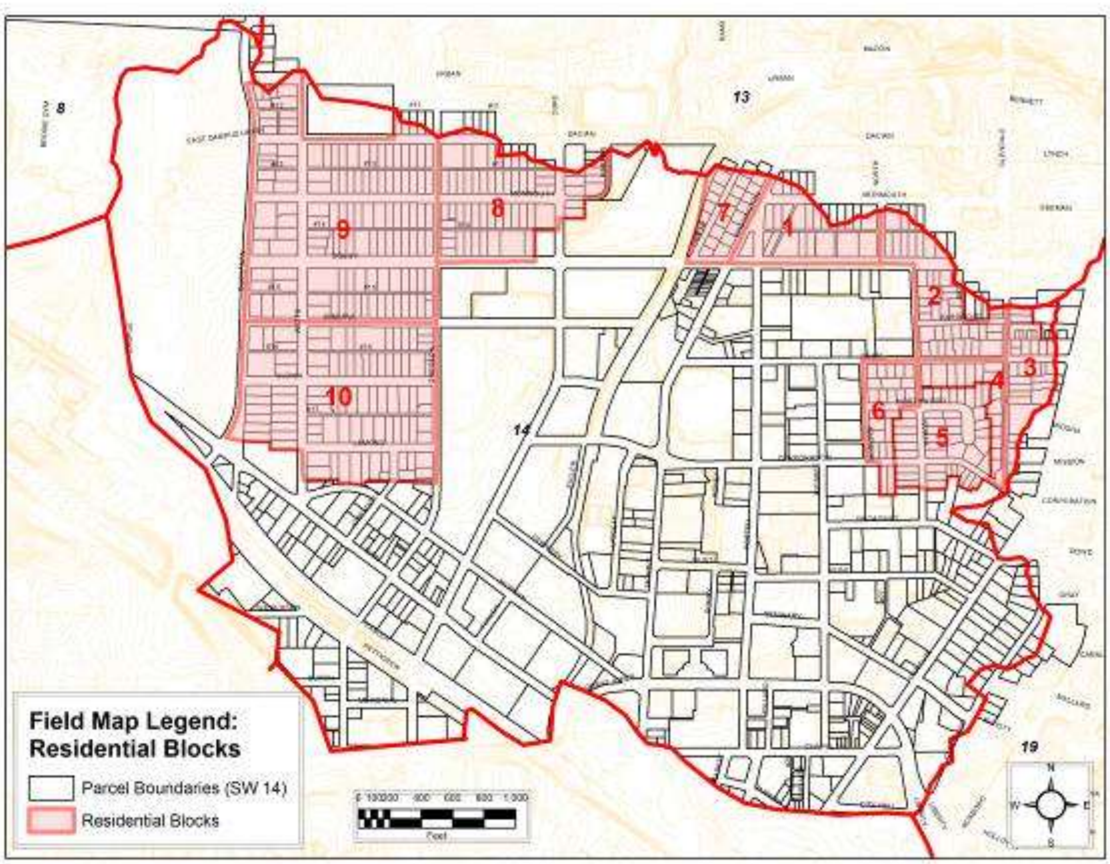


Figure 6. Neighborhood blocks assessed during fieldwork

ECWA and TJCOG used GIS-based parcel and impervious cover data to determine the average parcel size for each block. This average parcel size assumption was based on the grouping of similar parcels and development patterns into neighborhood blocks and greatly reduced model complexity. Using GIS, the impervious area layer was intersected with the parcel layer to compute the average impervious area per parcel for each block. The impervious area layer contains building, paved, and "other" impervious areas. A value was calculated for each type of impervious area.

The computed average impervious cover area per parcel was compared to the field data and found to match closely, with less than 5% error between the two data sources. This percentage corresponds with the visual limit of field teams and enhanced confidence in the field data. Due to the similarity of these methods, field observations were used to estimate the remaining non-impervious land cover types and percentages for the neighborhood blocks.

Figure 7 provides a stylized diagram of the average parcel. The overall parcel area is apportioned into land cover types, such that the sum of the component areas equals the overall parcel area. It is acknowledged that parcel characteristics may vary across individual parcels; however, parcels within each of the 10 neighborhood blocks displayed similar average values of area for each type of land cover present. Table 4 documents the computed values for average parcel size, percent imperviousness, average building area, and the number of parcels that were included in the sample for each neighborhood block.

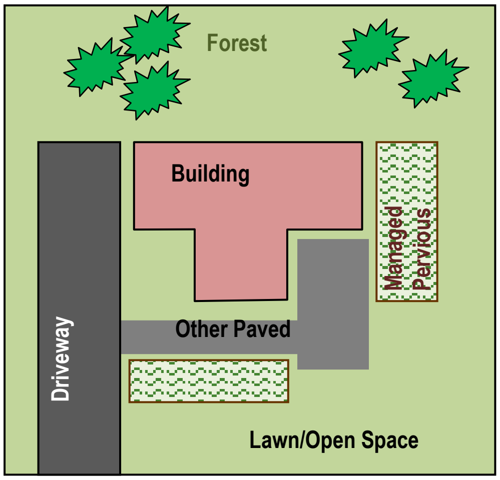


Figure 7. The average residential parcel with land cover types.

Table 4. Summary of average parcel characteristics by block for residential analysis.

Block	Work Area	# of Parcels	Avg. Parcel Area (sf)	Avg. % Impervious	Avg. Building Area (sf)
block 1	5	19	11378	29.5%	2304
block 2	5	42	6675	37.7%	1923
block 3	5	26	5964	39.8%	1930
block 4	5	15	7883	34.3%	1868
block 5	5	32	6067	33.5%	1600
block 6	5	21	6116	43.5%	1717
block 7	5	24	5608	30.0%	1381
block 8	2	55	8461	42.0%	2448
block 9	2	120	8686	40.0%	2698
block 10	2	86	9736	46.3%	2856

Values for the non-structural land cover types were computed for the average parcel in each block. Figure 8 shows how the component land cover types add up to the total parcel area in the average parcel for each block. Paved/parking areas are shown in gray, building area in red, and sidewalk or other impervious areas are in black. The other three land cover types are pervious.

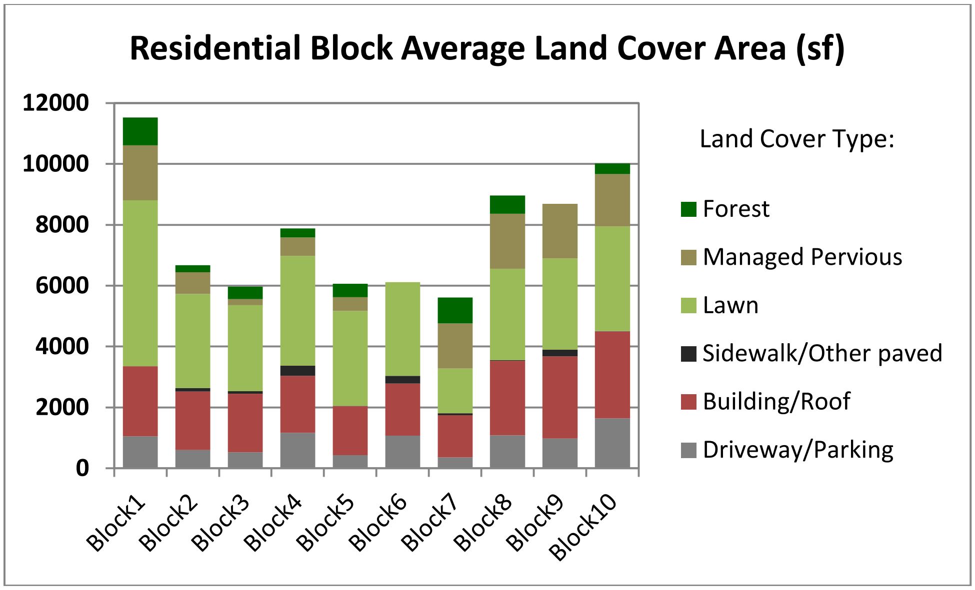


Figure 8. Average parcel area (sq.ft) summed by land cover type for each block.

In order to better evaluate the potential for rain gardens and rain water harvesting opportunities in Work Areas 2 and 5 resulting from the NSA, staff from TJCOG and ECWA conducted site-specific assessments of each of the 440 residential parcels between June and July 2013. A criteria-based score (Table 5) was computed for each opportunity on each parcel.

Table 5. Criteria for assessing residential parcels for rain garden or rain water harvesting potential.

Criterion	Rain Gardens	Rain Water Harvesting
Gutter/ Downspout condition	Adequate=1, Inadequate=0	Adequate=1, Inadequate=0
Household/yard managed	Adequate=1	Adequate=1
Owner-occupied	Yes=1	Yes=1
Downspouts directly connected to stormwater system	Yes=1	Yes=1
Adequate location visible (no obvious constraints, enough space)	Yes=1	Yes=1
Outdoor water demand	Yes=1	Yes=1
Wet/flooding area	N/A	Yes=1
Existing RG/RWH	Yes=1	Yes=1
Total Possible Score	**7**	**8**

Each parcel was given two numeric scores to describe the potential for a rain garden or rain water harvesting practice. Any residential parcel receiving a total score of 4 or greater in the rain garden category was designated as an immediate opportunity for a rain garden. Similarly, any parcel with a total rain water harvesting score of 4 or greater was designated as an immediate opportunity for a residential rain water harvesting practice. These parcels must have had 'yes' (1) for both Gutter/Downspout condition and Adequate location visible in order to receive this designation. ECWA staff entered the parcels identified for these practices into the online maps.

4.3.3 Green Streets Retrofit Field Investigation

A limitation of the large site RRI, and residential field work analyses is that neither considers the 60+ acres of area within the street right-of-way. This area is dominated by sidewalk, walkways/driveways, planted/green area, and parking lane and is a significant portion of the catchment.

In April 2013, ECWA and American Rivers staff conducted a field survey to identify the following prototypical street blocks to be used as models for potential "green streets" best management practices:

- Residential right-of-way: 1000 block of W. Trinity Avenue
- Commercial right-of-way: 200 block of Rigsbee Avenue
- Commercial right-of-way, bioretention: 100 block of E. Morgan St.

Three types of retrofits were identified for the green street field work. These include permeable paving and two types of bioretention device; a "right of way" bioretention located in the right of way in existing pervious areas and an 'in-street' which is a small bioretention cell placed in the street along the curb with an overflow to a storm drain. This smaller type of practice is designed to treat a small area of the street and parking lane.

The field work and GIS assessment also identified potential retrofit sites in planted/green areas or the parking lanes of each block. Each of the potential bioretention areas was measured and noted on a printed map of the block. In placing potential bioretention, existing infrastructure such as water and gas lines were noted and accounted for; additionally the prevalence of street trees in the right of way of the residential study area limits the possibilities for new bioretention until the shade trees needed to be replaced. When shade trees are being replaced in the right of way this can create an opportunity to incorporate bioretention into that area and the surrounding right of way area.

Areas for permeable pavers were identified with very few limitations put on these potential locations. Three assumptions were made for permeable paver placement, first, engineered solutions will be installed to protect existing utility infrastructure from seepage (e.g. a water proof membrane) while connectivity of the water storage would be maintained; second, all sidewalks and parking lanes in the study area will be connected to existing stormwater infrastructure through an underdrain or overflow as needed; and third, that proper maintenance of the pavers will be performed to ensure continued performance in heavily shaded areas. Permeable pavers were not recommended in areas of heavy truck traffic or in travel lanes of the roads. An analysis of permeable pavers in alleys was not conducted despite numerous potential opportunities for this retrofit in this catchment.

Based on the prototypical blocks fieldwork, the GI partners made the following assumptions. In residential areas, it was assumed 40% of sidewalks, walkways, and driveways could be retrofitted with permeable pavers in the near future (less than 10 years), and 80% of these paved areas have potential for retrofit over the long run (e.g. 30 years). The primary limitations are in areas with a slope greater than 7% and without paved surfaces (e.g. utility access boxes). Other assumptions include that 10% of planted/green area in the right-of-way is available for right-of-way bioretention; there are opportunities for bioretention within one parking space per every five (20 per 100 feet); and a site-by-site analysis was needed to identify opportunities for bioretention in the parking lane at the beginning or end of each block. The remainder of the parking lane would be converted to permeable pavers but would exclude areas that are used as bus stops. It was also assumed that these practices might not treat all of the stormwater that entered them and would either overflow into the existing stormwater conveyance or would be built with an overflow drain connected to the existing stormwater system. The impact of street tree replacement was not assessed; street trees can provide significant stormwater management. Alleys were not considered in this analysis. Replacement of street trees creates opportunities for additional stormwater control at the time of tree replacement. For the Immediate Opportunities Scenario, it was assumed half of all identified potential retrofits could be built.

The prototypical commercial block yielded similar results. Forty percent (40%) of sidewalks, walkways, and driveways could be retrofitted with permeable pavers in the near term, and 80% of these paved areas have potential for retrofit in the long run (e.g. 30 years). Commercial driveways were excluded from retrofitting since the amount of traffic would negatively impact potential infiltration. There are limited possibilities for planted/green areas, but in those few areas, 70% could be converted to bioretention. All parking lanes that are not loading zones could be converted to permeable pavers. Bioretention outside of the travel lanes but in the roadway would need to be determined on a block by block basis, while within the parking lane one of every five parking spaces (20 of every 100 feet) could be retrofitted with bioretention. The impact of street tree replacement was not assessed in the commercial block either. Replacement of street trees creates opportunities for additional stormwater control at the time of tree replacement.

Partners worked September through November on a block by block analysis building a data set that measured the square footage of all public rights-of-way by type in the study blocks. The analysis was a mix of field and desktop work using Google Maps satellite view and measurement tool, Google street view to verify parking areas and travel lanes, and ArcGIS to measure drainage area. Partners tabulated these measurements by block and side of the street within each work area (Figure 3). The measurements were then run through the assumptions from the prototypical blocks to identify the amount of bioretention and permeable pavers that could be retrofitted on each block. The treatment area was measured as the right-of-way and the street to the centerline of each block.

The retrofit opportunities were categorized as either Immediate Opportunities or Full Green Scenario opportunities. In the near term, the partners assumed all of the bioretention retrofits would not be possible due to the limitations placed on them from the prototypical block and 50% of the permeable paver retrofits were included due to repaving and streetscape upgrades that have recently occurred. The Full Green Scenario analysis added in the remaining permeable pavers, which would occur as the new sidewalks and streets needed to be resurfaced or replaced.

4.4 Post-field work assessment: Estimation of pollutant loading reductions using the Jordan and Falls Lake Stormwater Nutrient Load Accounting Tool

Sections 4.4 describes steps taken to model fieldwork recommendations considered to be immediate opportunities that could be implemented technically without significant changes to infrastructure at a given site. Section 4.5 describes modeling of a "Full Green Scenario," which assumes that additional fieldwork-identified projects can be implemented over the long-term (e.g. 30 years) as a part of ongoing improvements to infrastructure or site redevelopments or improvements. For example, a surface parking lot downtown would have been assumed to be converted to either a parking deck or a building, and the long-term, Full Green Scenario might assume an appropriate GI practice would be installed at the time of redevelopment.

4.4.1 Modeling Immediate Opportunities in Ellerbe Creek

Based on need to estimate and compare potential pollutant and water volume reductions from the implementation of GI practices recommended by this project, project partners used the Jordan and Falls Lake Stormwater Nutrient Load Assessment Tool, Version 1.0 (JFSNLAT) (NCDENR 2011) to estimate potential volume and pollutant reductions. Several other models were considered, but the JFSNLAT was selected because of its ease of use, widespread acceptance in North Carolina, and because it was developed specifically considering the regulatory requirements for nutrients in Jordan and Falls Lake watersheds. It is important to note that the JFSNLAT is continuously in development, and subsequent versions of the tool will surely improve upon the version used for this project. Version 3.0 of the JFSNLAT is developed but has not yet been approved, and this version will likely address shortcomings in Version 1.0, for example the under-estimation of loading reductions by cisterns.

