City of Camden Green Infrastructure Design Handbook: Integrating Stormwater Management into Sustainable Urban Design

Photo: Camden Waterfront, US EPA

AUGUST 2013
EPA 830R13003

About the Green Infrastructure Technical Assistance Program

Stormwater runoff is a major cause of water pollution in urban areas. When rain falls in undeveloped areas, the water is absorbed and filtered by soil and plants. When rain falls on our roofs, streets, and parking lots, however, the water cannot soak into the ground. In most urban areas, stormwater is drained through engineered collection systems and discharged into nearby waterbodies. The stormwater carries trash, bacteria, heavy metals, and other pollutants from the urban landscape, polluting the receiving waters. Higher flows also can cause erosion and flooding in urban streams, damaging habitat, property, and infrastructure.

Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, green infrastructure refers to stormwater management systems that mimic nature by soaking up and storing water. These neighborhood or site-scale green infrastructure approaches are often referred to as low impact development.

EPA encourages the use of green infrastructure to help manage stormwater runoff. In April 2011, EPA renewed its commitment to green infrastructure with the release of the Strategic Agenda to Protect Waters and Build More Livable Communities through Green Infrastructure. The agenda identifies technical assistance as a key activity that EPA will pursue to accelerate the implementation of green infrastructure. In February 2012, EPA announced the availability of $950,000 in technical assistance to communities working to overcome common barriers to green infrastructure. EPA received letters of interest from over 150 communities across the country, and selected 17 of these communities to receive technical assistance. Selected communities received assistance with a range of projects aimed at addressing common barriers to green infrastructure, including code review, green infrastructure design, and cost-benefit assessments. Cooper's Ferry Partnership was selected to receive assistance on integrating low impact development design strategies and green infrastructure practices within the City of Camden Waterfront, as well as the City as a whole.

For more information, visit http://water.epa.gov/infrastructure/greeninfrastructure/gi_support.cfm.

City of Camden Green Infrastructure Design Handbook

A handbook for the integration of green infrastructure into sustainable urban design.

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This guidance manual was developed under EPA Contract No. EP-C-11-009 as part of the 2012 EPA Green Infrastructure Technical Assistance Program.

Project Summary

In 2011, the Camden SMART Initiative was formed to develop a comprehensive network of green and grey infrastructure programs and projects as a means to alleviate recurring flooding events, improve water quality, and restore and revitalize the City's neighborhoods. Formed as a public-private collaboration, its members include the City of Camden, Cooper's Ferry Partnership, the Camden County Municipal Utilities Authority, the Rutgers Cooperative Extension Water Resources Program, the New Jersey Tree Foundation, and the New Jersey Department of Environmental Protection.

With Camden's future tied to the environmental and economic health of the region, sustainability is a fundamental component of the city's revitalization strategy. The Camden SMART Initiative has taken the lead on implementing numerous green infrastructure projects that serve to improve the City's overall sustainability by: improving air, water, and climate quality; preventing neighborhood flooding and reducing combined sewer overflows; developing environmental policy; creating sustainable green jobs; adding recreational amenities and open space; providing economic development opportunities; beautifying neighborhoods; and increasing property values. This handbook is intended to further Camden SMART's effort by providing residents, builders, city and county staff, and other interested groups with practical, state-of-the-art information on integrating low impact development design strategies and green infrastructure practices within the City of Camden.

This green infrastructure handbook is broken down as follows. *Section One* defines green infrastructure and identifies the multiple benefits it proves, while *Section Two* provides examples of green stormwater infrastructure tools - from the rooftop to the street - that are applicable to the City of Camden. *Section Three* shows how these tools can be used within new development and retrofit projects within the City of Camden.

This plan has been prepared under the guidance of the Cooper's Ferry Partnership as part of the US EPA Green Infrastructure Community Partnership for targeted technical assistance.

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Principles of Green Infrastructure

Definition of Green Infrastructure and Low Impact Development

Green infrastructure refers to the natural and constructed stormwater controls that mimic the natural hydrologic cycle by capturing, treating, and/or using stormwater runoff from public and private properties. These practices are incorporated into the planning, site design and construction phases of development projects. Green infrastructure practices are very flexible and can be integrated into many different development contexts, including new development, redevelopment, and retrofit of public and private properties. Green infrastructure can also be woven into the built environment at many different spatial scales – from the site scale to the watershed scale.

When applied at the site development level, green infrastructure is often referred to as Low Impact Development (LID). Green infrastructure practices include, but are not limited to: rain gardens, permeable pavements, and green roofs.