The tool allows users to estimate Nitrogen and Phosphorous loads and total flow based on conditions at a site before and after implementing best management practices. The model estimates the site's annual volume, nitrogen, and phosphorus export factors by the site's component land cover types. Reductions from BMPs are calculated using event mean concentration methodology. The model results give annual reductions in volume, nitrogen, and phosphorus loading on a net and per area basis. The tool is typically used to assess impacts resulting from a site redevelopment (with a change in land use). When used for retrofits, however, pre and post development land use is largely the same. When used at the catchment scale, the tool is limited because it does not account for nutrient transport. For the purposes of this study, it is assumed that the total pollutant loading (and reduction) calculations are the sum total of individual results using multiple model calculations.

Although the model was developed specifically for North Carolina, it is flexible to account for differences by location in the state. These distinctions are set by three inputs: Physiographic/Geologic Region, Soil Hydrologic Group, and Precipitation Location. The Physiographic/Geologic region selected for all studies is Triassic Basin. Ellerbe Creek's watershed is roughly at the boundary between Piedmont and Triassic basin according to the map in the model's guidance manual (NCDENR 2011), but the study area was determined to be more appropriately defined as Triassic Basin. (The annualized BMP performance is worse especially with regard to volume in Triassic Basin soils, and so model results would be more conservative.) The Precipitation Location selected was Carrboro because it is the closest location to the study area. According to maps and GIS data available from the Natural Resource Conservation Services' Soil Survey Geographic Database (SSURGO), the soils in the study area vary, with Urban (Ur) and White Store Urban Land Complex predominating (Hydrologic Soils Group D), and with some small areas of Cartecay and Chewlaca (HSG C), and Pinkston (HSG B). Soils in the D Hydrologic Group are more prominent than B or C, and represent an "average" condition for the area, so "D" was selected for all of the modeling.[2]

The JFSNLAT models small catchments with land cover defined by the user. Each retrofit identified in the Retrofit Reconnaissance Inventory was modeled by only considering the drainage area to the proposed retrofit. The field analysis collected the key information for each site drainage area including the size of the drainage area, land cover type, percent imperviousness, and notes on key details such as existing BMPs, slope conditions, and state of development. Desktop analysis using aerial photos, parcel and impervious cover data was used to aid the modeler in selecting the appropriate land cover for each parcel.

The model defines land cover types and characterizes them according to their loading export rates for nitrogen, phosphorus and runoff. While the model does have some more general categories representing averages for types of developments (1/4-acre residential parcels, etc.), the modeling for this project only used the specifically defined land cover types. Namely, these include the following, along with their average model loading rates for Durham's conditions:

[2] It should be noted that based on field observations from over test holes of over 20 installed rain gardens, the White Store and Urban soils conduct water at a much faster pace than is expected of a Hydrologic Soil Group D soil (0.14 inches/hr), behaving more like a Hydrologic Soil Group C (hydrologic conductivity of 1 inch/hr or greater).

Table 6. Land Cover types and Nitrogen, Phosphorus Event Mean Concentrations (EMC) and Loading and Runoff rates used for Catchment 14 in the JFSNLAT

Land Cover Type	N EMC (mg/L)	P EMC (mg/L)	N loading (lbs/ac/yr)*	P loading (lbs/ac/yr)*	Runoff (cf/ac/yr)*
Rooftops	1.08	0.15	10.78	1.50	159907
Parking Lot (commercial)	1.44	0.16	14.38	1.60	159907
Parking Lot (Industrial)	1.44	0.39	14.38	3.89	159907
Sidewalk	1.40	1.16	13.98	11.58	159907
Roads	1.40	0.52	13.98	5.19	159907
Transit – Primary	3.67	0.43	36.64	4.29	159907
Open Space/Lawn	2.24	0.44	1.18	0.23	8416
Forest	1.47	0.25	0.77	0.13	8416
Managed Pervious	3.06	0.59	1.61	0.31	8416
Buffer/Wetland/Water	-	-	-	-	-

* Calculated value

The model's loading rates by land cover type are based on research, primarily from North Carolina and the mid-Atlantic. Full documentation can be found in the model's manual (NCDENR, 2011).

Using the information from the field forms, pictures from the field work, and aerial maps and photography, the total area to be treated by the BMP was split into the land use categories listed above. The field teams recorded the intended BMP for each location, and the modeler entered those locations with a few exceptions. Several general assumptions were made for certain BMP types without an exact match in the model. In general, field teams performed preliminary sizing in the field to ensure that the space could accommodate an appropriately sized BMP. If the available area was just a little too small, field teams were encouraged to enter the BMP anyway, and note the space limitation. The field teams indicated the amount of available space to place the BMP, so in some cases, based on the calculations (or field notes), a BMP was modeled as undersized (the model allows up to 50% under-sizing).

4.4.2 Modeling the (RRI) Site Retrofits

In the model, once the watershed area and characteristics are input, the BMP characteristics must be specified. This process includes selecting BMPs to treat the area, and then specifying what portion of the area is treated by the BMP. Table 7 shows the BMP types available for selection, and the associated volume reduction and effluent concentrations built into the model. The model also allows under-sizing of BMPs by up to 50 percent. Under-sizing would occur when site conditions would not allow a full-sized BMP due to space or media depth limitations, but drainage conditions are suitable for collecting runoff, and there is an appropriate location for a BMP with the ability to handle any overflow due to under-sizing.

Table 7. BMP types available for selection in the JFSNLAT, and their volume reduction and TN and TP effluent concentration.

BMP DETAILS			
BMP	**Volume Reduction (%)**	**TN Effluent Concen. (mg/L)**	**TP Effluent Concen. (mg/L)**
Bioretention with IWS	35%	0.95	0.12
Bioretention without IWS	15%	1.00	0.12
Dry Detention Pond	0%	1.20	0.20
Grassed Swale	0%	1.21	0.26
Green Roof	50%	1.08	0.15
Level Spreader, Filter Strip	20%	1.20	0.15
Permeable Pavement*	0%	1.44	0.39
Sand Filter	5%	0.92	0.14
Water Harvesting	user defined	1.08	0.15
Wet Detention Pond	5%	1.01	0.11
Wetland	15%	1.08	0.12

*if treating commercial parking lot, TP effluent concentration = 0.16 mg/L

Table 8 shows the model BMP types that were used to represent the retrofits identified during GIS and field analysis.

Table 8. Retrofit Types from the RRI form (Schueler et al. 2007) and BMPs used to model them in the JFSNLAT.

Retrofit Type	JFSNLAT BMP Type
ST-1 **Extended Detention**	*Dry Detention Pond*
ST-2 **Wet Ponds**	*Wet Detention Pond*
ST-3 **Constructed Wetlands**	*Wetland*
ST-4 **Bioretention**	EITHER *Bioretention with Internal Water Storage* (IWS) OR *Bioretention without IWS* (depending on circumstance)
ST-5 **Filtering Practices**	*Sand Filter*
ST-6 **Infiltration Practices**	No direct match. Bioretention without IWS and Level Spreader/Filter Strip are closest matches based on volume reduction, function. Choose *Level Spreader, Filter Strip* which has higher volume reduction, but has higher effluent concentrations than most other BMPs.
ST-7 **Swales**	Depends on swale type. For pure grassed swales, model as *Grassed Swale*. For engineered dry swale, model as undersized *Bioretention without IWS*. For wet swale, model as undersized *Wetland*.
RR-1 **Stormwater Planters**	*Bioretention without IWS*.
RR-2 **Cisterns**	*Water Harvesting*.
RR-3 **Green Roofs**	*Green Roof*.
RR-5 **Rain Gardens**	*Bioretention without IWS*.
RR-7- **Permeable Paving**	Permeable Pavement. (Model does not offer any credit for this BMP in Triassic Basin with C soils, although the NC BMP Manual does provide credit for permeable pavement.) Used the NCSU Permeable Pavement Hydrologic Model (NCSU, 2008) to determine that even with 0.5 in/hr infiltration, and undersized base layer, can achieve 5% volume reduction.
LCC – **Land Cover Change**	Adjust land cover types for pre- and post-development inputs in model.

Following selection of a BMP, the user must input how much of the watershed area entered is treated by the BMP. The model allows breaking the watershed area into up to six catchments, with as many as three BMPs treating the areas in series. In general, because the site area was originally specified as draining to the proposed BMP, it was assumed that all of the site's area drains to the proposed BMP in the model. A model was completed for each of the large site retrofits identified, and the overall reductions in the Results section is a summation of the individual model results.

Standard and High Estimates of Load Reductions

In many cases, small variations in the design of a BMP can make a difference in practice performance. The field teams had considerable flexibility to recommend particular design features in the notes and could indicate if other retrofits could be added as complementary to the main retrofit type. As a result, for many of the retrofit sites, field teams developed a standard, conservative estimate and a second, higher-performing retrofit (i.e. more load reduction). For many retrofit types, relatively standard assumptions about the difference between low and high scenarios could be developed. But in any individual case, a site plan based on field notes was developed as applicable to represent a high scenario. Table 9 summarizes these assumptions.

Table 9. Base Assumptions for Standard and High Estimates of Loading Reductions for Site Retrofit (RRI) Analysis

Retrofit Type	Standard Estimate	High Estimate (default)	# of High cases (default)	# of special cases	# w/o High Estimate
RR2 – Cistern	Water Harvesting 30 - 40% volume capture, draw-down device and/or dedicated use assumed	Water Harvesting 50% - 70% volume capture, draw-down device and/or dedicated use assumed	10 of 11	1 of 11	0
RR3 – Greenroof	Extensive Greenroof (50% vol. capture)	Intensive Greenroof (85% vol capture)	7 of 40	0	33 of 40
ST4 - Bioretention	Bioretention w/o IWS	Bioretention w/ IWS	25 of 30	5 of 30	0
RR1 – Planter Boxes; RR5- Rain Gardens	Bioretention w/o IWS, 75% sized	Bioretention w/o IWS, 100% sized	2 of 13	3 of 13	8 of 13
ST3 - Wetlands	Wetland	(Special case only)	0	1 of 2	1 of 2
ST5 – Filtration	Sand Filter	(Special case only)	0	1 of 4	3 of 4
ST6 - Infiltration	80% sized LSVFS	100% sized LSVFS or	1 of 2	1 of 2	0
ST7 – Swales	Grassed Swale or undersized (50-60%) Bioretention w/o IWS, or undersized Wetland	Bioretention w/o IWS	2 of 7	2 of 7	3 of 7
Land Cover Change, Dry Ponds, Permeable Pavement		None	0	0	13 of 13
TOTAL			47 of 122	14 of 122	61 of 122

Roughly half of the opportunities had no high estimate calculated. About three-quarters of the opportunities with a high estimate followed a standard high assumption, and about one quarter followed a special case assumption based on the field notes or site conditions. In general, the bioretention practices are well suited to a standard and high estimate since they can be installed in a simpler manner without IWS, but in most cases, can be engineered to include IWS.

4.4.3 Modeling the Residential Retrofits in JFSNLAT

Using the land cover assumptions shown in Figure 8, a JFSNLAT model was developed for each prototypical parcel. Ten models were created in all. Each model could then be used to determine the average reductions a given type of BMP would have on the parcel's overall runoff and nutrient export load.

Two types of BMPs were considered for analysis: Residential Rain Gardens, and Residential Rainwater Harvesting. Using the JFSNLAT, rain gardens were modeled as Bioretention without Internal Water Storage (IWS). It is recognized that the most current version of the JFSNLAT model does not account for residential rain gardens, and the choice of Bioretention without IWS may overestimate reduction values in the non-growing season. Rainwater harvesting was modeled as Water Harvesting with 50% capture of the volume of the treated roof area, assuming that practices will be installed with appropriately installed drawdown devices.

The field analysis did identify potential properties for retrofits, so the number of practices reflects a real assessment of sites that could feasibly incorporate a real BMP. Furthermore, the proposed retrofits were mapped, so the number of each type of retrofit in each block was easily determined.

It is assumed that for potential rain gardens, all sites have the infiltrative capacity to accommodate a rain garden, rain gardens are sized properly to manage a 1-inch storm, and rain gardens are maintained sufficiently to ensure proper functioning. For rainwater harvesting, it is assumed that cisterns are sized properly to manage a 1-inch storm, have a passive draw-down device located to ensure 50% of annual rainwater capture from their catchment area, and are maintained sufficiently to ensure proper functioning.

Using the prototypical parcel approach (Fig. 5 and Table 4), the average reduction impact of a single cistern or rain garden could be calculated based on the average land cover areas and assumed treatment percentage (e.g. 25% of a rooftop to one cistern) for each block. Then, the total impact for the block could be calculated by simply multiplying the single practice reduction amount for a given block by the number of BMP opportunities identified in that block.

Unlike the larger site retrofits, the models of the prototypical parcel were built for the entire parcel area, not just area to be treated by the proposed retrofit. Given that rain gardens and cisterns only capture from a portion of the area, the treated area must be specified. Due to the fact that the parcel characteristics vary from block to block, the same treated area assumption cannot simply be used for all blocks. For instance, assuming a rainwater harvesting cistern that collects from 25% of 1200 square foot roof could also easily collect from 25% of a 3500 square foot roof does not make sense because a much larger cistern would be necessary in the latter case. **Error! Reference source not found.** shows the assumption for the portion of each type of area treated for rain garden BMPs. In general, the bioretention area is designed to treat rooftop runoff from one or two downspouts, but because of the slope of the yard and layout of the parcels, it is common to capture some runoff from the lawn areas directly uphill of the rain garden. Each parcel is different, and the assumptions are only based on parcel averages. (Additionally, many of the land cover types only average a few dozen square feet, so the actual area treated is quite small.) In general, the majority of the area treated by the rain gardens is either rooftop or lawn area.

Table 10. Portion of prototypical parcel land cover type areas treated by block for Rain Gardens.

Land Cover Block:	1	2	3	4	5	6	7	8	9	10
Driveway	0.02	0.05	0.05	0.01	0.05	0.02	0.05	0.02	0.02	0.02
Roof	0.25	0.25	0.25	0.30	0.30	0.30	0.35	0.20	0.20	0.20
Sidewalk	0.00	0.10	0.10	0.05	0.15	0.05	0.15	0.15	0.10	0.15
Lawn	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.10	0.10	0.10
Managed Pervious	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0.04	0.04	0.05	0.05	0.05	0.00	0.04	0.05	0.05	0.05

Table 11 presents the modeling assumptions for treated area for rainwater harvesting cisterns, which only collect from rooftops. The % Volume Reduction is also presented, as it is a required model input for Water Harvesting BMPs.

Table 11. Portion of prototypical parcel land cover type areas treated by block for Water Harvesting.

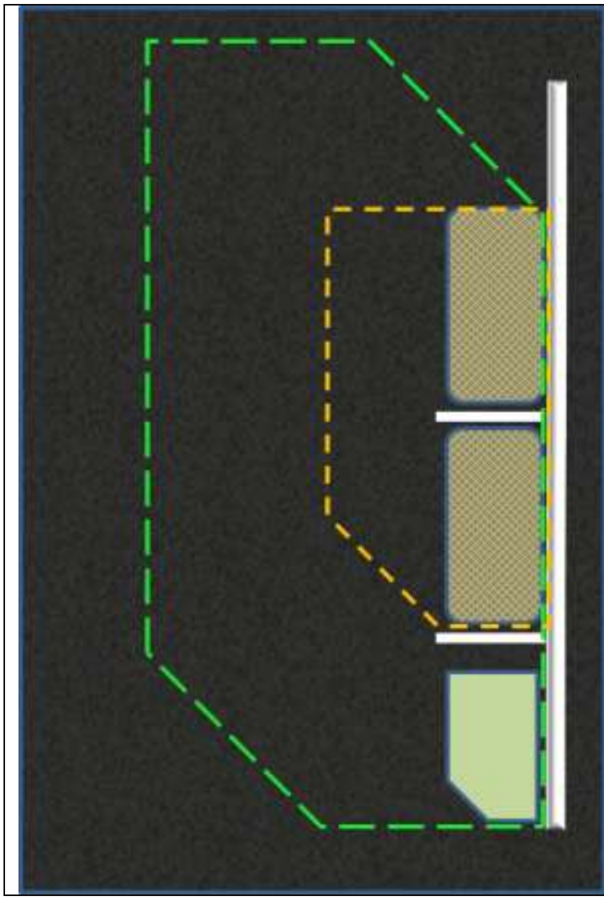
Land Cover Block:	1	2	3	4	5	6	7	8	9	10
Roof	0.20	0.25	0.25	0.25	0.25	0.25	0.25	0.15	0.15	0.15
All other types	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Vol Reduction	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Using these assumptions, the average volume and nutrient reductions were computed for each type of BMP for each block. Then, using the number of practices of each type identified for each block, the net loading reductions were computed by multiplication. The results section shows the results by block and retrofit type.

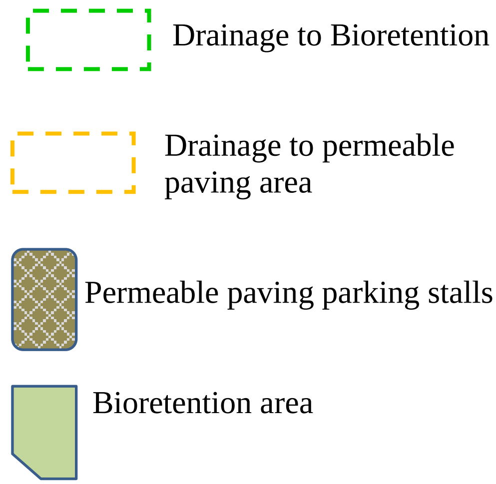
4.4.4 Modeling the Green Street Retrofits in JFSNLAT

From a combination of field work and GIS analysis, the total roadway area on each street block draining to existing storm drains was determined. As shown in Fig. 9, the primary retrofit practices identified in street rights-of-way are in street bioretention, right-of-way bioretention, and permeable pavement.

In-Street Bioretention



<u>Prototype In-street Bioretention</u>



The prototypical in-street bioretention is located adjacent to a curb drain, and drains the street (green line). Streetside parking areas were identified for conversion to permeable areas (as site and drainage conditions permit). The permeable areas also drain a portion of the street (orange line) within the bioretention drainage area.

Figure 9. In-street bioretention - typical drainage profile

The in-street bioretention retrofit is designed to treat a portion of the roadway area, often including street side parking. Generally, the bioretention cell is built next to an existing storm drain that would be able to handle overflow and flows from underdrains. The field work found that storm drains are located at the end of nearly all the blocks in the study area. The drains are near the street corners and often before a crosswalk. The drainage area to the proposed bioretention would roughly equal that of the storm drain, and would extend across the roadway as far as the crown of the road, and along the roadway uphill along the curb lane.

For the purpose of this analysis, it was determined that the in-street bioretention could be most effectively modeled using a prototype model in JFSNLAT to determine the loading reduction factors per unit area. It should be noted that the bioretention cells would have to be carefully designed (perhaps with pretreatment) to limit leaves, grass clippings and other organic materials from packing into the soil media.

The field analysis also determined potential locations for permeable paving retrofits in the street-side parking lanes. Finally, the field analysis identified the area of the potential bioretention cells. Using the areas identified in the field and related GIS analysis, the drainage to a typical in-street bioretention retrofit may be envisioned as in Figure 9.

In order to construct a prototype model, the proportions of area taken up by the bioretention area, permeable paving area, and untreated roadway had to be determined. Based on all of the field investigation data, it was determined that within the typical collection area, the bioretention cell would take up 8% of the area, permeable pavers 22%, and untreated roadway 70%. It is also assumed the permeable pavers intercept flow from adjacent roadway equal to their area. Field teams did not conduct a detailed assessment of all utility-related site limitations, and all sites should be assessed for feasibility prior to implementation.

Right-of-Way Bioretention

The fieldwork for the streets analysis also identified potential locations within existing rights-of-way for bioretention practices. Based on field observations and sizing guidelines for bioretention practices, the area treated was ten times the area of the bioretention area itself. Additionally, the collection area for each was estimated to be a mixture of pervious and impervious area (sidewalk and driveway, primarily).

The JFSNLAT model was used to calculate loading reduction factors for a 1000 square-foot collection area for a sample bioretention practice. Of those 1000 square feet, 500 square feet were assumed to be "Lawn", 400 square feet "Driveway/Parking Lot", and 100 square feet for the bioretention practice itself. The BMP selected was "Bioretention with IWS", and was modeled as fully sized. It should be noted that the bioretention cells would have to be carefully designed (perhaps with pretreatment) to limit leaves, grass clippings and other organic materials from packing into the soil media.

From the model outputs, the loading reductions were calculated for volume, nitrogen, and phosphorus. Because the model was run for a 1000 square-foot collection area, the associated loading reductions can be used for loading reduction factors on a per 1000 square foot basis.

For the Immediate Opportunities Scenario, it was assumed that 40% of the areas identified for right-of-way bioretention could be implemented. Thus, 40% of the area identified as bioretention, and its corresponding catchment area (10 times the bioretention) was assumed to be treated. This area (divided by 1000 square feet) was multiplied by the loading reduction factors to compute the total reductions.

Permeable Pavement

The field teams identified the total amount of sidewalk, driveway, and parking area within the public right-of-way (but outside of the street) that could be potentially converted to permeable pavers.

The JFSNLAT model was used to determine the potential loading reduction per 1000 square feet of area, by using a prototype 1000 square foot catchment. All 1000 feet of area were modeled as commercial parking lot, and it was assumed all 1000 square feet were converted to permeable paving, meaning no adjacent areas were treated. Since this version of the JFSNLAT model does not assign any credit to permeable paving given the soil types in the area, the BMP selected was Water Harvesting, and the volume reduction was set to 5%. This effectively models a permeable paving retrofit which reduces runoff by 5%, but has no concentration reduction. The five percent reduction assumption was determined by using the "Permeable Paver Hydrologic Design Model" (NCSU 2008) to determine an approximate minimum volume reduction. The permeable model was run with the soil having a low infiltration of 0.5 in/hr, and a base layer only 5 inches thick (reduced from the recommended 12 inches), and even under these conditions, exfiltrate into the soil would still be 5.1%, even before evapotranspiration. The upcoming version 3.0 of the JFSNLAT will correct this model shortcoming by allowing for permeable pavement with 5% volume reduction.

The model outputs the loading reduction for volume, N, and P for a 1000 square foot catchment. These values were multiplied by the total area identified for permeable paving retrofits, expressed in thousands of square feet, to get the total loading reduction.

Summary Loading Reduction Factors

All of the green streets analysis modeling was performed by using prototype models reflecting average watershed conditions for each retrofit type to generate loading reduction factors on per 1000 square foot basis. These factors were then multiplied by the total identified treated area for each retrofit type to determine total reductions for each block. Table 12 shows the loading reduction factors from the Green Street Retrofits analysis on a per-acre basis.

Table 12. Loading reduction factors per acre treated area, Streets Retrofits.

Treatment Type	Vol. [cf/acre]	N [lbs/acre]	P[lbs/acre]
In-street Bioretention	44,600	5.4	2.8
Right-of-way Bioretention	28,900	3.9	1.3
Permeable Pavement	8,000	0.7	0.27

4.5 Extending the Analysis – A "Full Green" Scenario

In order to envision the long-term potential of GI to improve water quality, it is also important to assess the potential effects of a more intensive implementation of GI practices that is not limited to existing site limitations. The Full Green Scenario is an extension to the Immediate Opportunities described in the previous section, which envisions a future in which most barriers to Green Infrastructure implementation are removed. In practice, some of the limitations to green infrastructure retrofits include high cost of retrofits, lack of available space or unwillingness to rededicate space on a parcel, potential ownership issues, and even bad timing (e.g. an owner that recently replaced a rooftop or parking lot may be less willing to retrofit it due to the recent expenditure). Other potential factors that may depress the potential for green infrastructure include lack of awareness of stormwater's connection to water quality issues, and lack of policies or incentives that encourage green infrastructure by private property owners.

The Full Green Scenario analysis takes a longer view (e.g. 30 years), during which time the study area is expected to continue changing as this area of Durham proceeds with a downtown revitalization. With the right combination of changes in policy, education, incentives, and new opportunities for retrofits, many of the current impediments to wider green infrastructure adoption may be surmountable in the future. Although it is also assumed that future technology will improve these practices and future modeling tools will model those improvements, the current analysis is limited to existing assumptions in the JFSNLAT Version 1.0. Thus, the methodologies described in this section are limited to opportunities identified as a result of desktop analyses and fieldwork that have the potential for implementation in the near future.

The Immediate Opportunities Scenario is a snapshot view of some of the potential green retrofit opportunities in the study area. It is recognized that the field inspection and methodology used in developing the immediate opportunities is limited in several ways. Firstly, the field teams were working with limited time and information, and did not have the ability to inspect all portions of the study area (e.g. go onto roofs, enter internal courtyards, areas obscured by fences, portions of private property far from roads, etc.). Secondly, the field teams can only see the conditions on the ground at the time of the field inspection. While it is known that some parts of the study area will change, a field inspector is not able to design retrofits for future conditions.

The Full Green Scenario attempts to go part of the way toward envisioning a future with appropriate management of stormwater fully integrated into the built environment of this area of downtown Durham.

4.5.1 - Site Retrofits Full Green Scenario

The non-residential site retrofits identified by the field teams using the Retrofit Reconnaissance Inventory methodology (Schueler et al. 2007) were surveyed and catalogued in sufficient detail to allow preliminary design and modeling. It is recognized that the field teams may have overlooked a considerable number of opportunities due to lack of time, access, or limited knowledge of sites. While all of the major opportunity locations identified in the GIS analysis were evaluated by the field teams, and the field teams were instructed to add other opportunities as they found them, there are certainly more potential opportunities on the non-residential sites.

Furthermore, the field teams of course do not have foresight about how the study area will change in the next 20-30 years and which sites may be suitable for retrofits in that time frame.

The Full Green Scenario analysis for the non-residential sites focuses on addressing the additional opportunities that may be present in the existing study area, and those opportunities that may arise in the long term due to ownership changes, redevelopments, or even normal maintenance.

For the sake of simplicity, additional non-residential site retrofits are divided into two categories, 1) those treating rooftop area, and 2) those treating primarily parking lot or patio area.

Rooftop Full Green Scenario Opportunities

Rooftop retrofits were among the most commonly identified in the site retrofits fieldwork. Approximately half of all identified site retrofits were either greenroofs, water harvesting, stormwater planters, or raingardens treating roof top runoff. The rooftop retrofits can be broken into three basic types:

- Greenroofs
- Water Harvesting
- Stormwater Planters/Rain Gardens

Full Green Scenario rooftop retrofit opportunities were identified by a GIS analysis of rooftop areas, combined with the results of the immediate opportunities site retrofit modeling. The following method was used.

1. The total rooftop area for each work area was determined by GIS analysis of the buildings data set from the City of Durham impervious cover layer. The proportion of area made up by rooftops under 3000 square feet, between 3000 square feet and ¼ acre, and over ¼ acre was calculated.
2. The total treated rooftop area from the immediate opportunities JFSNLAT modeling was summed by work area and subtracted from the total rooftop area.
3. It is assumed 25% of the remaining area is non-conducive to further retrofitting. For greenroofs, factors limiting the feasibility include highly sloped roofs, roofs made of materials nonconductive to greenroofs (e.g. corrugated metal), and rooftop obstructions (e.g. skylights, exhaust vents, HVAC equipment, walkways, etc.). For water harvesting and rain gardens, ability to implement is limited by lack of suitable downspouts (e.g. internal downspouts), certain rooftop materials or coatings, or extreme space limitations affecting cistern or planter placement.
4. After discounting the already treated area, and area assumed non-conducive to further retrofitting, the remaining area is deemed potentially treatable by one of three retrofit types: 1) Greenroofs, 2) Rainwater Harvesting, 3) Small Bioretention
5. For each work area, the percentage of the treatable area to be treated by each retrofit type was assumed based on best professional judgment and local knowledge of the work area. The breakdown of rooftop area into smaller than 3000 sf, between 3000 sf and ¼ acre of, and larger than ¼ acre within each work area was used to provide context. (Rooftop areas larger than ¼ acre were almost certainly assessed by the field teams, and those smaller than 3000 sf are likely private houses or accessory structures.)

6. The average volume and nutrient reduction rates (per 1000 sf of treated area) for each of the retrofit types were computed from the existing model results for each treatment type.
7. The nutrient reductions rates were then multiplied by the area treated for each treatment type in each Work Area.

Table 13. Percent of treatable rooftop area treated by retrofit type

Work Area	Potentially Treatable Rooftop Area [sf]	% Rainwater Harvesting	% Greenroof (Extensive)	% Rain Garden/Planter Boxes
1	121,613	***5%***	***5%***	***20%***
2	27,941	***20%***	***5%***	***10%***
3	328,679	***25%***	***20%***	***15%***
4	350,736	***15%***	***5%***	***30%***
5	116,126	***20%***	***10%***	***10%***
6	393,956	***20%***	***20%***	***30%***
7	372,426	***20%***	***5%***	***30%***

Full Green Scenario Paved Area Retrofits

Other than rooftops, many of the retrofit opportunities identified treated parking lots or other paved areas. Some of these areas may become parking decks, while some may become buildings. In a Full Green Scenario, a larger percentage of these areas could be treated. For paved areas which need to be resurfaced periodically, there would be significant potential for additional retrofitting over a period of 20-30 years. The methodology is similar to the Rooftop retrofits. The primary difference is that only two retrofit types are considered: Permeable Pavement and Bioretention. Additionally, the categorization of each block’s paved impervious area into size classes is used to more completely determine potential additional treated area.

1. The total paved area for each work area (Fig. 2) was determined by GIS analysis of the paved data set from the City of Durham impervious cover layer. The proportion of area made up by paved areas under 3000 square feet, between 3000 square feet and ¼ acre, and over ¼ acre was calculated.
2. The total treated paved area (impervious area minus treated rooftop area) from the Immediate Opportunities JFSNLAT modeling was summed by work area, and subtracted from the total paved area from the GIS analysis.
3. It is assumed 25% of the remaining area is non-conducive to further retrofitting. For permeable pavement, factors limiting the ability to implement include highly sloped ground, underground structures, unsuitable soils, lack of suitable overflow diversion, or legacy contaminants in the soil. For bioretention, the primary factor limiting potential implementation for the full green scenario is lack of an available location.

4. After discounting the already treated area and area assumed non-conducive to further retrofitting, the remaining area is deemed potentially treatable by one of two retrofit types: 1) Permeable Pavement, 2) Bioretention.
5. The breakdown of the paved areas into smaller than 3000 sf, between 3000 sf and ¼ acre of, and larger than ¼ acre within each work area was used to be able to better target additional retrofits to areas that may have been missed by previous fieldwork. (Paved areas larger than ¼ acre were almost certainly assessed by the field teams, but the smaller areas could be more conducive to additional retrofits.) For each work area, the percentage of the treatable area to be treated by each retrofit type for each of the three size classes was assumed based on best professional judgment and local knowledge of the work area.
6. The average volume and nutrient reduction rates (per 1000 sf of treated area) for each of the retrofit types were computed from the existing model results for each treatment type.
7. The nutrient reductions rates were then multiplied by the area treated for each treatment type in each Work Area.

Table 14. Assumed treatment percentages of paved areas for Full Green scenario.

Work Area	Potential treatable Area [sf]	Bioretention			Permeable Pavement		
		<3000 sf	3000-0.25 ac	>0.25 ac	<3000 sf	3000sf - 0.25 ac	>0.25 ac
1	563,467	***0%***	***20%***	***2%***	***0%***	***5%***	***10%***
2	73,093	***15%***	***25%***	***10%***	***20%***	***25%***	***5%***
3	423,601	***15%***	***25%***	***10%***	***10%***	***20%***	***5%***
4	531,195	***15%***	***25%***	***10%***	***10%***	***20%***	***10%***
5	36,411	***15%***	***25%***	***10%***	***20%***	***25%***	***5%***
6	396,690	***15%***	***25%***	***10%***	***10%***	***20%***	***5%***
7	222,637	***15%***	***25%***	***10%***	***10%***	***20%***	***5%***

Modeling the Full Green Scenario Site Retrofits in JFSNLAT

The JFSNLAT model was used to generate loading reduction factors on a per 1000 square foot basis.

For the rooftop retrofits, the collection area was modeled as 1000 square feet of rooftop. For the rainwater collection practice, the volume collection percentage was specified as 50%. The greenroof practice was simply input as the standard greenroof BMP (an extensive greenroof). For the planter raingarden practice, the BMP type selected was Bioretention without Internal water storage, and because space would be limited as compared to the standard bioretention practices, it was assumed the practice was 75% sized. Table 15 shows the loading reduction factors per 1000 sf of treated area for the three rooftop and two paved area retrofit types presented.

Table 15. Loading reduction factors per 1000 sq. ft. treated area, Site Retrofits, Full Green.

Code	Treatment Type	Treatment Area	Vol. [cf]	N [lbs]	P[lbs]
RR2	Rainwater Harvesting	Rooftop	1835.5	0.124	0.017
RR3	Greenroof (Extensive)	Rooftop	1835.5	0.124	0.017
RR1/RR5	Planter/Raingarden	Rooftop	963.6	0.077	0.011
ST4	Bioretention	Paved	1047.6	0.163	0.024
RR7	Permeable Pavement	Paved	183.5	0.017	0.002

4.5.2 – Residential Area Retrofits Full Green Scenario

Partners identified additional potential rain garden and rainwater harvesting retrofits that could be implemented over a long-term period of 20-30 years. As shown in Table 5, during residential fieldwork each residence was given two numeric total scores to describe its potential for a rain garden or rain water harvesting practice. Any residence receiving a total score of 3 or greater in the rain garden category, and having an obvious, adequate location was categorized as a long-term (Full Green Scenario) opportunity for a rain garden. Any parcel with a total rain water harvesting score of 3 or greater, and an obvious, adequate location was categorized as long-term opportunity for a residential rain water harvesting practice. In the long run, partners assumed that the current existence of downspouts should not be considered a factor in identifying a site for a long-term retrofit.

4.5.3 – Green Streets Full Green Scenario Analysis

The green streets analysis identified in-street bioretention opportunities, bioretention opportunities in the planted green areas of rights-of-way, and permeable paving opportunities for sidewalks and driveways. In the Immediate Opportunities Scenario, all of the bioretention in the planted green areas of the right-of-way are already assumed to be treated, and no additional treatment was assumed in the Full Green Scenario modeling. The Full Green Scenario analysis assumes an additional 40% of the identified area may be treated using additional permeable pavers and in-street bioretention, for a total of 80% of the areas identified. The loading reduction factors used remain the same (see Table 12).

5. Results

5.1 GIS analysis results

Table 16 shows the results of the GIS analysis conducted in Catchments 14 and 18. Appendix 1 provides detailed maps and tables of the storage and on-site retrofits described herein.

5.1.1. Storage Retrofits

Existing stormwater ponds offer good opportunities for retrofitting, particularly where existing dry detention can be converted to extended detention, constructed wetland, wet pond, or bioretention through excavation, embankment raising, riser modification, addition of a forebay, or some other internal modification (Schueler et al 2007). There were no existing stormwater ponds identified during the GIS analysis in the Downtown Ellerbe Creek catchment (catchment 14), and four ponds were identified in Catchment 18. A watershed-wide search for stormwater ponds was not conducted.

Table 16. GIS analysis results

Retrofit Location	Count (Acreage) Catchment 14	Count (Acreage) Catchment 18	Count (Acreage) Entire Watershed
SR-1 Existing Pond	0	4	NA
SR-2 Roadway Culvert	7	26	NA
SR-3 Below Outfall	17	80	408
SR-4 Conveyance System	10	37	NA
SR-6 Large Parking lot	0	0	27 (226 ac)
OS-8 Small Parking lot	102 (54 ac)	73 (60 ac)	834 (722 ac)
OS-10 Individual Rooftop	82 (51 ac)	28 (19 ac)	414 (312 ac)

Several SR locations were identified where low-order streams intersected roadway culverts (opportunity type SR-2). In Catchment 14, 7 such opportunities exist, and in Catchment 18 the analysis identified 26. Road crossings offer opportunities for storage above the culvert through installation of a new embankment or excavation of areas adjacent to the upstream channel, particularly for non-perennial (i.e. non-regulated) channels (Schueler et al 2007). It is important to note that these practices involve backing up water flooding land upstream of the culverts during rain events. Evaluation of the potential impacts is needed for each site, and easements may be required.

The GIS analysis also identified 17 and 80 locations in catchment 14 and 18, respectively, below stormwater outfalls (SR-3). This type of retrofit offers the opportunity to redirect a portion of the flow within the pipe to a newly constructed wetland, pond, or (less frequently) bioretention (Schueler et al 2007).

The analysis identified 10 (Catchment 14) and 37 (Catchment 18) areas where altered zero and first-order channels have the potential for retrofits that create storage, bioretention, or wetland cells. These practices could be implemented either in- or off-channel (Schueler et al 2007).

Large parking lots above 5 acres (SR-6, e.g. municipal, high school, regional shopping mall, stadium, auto dealership, airport, or commuter parking lots) are good retrofit opportunities to locate extended detention, ponds, constructed wetlands, or large areas of bioretention (Schueler et al 2007). The GIS analysis identified no such parking lots in either Catchment 14 or 18, although many opportunities for retrofits on smaller parking lots exist and are described in OS-8.

All potential storage retrofits in Catchment 14 were subsequently examined as part of the field verification.

5.1.2 On-Site Retrofits

The GIS analysis identified 102 small parking lots (<5 acres) in size that are municipally or institutionally owned, or a total of 54 acres of parking area, in Catchment 14, and 73 small parking lots, a total of 60 acres in Catchment 18. These sites offer multiple opportunities for retrofit, including impervious cover reduction, replacement with permeable pavement or pavers, bioretention islands or perimeters, sand filters, or filter strips.

The GIS analysis identified 82 individual rooftops (51 acres) and 28 rooftops (19 acres) in Catchments 14 and 18, respectively. These locations have the potential for onsite retrofits such as downspout disconnection from the stormwater system, rainwater harvesting in cisterns, raingardens or bioretention, stormwater planters, or green rooftops.

All potential onsite retrofits in Catchment 14 were subsequently examined as part of the field verification.

5.2 Field Reconnaissance Retrofit Opportunities Results

As shown in Figure 2, the field teams' results are broken into three categories: 1) larger site retrofits on public or private commercial or institutional property, 2) small residential retrofits, 3) retrofits on streets, sidewalks, or public rights-of-way. The field investigation section of this report explained how the field teams completed the RRI form, and the post-field work assessment section explained how the modeling was completed for each of the retrofit opportunities identified. The results section presents both the standard and high estimates for the flow and nutrient reductions calculated in the JFSNLAT.

Figure 10 shows the site retrofit and residential area retrofits identified as a result of desktop and fieldwork analyses

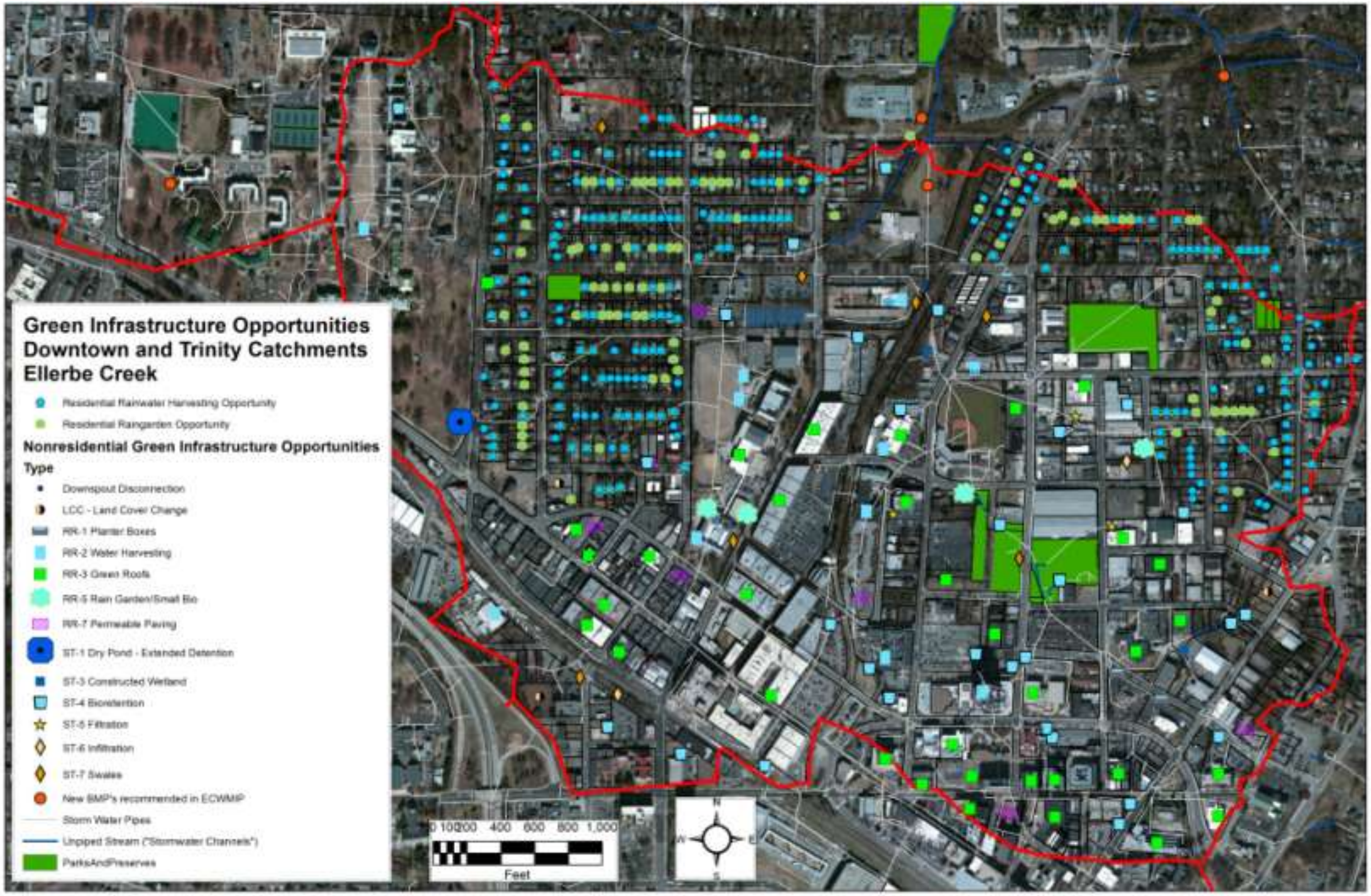


Figure 10. GI Opportunities Identified by the Site Retrofit and Residential Analyses in the Downtown Ellerbe Creek Catchment (Green Street Analyses results not shown)

5.2.1 Identified Site Retrofit Opportunity Results

The field teams identified 122 site retrofits in the study area. Each of these retrofits was modeled using the JFSNLAT, and calculations were performed for a standard case, and a higher case based on either an upgraded BMP or a variation with more BMPs functioning in a treatment train. In general, the larger site retrofits tended to be clustered in subareas 1,3,4,6, and 7, while the predominantly residential assessment subareas (2 and 5) had fewer large site opportunities identified.

The type of retrofit selected for an individual site depends largely on the judgment of the field teams working within the area, but for the most part, the site conditions should dictate certain BMP types that may be used at the location. Overall, with enough repetition, patterns begin to emerge within the study area of BMP types that are most appropriate for the site conditions. Given the densely developed, urban, highly impervious nature of the watershed, the types of BMP selected match up well with what would be expected for the area. Figure 11 shows the distribution and area treated of the BMPs selected by BMP type and Subarea.

Overall, it is clear that the watershed conditions show a clear inclination toward rooftop (green roof and water harvesting) and bioretention (bioretention, planter boxes, and rain gardens) BMPs. Rooftop BMPs accounted for 51 out of 122 total opportunities, and roughly a quarter of all treated acreage. Green roofs alone made up 40 of those. As a group, the various bioretention BMPs accounted for 43 separate opportunities, with over 30 acres treated. Permeable pavement and filtration BMPs, and land cover change opportunities were less common. Large storage BMP opportunities were rare within the study area, but the few that were found did account for a fairly large treated area.

The greatest number of and areas treated by rooftop BMPs are in the most urban work areas, areas 3, 4, 6, and 7. In addition, areas 2, 4, 5, 6, and 7 offer significant opportunities for bioretention. Of special note are the opportunities to treat almost 5 acres in work area 7 with constructed wetlands and the opportunity to treat over 13 acres in work area 1 with a dry pond.

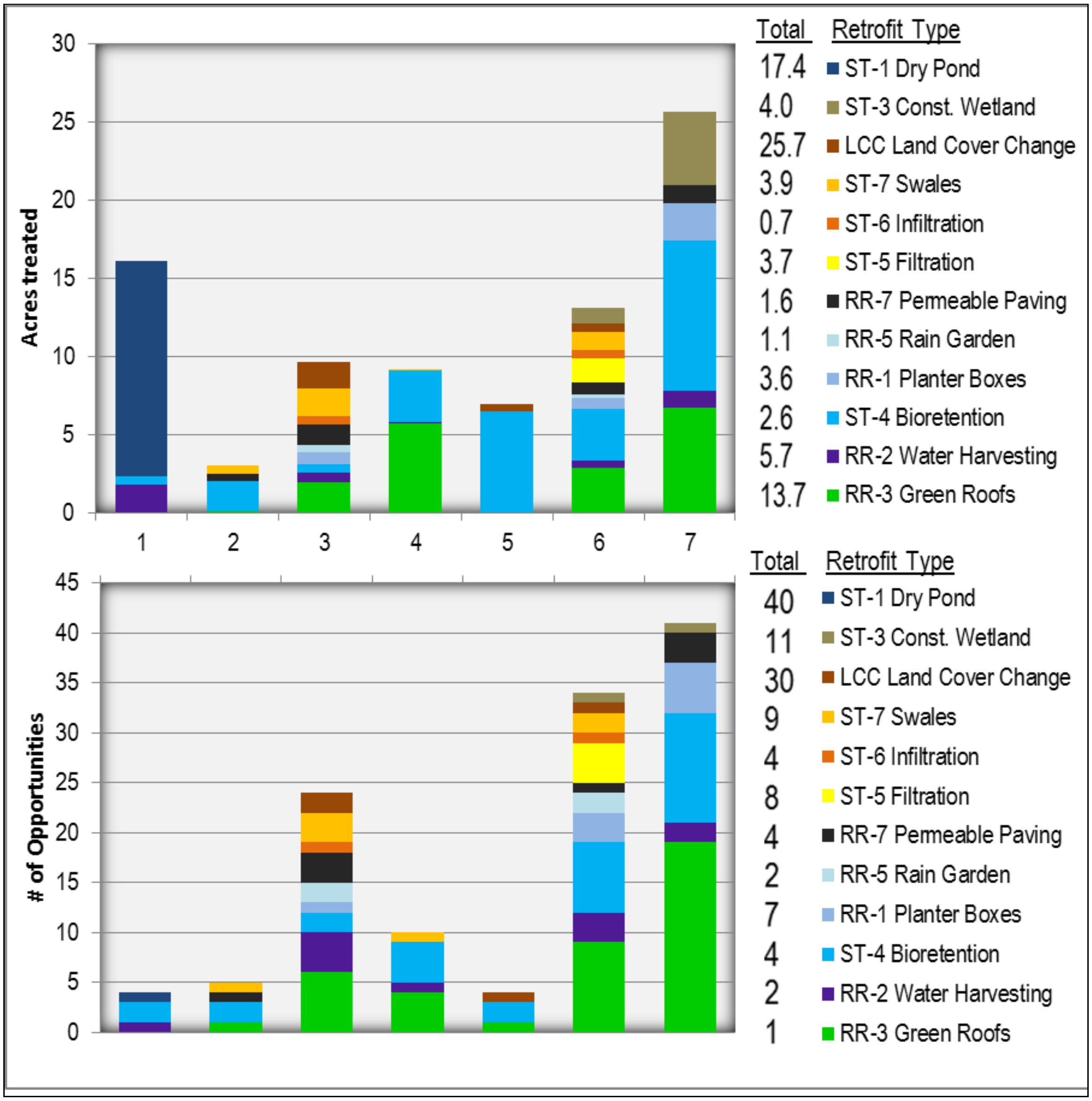
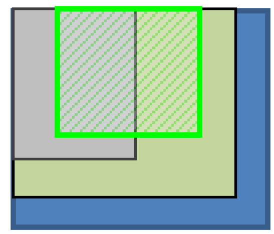


Figure 11. Site Retrofit Opportunities Identified and Area Treated, by Work Area and Retrofit Type.

While the number of BMP opportunities and area treated is important, it is necessary to view the opportunities in the context of the Downtown Ellerbe Creek catchment as a whole. Given that the Subareas are broken down by land use type already, it is useful to view the retrofits in that context as well.

Compared to the catchment as a whole, the areas draining to the individual retrofits tend to be more impervious and composed of primarily rooftop or parking lot areas. It is difficult to specify exactly the land cover of the entire catchment because of the limited availability of data detailing pervious and impervious land cover within the transportation rights-of-way. For the most part, the field work identified retrofits on existing parcels, where impervious cover GIS files are available. The illustration at right illustrates this, representing the overall land area as the blue square, the parcel area as the light green square, the impervious area within the parcels as the grey square, and the treated area of the proposed retrofit shown by the thick green outlines. Figure 12 shows the characteristics of each Work Area as a stacked bar graph, and shows the portions of the impervious and non-impervious parcels that were treated. The black labels identify the total area in the Work Area, and green labels the total treated area for the proposed retrofits.



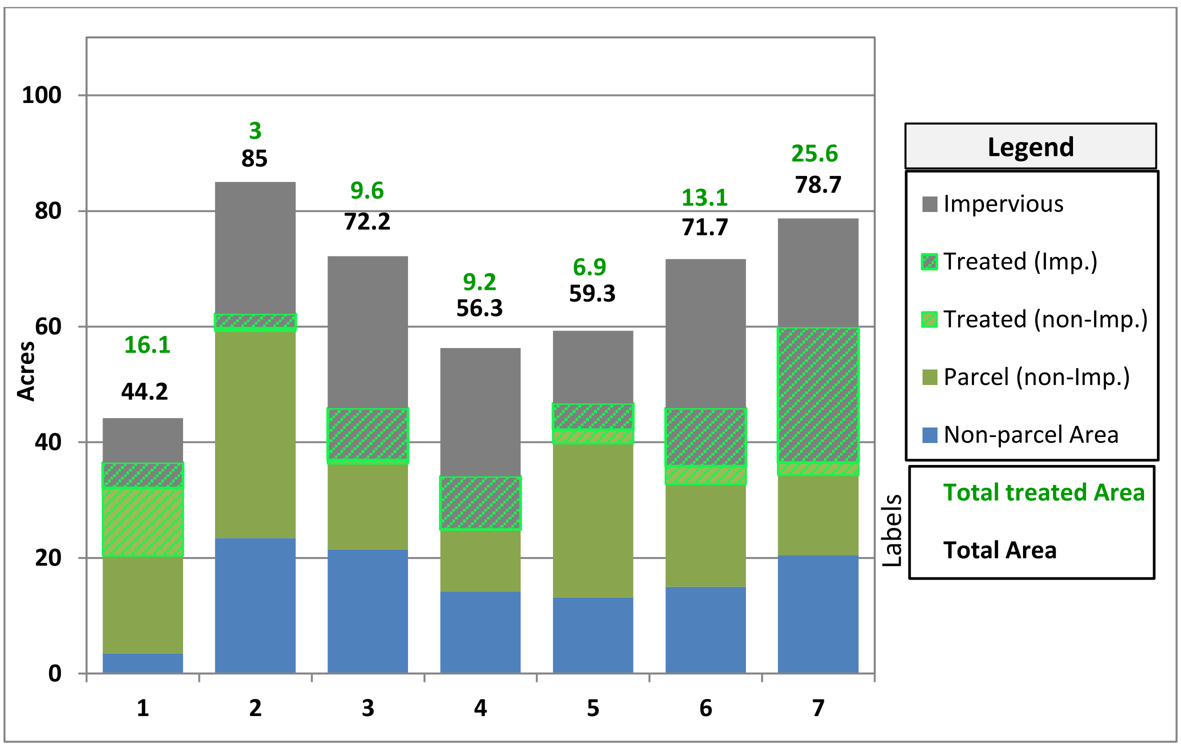


Figure 12. Treated Area by Work Area for the Site Retrofits.

These results show that certain subareas were more likely to be able to incorporate retrofit opportunities. The results for areas 2 and 5 do not include the residential or green street retrofits. Work area 7 shows the greatest potential for retrofits as identified by the field teams, with 44% of total parcel area treated, and 55% of the impervious area within parcels treated. The large number of greenroof opportunities (19) in area 7 certainly plays a role in this result. Work areas 3,4, and 6 have similar results, with roughly 20% of total area treated, and roughly 25% of impervious area treated. Work area 1 is a special case, with a few very large retrofits including a dry pond opportunity treating over 13 acres, and an extremely large rainwater harvesting opportunity.

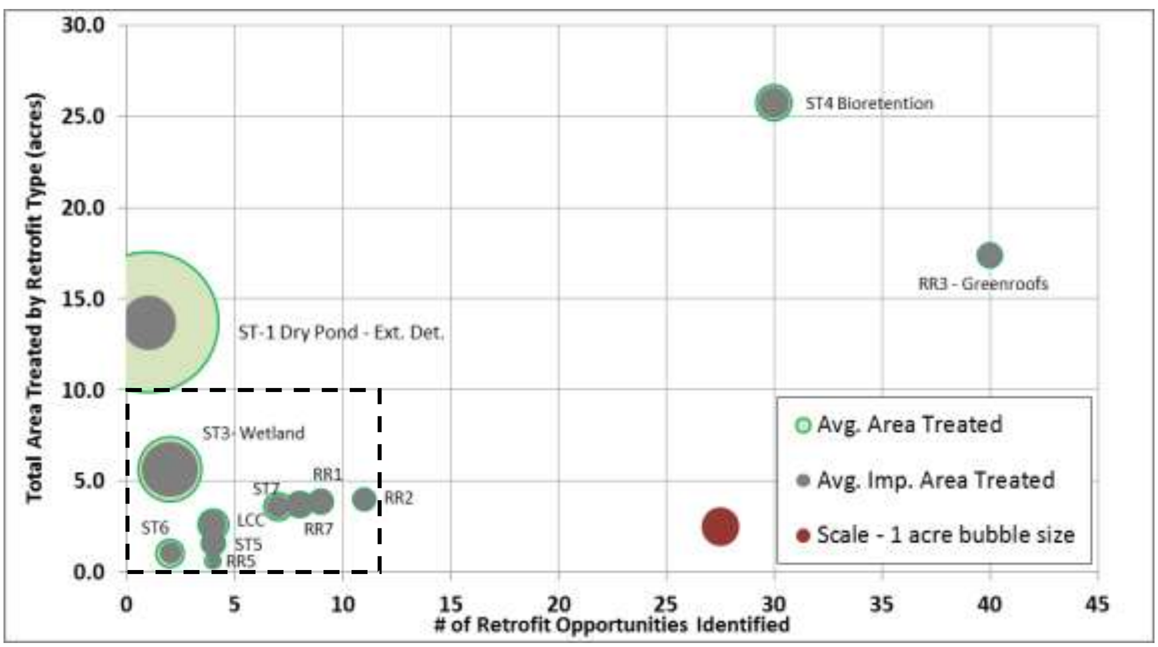
Another way to look at the results is to consider the characteristics of the retrofit types.

5.2.2 Area treated by retrofit type

The average identified retrofit treats an area of approximately two-thirds of an acre, but many of the retrofit types treat smaller areas of one-eighth to one-third of an acre. Fig. 13 shows the average and total area treated by retrofit type. The x-axis identifies the number of opportunities, the y-axis the total area treated, and the bubble size the average area treated. The outer green circle shows the total area, and the inner grey circle shows the total impervious area treated.

In general, the areas treated by the practices include significant impervious cover. Unsurprisingly, the treatment areas for Greenroofs, Water Harvesting, and Permeable Pavement practices are 100% impervious, as they are either rooftops or paved areas. The majority of the other retrofit types treat areas that are more than 70% impervious. The areas treated by stormwater planters reflect the total amount of treated area in each opportunity identified by the field teams, which usually included several individual planters.

Excluding the one large extended detention dry pond opportunity found in subarea 1, 121 retrofit opportunities with an average size of 0.58 acres account for a treated area of 69.8 acres, which is on average 87% impervious.



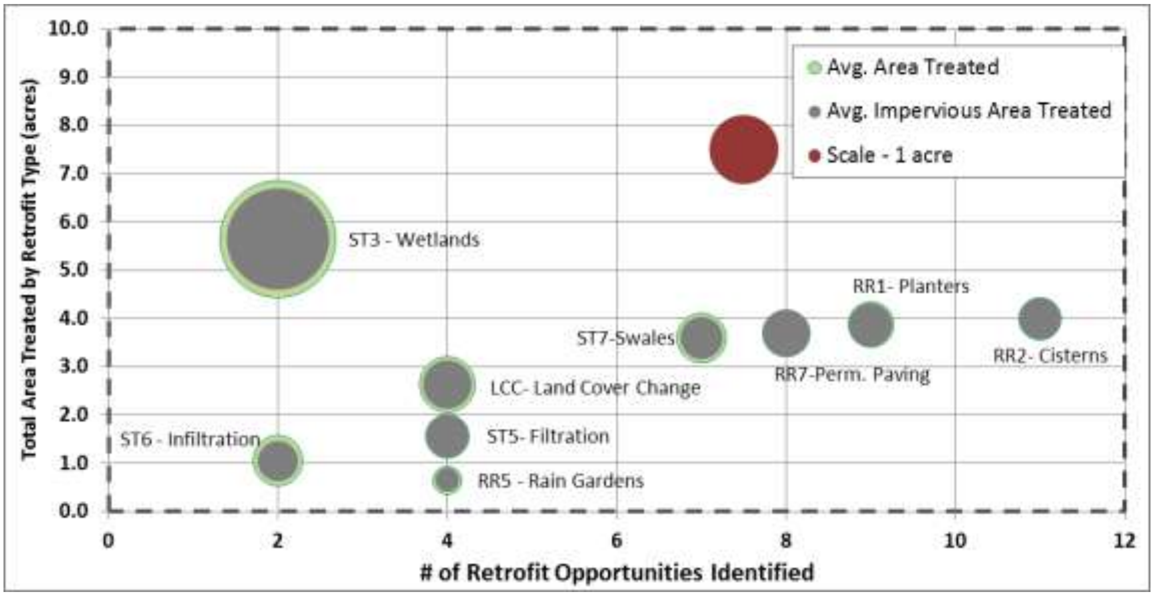


Figure 13 a,b. Total area treated by Retrofit type versus number of retrofits, with average area (and impervious area) per practice shown as bubble size. Lower chart is an inset of top chart, indicated by dashed line.

5.2.3 Volume and Nutrient Reductions by Treatment type

Table 17-19 show the model results by treatment type for the reductions in runoff, total nitrogen load, and total phosphorus load. Results are shown for both the Standard assumption case, and the High scenario, which assumed more effective BMPs, or a series of BMPs, as specified by field notes. The normalized reductions give the reductions in flow or load on an aerial basis, in terms of reductions per acre treated by the BMP.

Table 17. Volume Reduction by treatment type, Net and Normalized per acre.

				Net Vol Reduction [cf/yr]		Normalized Vol Reduction [cf/ac/yr]	
Treatment Type	Code	#	Acres	Standard	High	Standard	High
Greenroofs	RR3	40	17.02	1,389,079	1,710,271	81,617	100,489
Bioretention	ST4	30	25.73	444,701	943,009	17,280	36,644
Planter Boxes	RR1	9	3.87	79,167	122,880	20,466	27,171
Rain Gardens	RR5	4	0.65	11,333	15,384	17,322	23,513
Dry Ponds	ST1	1	13.70	-	-	-	-
Wetlands	ST3	2	5.65	96,291	108,548	17,037	19,205
Filtration	ST5	4	1.57	12,555	26,408	7,997	16,821
Infiltration Trench	ST6	2	1.05	18,109	18,404	17,223	17,504
Swales	ST7	7	3.61	29,374	33,606	8,145	9,318
Rainwater Harvesting	RR2	11	3.99	235,676	406,724	59,000	101,821
Permeable Pavement	RR7	8	3.70	29,582	29,582	7,995	7,995
Land Cover Change	LCC	4	2.65	275,367	275,367	103,864	103,864
TOTAL		**122**	**83.5**	**2,621,233**	**3,690,183**	**31,504**	**44,138**

Table 18. Nitrogen Reductions by Treatment Type, Net and Normalized per acre.

				Net N Reduction [lbs/yr]		Normalized N Reduction [lbs/ac/yr]	
Treatment Type	Code	#	Acres	Standard	High	Standard	High
Greenroofs	RR3	40	17.02	93.90	115.50	5.52	6.78
Bioretention	ST4	30	25.73	123.03	155.35	4.78	6.04
Planter Boxes	RR1	9	3.87	13.33	23.81	2.95	5.26
Rain Gardens	RR5	4	0.65	2.03	2.37	3.11	3.63
Dry Ponds	ST1	1	13.70	6.89	6.89	0.50	0.50
Wetlands	ST3	2	5.65	16.76	17.95	2.97	3.18
Filtration	ST5	4	1.57	8.09	8.97	5.15	5.71
Infiltration Trench	ST6	2	1.05	1.93	2.41	1.83	2.29
Swales	ST7	7	3.61	8.10	8.78	2.25	2.44
Rainwater Harvesting	RR2	11	3.99	15.96	27.58	3.99	6.90
Permeable Pavement	RR7	8	3.70	2.78	2.78	0.75	0.75
Land Cover Change	LCC	4	2.65	24.49	24.49	9.24	9.24
TOTAL		**122**	**83.5**	**317.3**	**396.8**	**3.81**	**4.77**

Table 19. Phosphorus Reductions by Treatment Type, Net and Normalized per acre.

				Net P Reduction [lbs/yr]		Normalized P Reduction [lbs/ac/yr]	
Treatment Type	Code	#	Acres	Standard	High	Standard	High
Greenroofs	RR3	40	17.02	13.04	16.04	0.77	0.94
Bioretention	ST4	30	25.73	19.69	23.55	0.76	0.92
Planter Boxes	RR1	9	3.87	6.00	6.83	1.33	1.51
Rain Gardens	RR5	4	0.65	0.49	0.53	0.74	0.80
Dry Ponds	ST1	1	13.70	2.50	2.50	0.18	0.18
Wetlands	ST3	2	5.65	7.45	7.83	1.32	1.39
Filtration	ST5	4	1.57	3.18	3.38	2.02	2.16
Infiltration Trench	ST6	2	1.05	0.66	0.84	0.63	0.80
Swales	ST7	7	3.61	0.96	1.77	0.27	0.49
Rainwater Harvesting	RR2	11	3.99	2.22	3.84	0.55	0.96
Permeable Pavement	RR7	8	3.70	0.31	0.31	0.08	0.08
Land Cover Change	LCC	4	2.65	2.61	2.61	0.98	0.98
TOTAL		**122**	**83.5**	**59.1**	**70.0**	**0.71**	**0.84**

There are many BMP design considerations, including peak flow reductions, that are not explicitly explored in these results. Some patterns begin to become clear, though. On a per area basis, the practices that capture the most volume end up being very effective overall. Notably, greenroofs, water harvesting, land cover change, and bioretention (High scenario) all capture 35% or more of the volume hitting the treatment area. This volume reduction translates into high nutrient reductions, even without much additional treatment benefit (in the case of greenroofs, water harvesting, and land cover change). The bioretention practices do relatively well with both volume and nutrient reduction.

It should be noted that the reductions depend not only on the BMP type, but also reflect the existing site loading of the treatment areas. Some practices tend to treat areas of land cover with higher baseline nutrient loading. For example, the high phosphorus reductions of planter boxes may be a result of planter boxes treating sidewalk areas, which have relatively high baseline phosphorus export, as shown in Table 7.

Finally, the overall results should not be ignored. Treating 83 acres, the 122 practices identified could reduce stormwater runoff flow to Ellerbe Creek by 2.7 to 3.8 million cubic feet per year (19.6 to 27.6 million gallons per year). Furthermore, nitrogen loadings could be cut by 328 to 397 pounds, and phosphorus loadings by 60 to 71 pounds.

Figure 14 shows the distribution of loading reductions by Work Area for volume, nitrogen, and phosphorous for both the Standard and High Estimates from the model. The legend also displays the totals for the watershed.

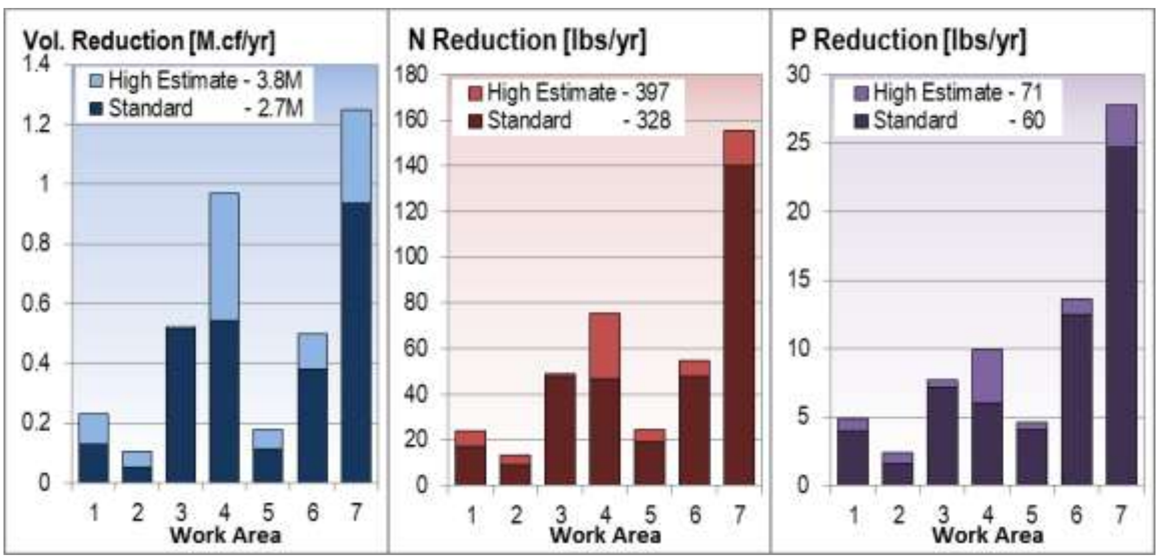


Figure 14. Site Retrofit loading reductions by work area for Volume, N, and P

5.2.4 Modeling results by Field Teams' Priority Ranking

The site retrofits were identified by the field teams as physically feasible given the site conditions. The Standard and High Estimates offer a range of potential results given design differences in the BMP implemented for the site. In many cases, even though a site retrofit was physically feasible, and had an RRI form completed, certain considerations make some retrofits more implementable than others.

The field forms included an "Evaluation Priority" (see Appendix 1) data field that the field teams used to rate each potential retrofit's priority level or potential for implementation. For instance, issues of site ownership, the cost of the potential retrofits, or missed opportunity due to recently completed landscape renovations could impact the chance the retrofit would be implemented. The evaluation priority field was on a 1 to 5 scale, with 5 being the highest likelihood of implementation.

Fig. 15 shows the distribution of Nitrogen reductions (standard estimate) by evaluation priority score given to the opportunity by the field team. The x-axis shows all practices of the indicated score or higher. Thus, the loading reductions from the practices at the left are from the most implementable opportunities found in the field, which were scored as a "5". The total loading of all practices rated 3 or higher accounts for roughly 250 out of the potential 328 lbs of reductions.

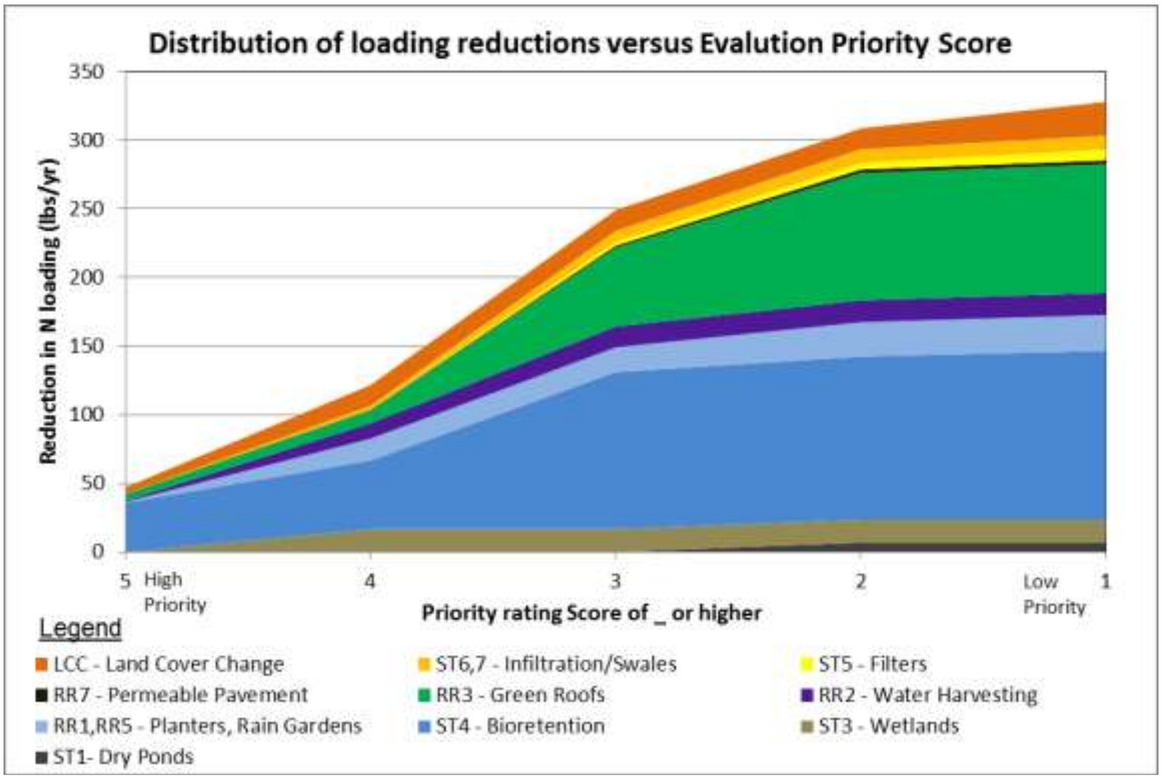


Figure 15. Nitrogen Loading Reductions versus evaluation priority score.

The figure also shows the relative contributions by practice type. It is evident that bioretention practices contribute to a large percentage of the total reductions, and the majority of bioretention opportunities were scored at 3 or higher, including a considerable number at a '5' rating. Greenroofs also accounted for a significant portion of the total reductions, although all but a few greenroofs received scores of either 2 or 3. Two potential limitations of our methodology are: 1) greenroofs may have received lower scores because field teams could not easily assess roof conditions; and 2)teams judged that a combination of current ownership issues and cost may make building less feasible for the practice, but still achievable in the right conditions or under a longer time horizon. It is also important to note that the JFSNLAT Version 1.0 likely underestimates the reductions associated with water harvesting, and Version 3.0 of the tool will likely correct this underestimation.

Fig. 16 shows similar results for Phosphorus reductions, and Fig. 17shows the results for runoff volume reductions.

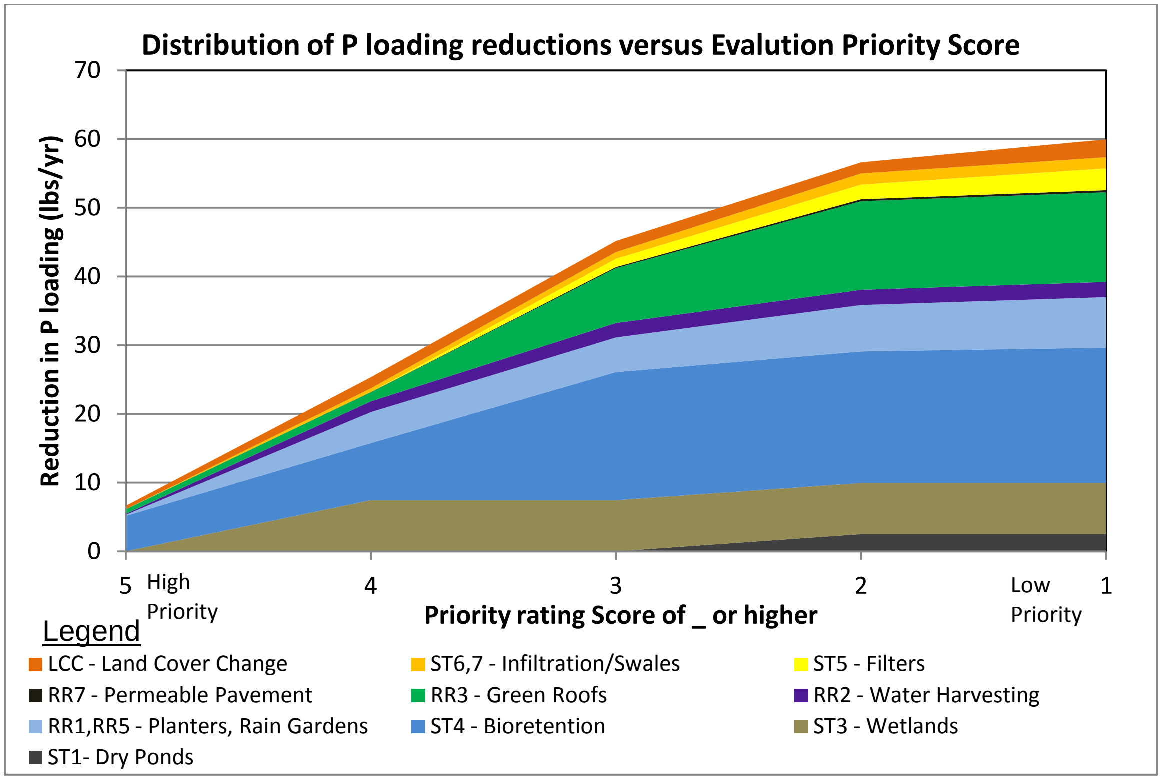


Figure 16. Phosphorus Loading Reductions versus evaluation priority score.

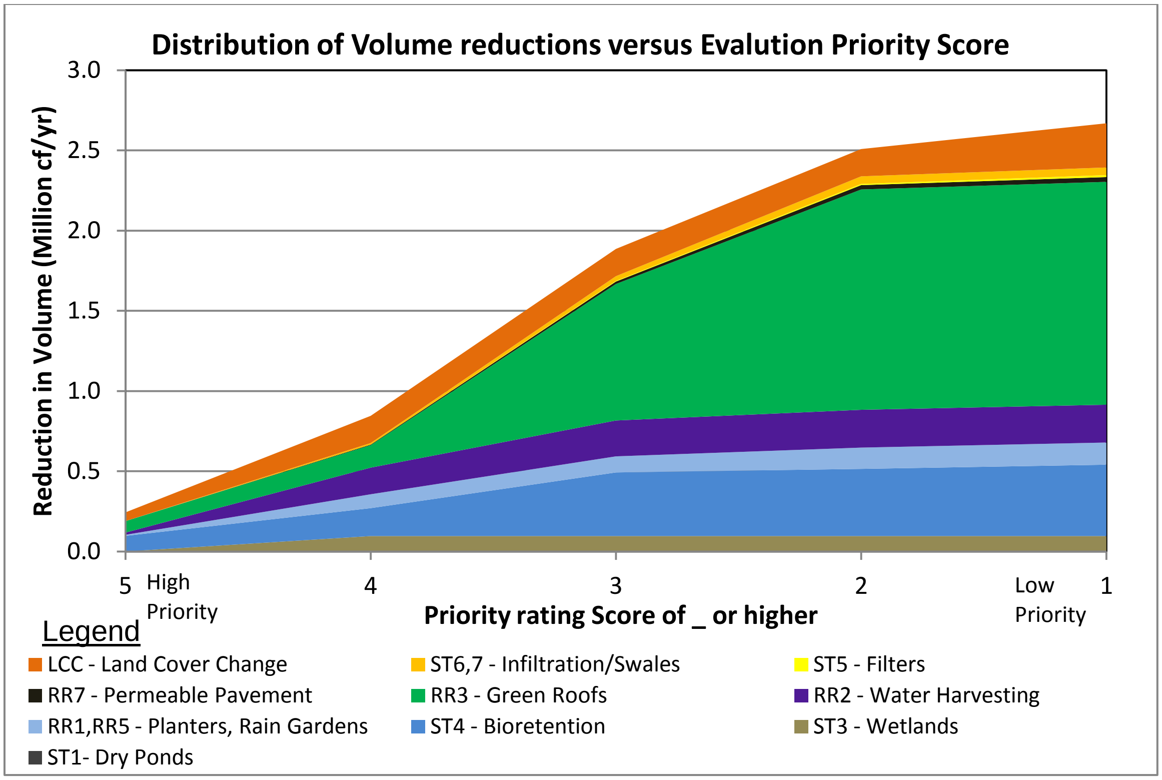


Figure 17. Runoff Volume Reductions versus evaluation priority score.

5.2.5 Full Green Scenario Retrofits for RRI Site Investigations

The Full Green Scenario extension to the site retrofit methodology identified potential additional retrofits that could treat additional rooftop or paved area. Three retrofit types, including rainwater harvesting, green roofs, and small bioretention practices (stormwater planters and raingardens), were modeled for the rooftops. Two retrofit types, including bioretention and permeable pavement were modeled for the paved areas.

The net reductions by retrofit type were calculated for all of the work areas and are shown in Fig. 18.

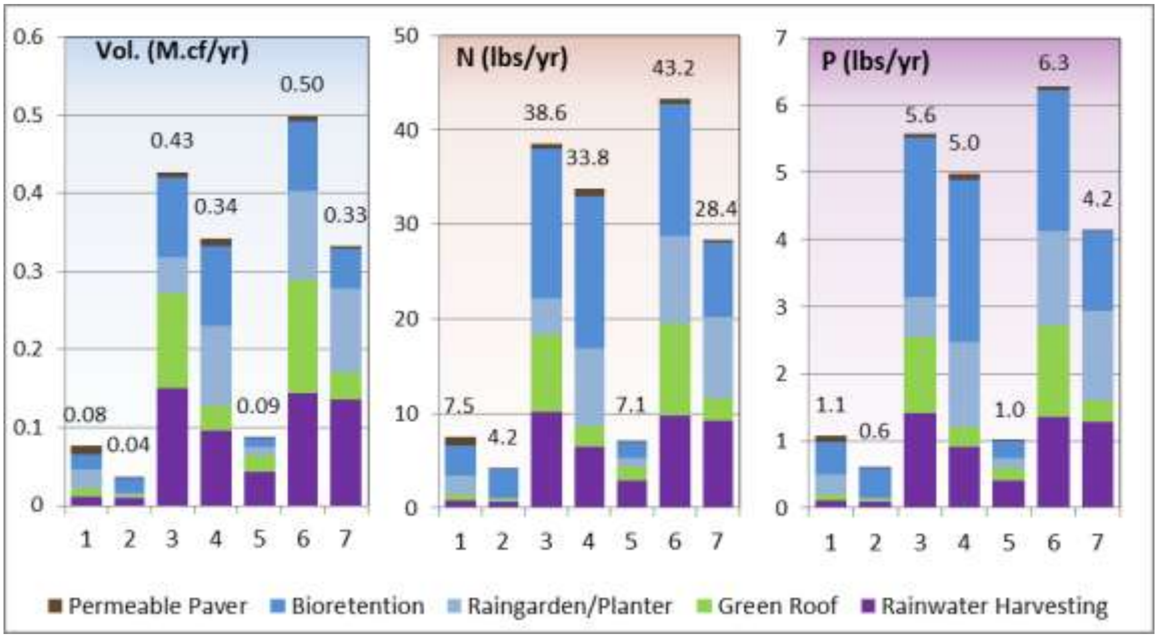


Figure 18. Full Green Scenario Volume, Nitrogen, and Phosphorus load reductions by retrofit type and work area.

5.3 Neighborhood Site Assessment Results

Table 20 shows the results by block for the rainwater harvesting and rain gardens BMP types. The block number and average parcel size are shown at left, and at right, the BMP's area treated and associated reductions in flow and nutrient loading are shown.

Table 20. JFSNLAT Model Results by Block for Cisterns and for Rain Gardens.

Block Characteristics			Cisterns Results – Per Practice				Rain Gardens Results - Per Practice			
Work Area	Block	Avg. Parcel Area (ac)	Area Treated (sf)	Flow (cf/yr)	N (lbs/yr)	P (lbs/yr)	Area Treated (sf)	Flow (cf/yr)	N (lbs/yr)	P (lbs/yr)
5	Block1	0.265	461	846	0.0572	0.0079	1178	389	0.051	0.014
5	Block2	0.153	481	882	0.0596	0.0083	995	364	0.051	0.018
5	Block3	0.137	483	886	0.0599	0.0083	961	352	0.048	0.016
5	Block4	0.181	467	857	0.0579	0.0080	1145	365	0.046	0.015
5	Block5	0.139	400	734	0.0496	0.0069	995	337	0.045	0.013
5	Block6	0.140	429	788	0.0533	0.0074	1011	360	0.048	0.016
5	Block7	0.129	345	634	0.0428	0.0060	766	326	0.040	0.013
2	Block8	0.206	367	674	0.0456	0.0063	845	338	0.043	0.013
2	Block9	0.199	405	743	0.0502	0.0070	880	369	0.047	0.017
2	Block10	0.230	428	786	0.0532	0.0074	966	412	0.055	0.017

These results show the pollutant reduction for a single BMP (either cistern or rain garden) that could be expected on average if it was installed on a parcel in the given block. To compute the total impact, these individual parcel results were multiplied by the number of BMP retrofit opportunities identified in each block. Table 21 shows the number of practices that were identified in the field work and had scores suitable for recommendation as immediate retrofit opportunities.

Table 21. Number of practices identified in field investigation by Type and Block.

		Cisterns		Rain Gardens		All Practices	
Work Area	Block	# of Practices	Area Treated (sf)	# of Practices	Area Treated (sf)	# of Practices	Area Treated (sf)
5	Block1	**6**	2,765	**13**	15,310	**19**	18,075
5	Block2	**20**	9,615	**20**	19,900	**40**	29,515
5	Block3	**12**	5,790	**4**	3,842	**16**	9,632
5	Block4	**10**	4,670	**5**	5,726	**15**	10,396
5	Block5	**14**	5,600	**10**	9,950	**24**	15,550
5	Block6	**8**	3,434	**9**	9,097	**17**	12,531
5	Block7	**12**	4,144	**3**	2,299	**15**	6,443
2	Block8	**28**	10,282	**26**	21,965	**54**	32,246
2	Block9	**65**	26,306	**71**	62,507	**136**	88,812
2	Block10	**44**	18,850	**39**	37,686	**83**	56,536
Work Area 2		137	55,437	136	122,158	273	177,595
Work Area 5		82	36,018	64	66,126	146	102,143
TOTAL		**219**	**91,454**	**200**	**188,283**	**419**	**279,738**

If all of these practices were implemented, their cumulative total reductions for Volume, Nitrogen and Phosphorus are shown by Work Area in Fig. 19.

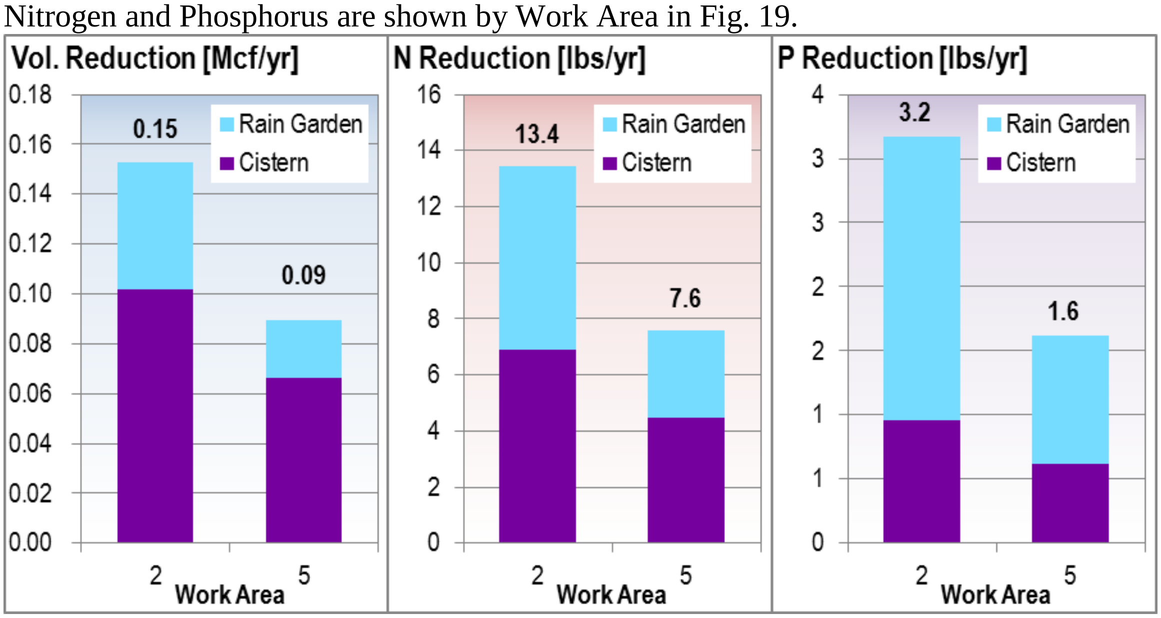


Figure 19. Residential practice loading reductions by work area for Volume, N, and P

Table 22. Summary Residential Retrofit Results, Immediate Opportunities Scenario

	# of Practices	Area Treated (sf)	Flow Reduction (cf/yr)	N Reduction (lbs/yr)	P Reduction (lbs/yr)
Cisterns Work Area 2	137	55,437	101,753	6.88	0.96
Cisterns Work Area 5	82	36,018	66,110	4.47	0.62
All Cistern Subtotal	219	*91,454*	167,863	*11.35*	*1.58*
Rain Gardens Work Area 2	136	122,158	51,095	6.57	2.21
Rain Gardens Work Area 5	64	66,126	23,159	3.11	0.99
All Rain Garden Subtotal	200	*188,283*	74,254	*9.68*	*3.21*
All Practices Work Area 2	273	177,595	152,848	13.45	3.17
All Practices Work Area 5	146	102,143	89,269	7.58	1.61
All Residential Practice Total	**419**	**279,738**	**242,117**	**21.03**	**4.78**

These results show that 219 cisterns and 200 rain gardens on the total 440 parcels could treat 242,117 cubic feet per year of stormwater.

Full Green Scenario Results for Neighborhood Site Analysis – Residential Retrofits

The simple assumption that all homes with no downspouts will eventually have downspouts and will become eligible for a residential practice is the key difference between the Immediate and Full Green analyses. Table 23 shows the additional practices that would be added under this scenario.

Table 23. Summary Residential Retrofits Results - Full Green Scenario

	# of Practices	Area Treated (sf)	Flow Reduction (cf/yr)	N Reduction (lbs/yr)	P Reduction (lbs/yr)
Cisterns Work Area 2	5	2,081	3,819	0.26	0.04
Cisterns Work Area 5	11	4,958	9,100	0.62	0.09
All Cistern Subtotal	16	*7,038*	12,919	*0.87*	*0.12*
Rain Gardens Work Area 2	9	8,160	3,402	0.44	0.14
Rain Gardens Work Area 5	14	13,532	4,994	0.67	0.22
All Rain Garden Subtotal	23	*21,692*	8,396	*1.11*	*0.36*
All Practices Work Area 2	14	10,241	7,221	0.70	0.18
All Practices Work Area 5	25	18,489	14,094	1.28	0.31
All Residential Practice Total	**39**	**28,730**	**21,315**	**1.98**	**0.48**

The Full Green Scenario adds only 39 total practices to the analysis, totaling a combined 458 practices under the long-range assumptions of the analysis. This may be an underestimate of the long-term potential for residential retrofits because the analysis does not assume that any of the adopters might eventually treat a greater area of rooftop or yard with larger cisterns or rain gardens. Thus, this is a conservative scenario.

5.4 Green Streets Results

The green streets analysis consists of three parts, permeable pavement, in-street bioretention, and right-of-way bioretention. Fig. 20 shows the loading reductions for these retrofit types by work area. No field investigation was completed in Work Area 1 (land use is entirely institutional, and lacks standard streets).

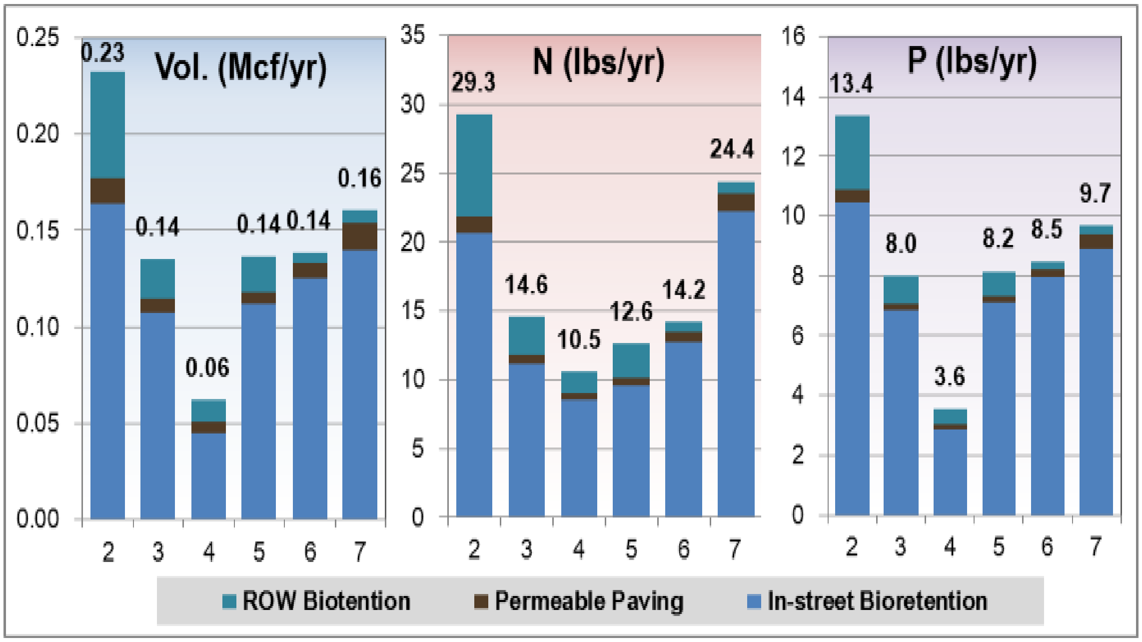


Figure 20. Green streets analysis loading reductions by work areas.

These results apply to either the Immediate Opportunities Scenario or Full Green Scenario, as the Full Green Scenario simply doubles the treated area.

Table 24 summarizes the green streets analysis volume, nitrogen, and phosphorous reductions. The in-street bioretention retrofits provide the greatest amount of reductions by far.

Table 24. Green Streets Retrofit Analysis summary results.

Scenario	Retrofit Type	Area Treated [sf]	Volume Reduction [Mcf/yr]	N Reduction[lbs/yr]	P Reduction [lbs/yr]
Immediate Opportunities Scenario	In-street Bioretention	677,800	0.69	84.8	44.1
	Permeable Paving	294,100	0.05	4.9	1.8
	ROW Bioretention	71,300	0.12	16.0	5.3
	SUM	**1,043,100**	**0.87**	**105.7**	**51.3**
Full Green Scenario	In-street Bioretention	677,800	0.69	84.8	44.1
	Permeable Paving	294,100	0.05	4.9	1.8
	ROW Bioretention	71,300	0.12	16.0	5.3
	SUM	**1,043,100**	**0.87**	**105.7**	**51.3**
TOTAL		***2,086,300***	***1.73***	***211.3***	***102.5***

5.5 Summary Total Results

Table 25. Summary Results for all scenarios.

Scenario	Volume reduction [M.cf/yr]	N reduction [lbs/yr]	P reduction [lbs/yr]
RRI (Site Retrofits) – Immediate Opportunities	3.8	396.5	70.9
RRI (Site Retrofits) - Full Green	1.8	162.8	23.7
RRI (Site Retrofits) - Total	**5.6**	**559.3**	**94.6**
Residential – Immediate Opportunities	0.24	21.0	10.4
Residential - Full Green	0.02	2.0	0.5
Res. Total	**0.3**	**23.0**	**10.9**
Streets – Immediate Opportunities	0.9	105.7	51.3
Streets - Full Green	0.9	105.7	51.3
Streets - Total	**1.7**	**211.3**	**102.5**
Subtotal - Immediate Opportunities	*4.9*	*523.2*	*132.6*
Subtotal - Full Green	*2.7*	*270.4*	*75.4*
TOTAL	***7.5***	***793.6***	***208.0***

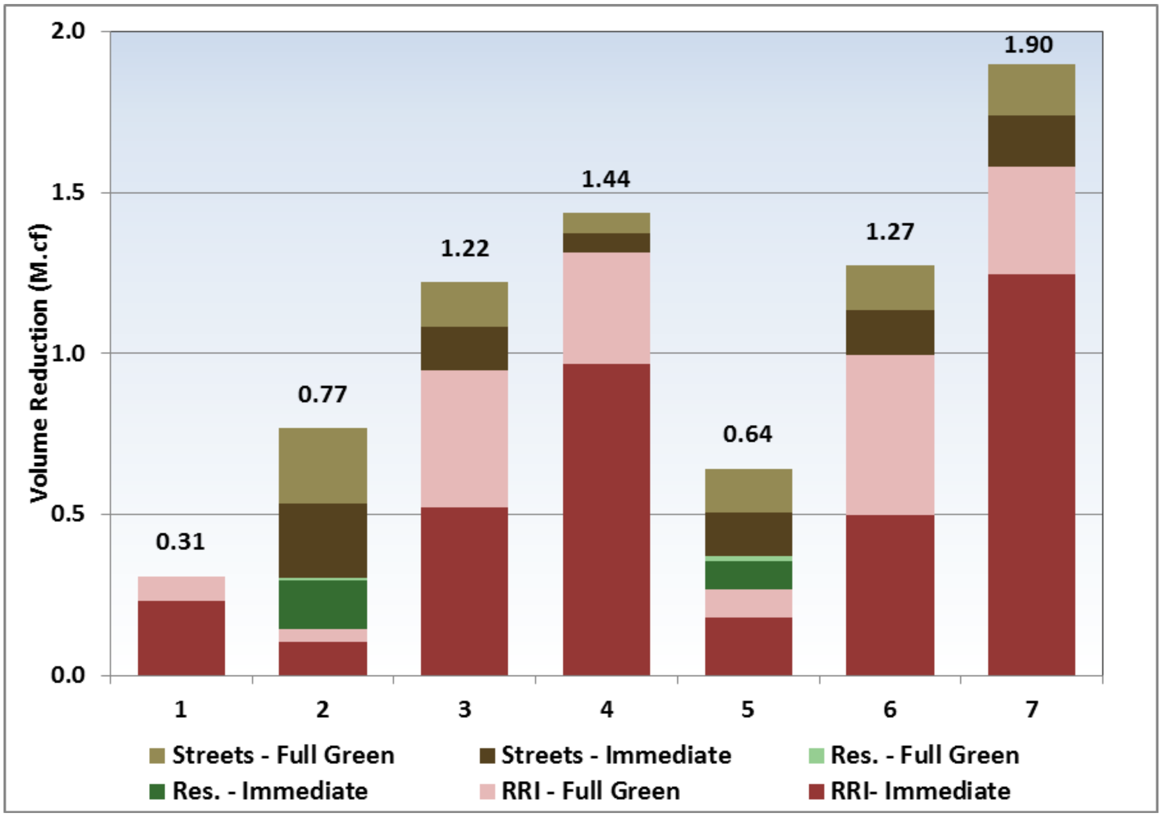


Figure 21. Total Potential Volume Reduction (M.cf/yr) by Work Area including Full Green

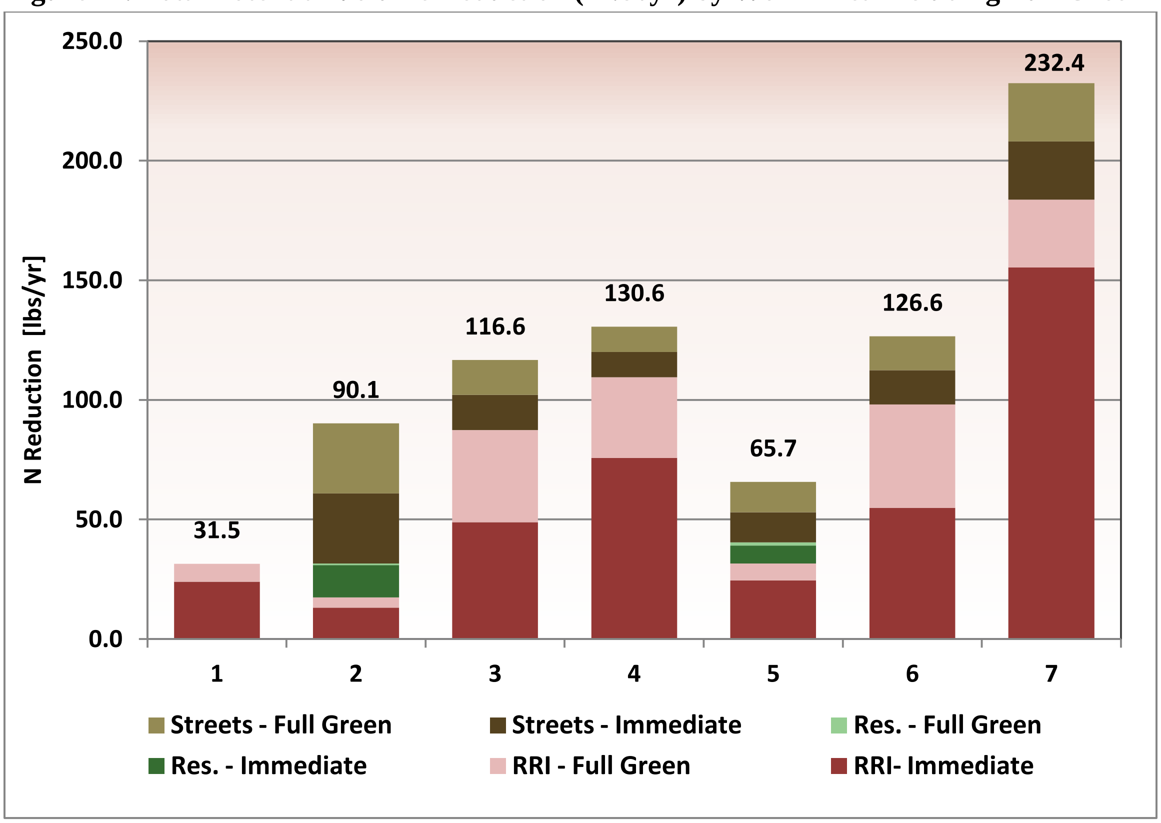


Figure 22. Total Potential N Reduction (lbs/yr) by Work Area including Full Green Scenario

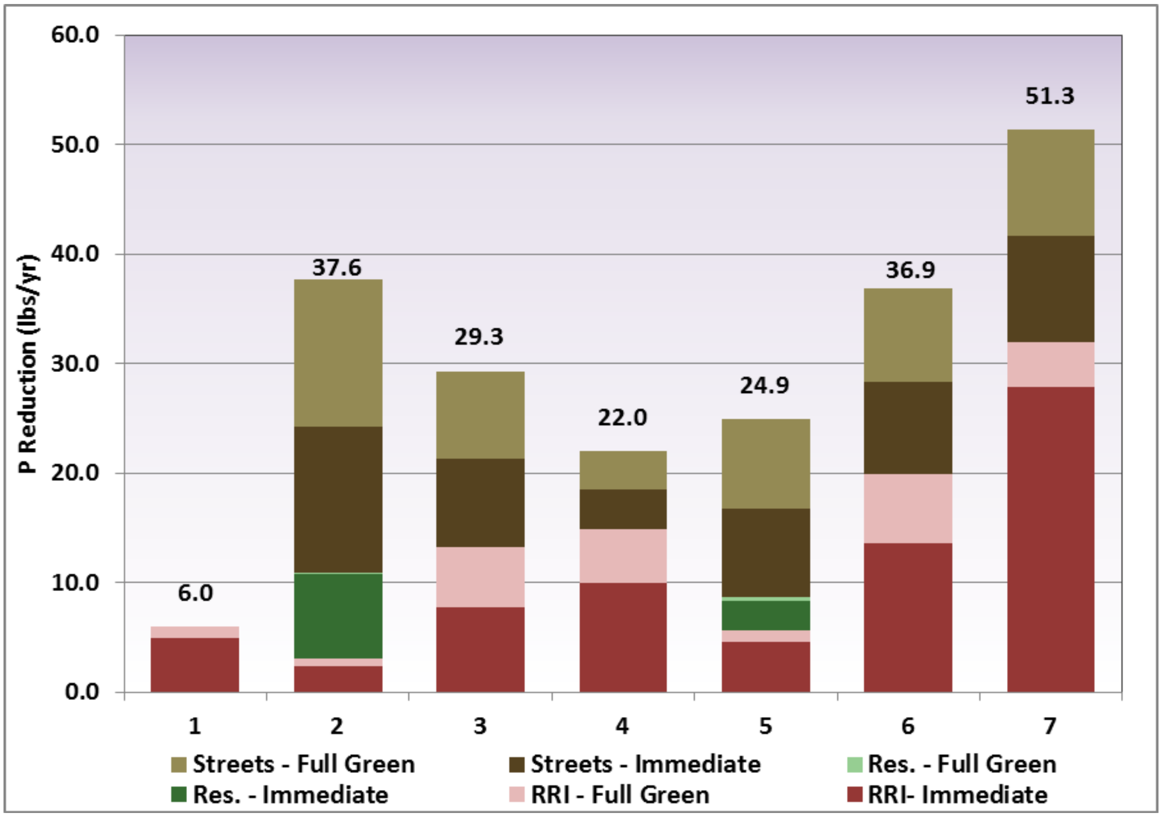


Figure 23. Total Potential P Reduction (lbs/yr) by Work Area including Full Green Scenario

6. Discussion

The results from the large site (RRI) best management practice analyses reveal several important considerations.

- Full Green Scenario assumes the removal of barriers to GI adoption such as the high cost of retrofits, lack of available space, lack of awareness of stormwater's connection to water quality issues, lack of policies or incentives, as well as other barriers.
- The greatest amount of volume reductions in the short run would come from implementing green roofs and bioretention.
- In the long-run, green roofs have the greatest potential for volume reduction in this highly urbanized catchment.
- Bioretention has the greatest potential for nitrogen and phosphorous reductions in the short and long runs.
- Green roofs have significant nitrogen and phosphorous reduction potential if projects with moderate priority are implemented.
- Although rainwater harvesting does account for a relatively low proportion of the overall reductions, updated versions of the JFSNLAT tool will significantly increase the loading reductions provided by rainwater harvesting, and this study likely significantly underestimates the potential of rainwater harvesting.

Although residential practices do not account for as much treatment, they represent the greatest potential number of practices as a group. This is significant because the implementation of the 419-458 potential residential retrofit projects has the potential to reach more than 50% of households in this small area. Implementation of projects at more than half of the households within a small area has the potential to raise awareness about water quality and conservation issues. The people who adopt these practices have a more intimate relationship with the BMP because they manage and benefit from the practice. Finally, one practice that holds some promise for implementation in residential neighborhoods is downspout disconnection and discharge to pervious areas. The current version of JFSNLAT does not include downspout disconnections, but studies conducted by NC Cooperative Extension in the Durham Triassic Basin suggest that these practices can significantly manage stormwater volume and nutrient loading, and future versions of the modeling tool may include downspout disconnections.

It should be noted that all of the reductions in this study are based on annual assumptions, but Triassic Basin soils differ greatly from non-growing to growing seasons (Boggs et al. 2012, Dreps et al. 2014) so the practices may perform at higher efficiency during growing season than credited in the model.

7. Next Steps

This Technical Report includes the technical background and appendices describing the planning, desktop analyses, fieldwork, and modeling analyses that will inform the Ellerbe Creek Green Infrastructure Project study under EPA Urban Waters grant funding. That study will consist of this Technical Report, other reports or analyses referred to in this report, and the Ellerbe Creek Green Infrastructure Project summary that is forthcoming. The production of the summary report, outreach, and implementation steps involved with this EPA Urban Waters grant are summarized below.

Cost Summary

Project partners (ECWA and American Rivers) will create a brief cost summary memorandum and spreadsheet for the projects identified in this Technical Report. ECWA and American Rivers will depend on detailed guidance from other partners for cost estimates and memo / spreadsheet review.

Project Summary

American Rivers, Downtown Durham, Inc., and ECWA will produce a project summary report summarizing the findings from this Technical Report into a short format brochure for public use. The project summary report will include some more general analyses of other benefits and potential costs of the recommended GI retrofits. American Rivers will professionally print the summary report document, and partners will distribute it as part of project outreach.

Outreach

American Rivers, Downtown Durham, Inc., the Triangle J Council of Governments, and ECWA are currently meeting to develop a community engagement strategy for presenting the findings of the Ellerbe Creek Green Infrastructure Partnership plan to City of Durham staff and officials, to the public at select local government meetings (e.g. Durham Environmental Affairs Board, City Council work sessions and/or meetings), to the business community (e.g. Downtown Durham Inc.), and to the neighborhoods that are included in the study area (Trinity Park and Old North Durham neighborhoods). The outreach materials will include the project summary, presentations for local government, business and community groups, press releases, and potential press release events. American Rivers and TJCOG will lead on local government outreach, American Rivers and Downtown Durham, Inc. will lead on business outreach, and ECWA will lead on neighborhood outreach.

Implementation

Although not specifically supported under the EPA Urban Waters grant funding, members of the Ellerbe Creek GI Partnership are actively working to implement some portions of the projects documented in this Technical Report.

The City of Durham Stormwater and GIS Services are providing funding to ECWA to install a limited number of residential rain gardens and cisterns. Now in its second year, this contract has expanded, and ECWA and the City of Durham have secured matching grant funding to add additional retrofits to the work funded by the City. This work will operate within, but not be limited to, the downtown Ellerbe Creek catchment.

Implementation of GI projects will require, in most cases, feasibility studies for individual potential Site Retrofit or Green Street projects. Once determined feasible, a potential project will require design and engineering, as well as permitting before construction. Once construction is completed, regular inspections, maintenance are required to insure the ongoing effectiveness of such projects, just as maintenance and inspection is required for any stormwater infrastructure. In the case of small-scale GI, achieving maintenance will require effective guidance to the landowner, likely from the local government or its contractors.

Partners are working to secure funding toward the implementation of larger-scale (non-residential) GI practices, including applying for short-term funding through state, federal, and private grants to match funding from the City of Durham.

In the long-run, the greatest individual source of funding for stormwater BMP retrofits is clearly the local stormwater utility, as is evidenced in the many cases around the USA where utilities have set major pollution reduction goals. The most recent example is, Prince George's County, Maryland, which has set an ambitious 30-year plan to install over 46,000 GI practices with the goal of improving water quality in its waters. In this case, the undertaking's primary source of funding is its stormwater utility fee.

8. References

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Appendices

Site Retrofit (RRI) Field Forms: Appendix 1A

Residential Retrofit (NSA) Field Forms: Appendix 1B