Green Infrastructure and Stormwater Management

Green infrastructure and LID are designed to function as part of a sustainable stormwater strategy that serves to meet regulatory compliance and other goals by reducing stormwater runoff volumes and flows, and by improving water quality. The City of Camden, New Jersey, is an older, industrial urban community situated along the scenic Delaware River, and is one of 30 municipalities or other public entities in the state that has a combined sewer system.[1]

Whereas a separate stormwater sewer system collects only stormwater and transmits it with little or no treatment to nearby waterways, a combined sewer system collects both stormwater and sewage in the same pipe. Most of the time, Camden's combined sewer system is able to successfully transport all of the wastewater it collects to the Camden County Municipal Utilities Authority, where it is treated before being released into the Delaware River. During periods of heavy rainfall or snowmelt, however, the system can become overwhelmed, causing wastewater to overflow into the Delaware Estuary via one of the City's 22 active combined sewer outfall locations.

Green infrastructure helps to supplement traditional investments in sewers, storage tunnels and treatment facilities by adding storm water storage capacity throughout the landscape. This, in turn, can help reduce localized flooding and stormwater-related pollution in nearby waterways during rainfall events. Green infrastructure is often a cost-effective alternative that

Above: A green roof installation on the Geraldine R. Dodge Foundation headquarters in Morristown, NJ. In addition to its stormwater benefits, the native plant rooftop provides bird habitat in a downtown setting.

serves to provide additional community benefits such as improved air quality, improved neighborhood aesthetics and safety, and reduced treatment costs.

Multiple Benefits of Green Infrastructure

The benefits of green infrastructure extend beyond improved stormwater management. Green infrastructure helps to protect and restore local watersheds, to enhance and facilitate the experience of walking, biking, and other community activities, and to create sustainable and attractive community gateways. Trees, for example, can provide shade and cooling, improve local air quality, and create improved perceptions of a street or neighborhood.[2] Some benefits have a direct monetary value, such as reduced capital costs for stormwater infrastructure, reduced long-term O&M costs, and increased property values.

One approach for evaluating the effect and overall value of the multiple benefits is the Triple Bottom Line (TBL) approach.[3] This approach aides decision makers and stakeholders by considering the social, economic, and environmental benefits of projects rather than just the construction life-cycle costs. The TBL approach can identify opportunities to integrate green technologies into public and private development and redevelopment projects as well as planned and ongoing improvements to the transportation infrastructure.

Expected Environmental Benefits

Air Quality

Green infrastructure features such as trees and other vegetation help to reduce ground level ozone by reducing power plant emissions, reducing the amount of electricity used for air conditioning, and reducing temperatures. Trees and vegetation also reduce particulate matter within the air by absorbing and filtering pollutants which, left unabated, can enter into the lungs and cause serious health problems.[4] Green infrastructure's air quality benefits are of special importance to the City of Camden, which is designated by the US EPA as non-attainment areas for not meeting national air quality standards for fine particles in the ambient air.[5]

In the Camden Waterfront South area, a three-year study further identified toxic components such as arsenic and lead in airborne particulate matter. Increasing vegetation was one of four recommendations provided for reducing overall particulate amounts, and was identified as a strategy with relatively immediate short-term gains.[6]

Above: Street trees adorn Chestnut Street in nearby Philadelphia's Chinatown. The city has a goal to plant 15,000 new trees in Philadelphia every year.

Climate Change
Climate change is considered a critical threat to our social well being and economic future.[7] In the North, average annual temperatures have increased by 2°F and winter temperatures by 4°F since 1970. In the Delaware Estuary region, annual temperatures are expected to rise between another 3° to 7°F, precipitation is expected to increase by 7-9%, and the sea level is expected to rise between 1.7 and 5 ft. or greater by the year 2100.[8]

Strategically locating green infrastructure and adding green spaces into urban environments has the potential to help cities to adapt through the provision of cooler microclimates and reduced runoff.[9] Green roofs, for example, have the ability to retain large amounts of stormwater, reduce roof surface and ambient temperatures, and sequester carbon. Planting trees in a manner that optimizes cooling and wind break effects has been shown to indirectly impact climate change through reducing the amount of energy needed for heating and cooling, as well as reducing stormwater requiring treatment off-site.

Urban Heat Island
Annual mean temperatures in urban areas can average 2-5°F higher than suburban temperatures. On a clear night, the difference can be as much as 22°F. This difference is due to the large amount of hard, reflective surfaces in developed areas that absorb solar radiation and re-radiate it as heat.[10] By substituting soils and vegetation for hard, heat-absorbing pavement and pervious surfaces,[9] green infrastructure can help reduce the urban heat island effect. Water vapor emitted by trees and other plant materials also acts to cool ambient temperatures because heat energy is used by vegetation to evaporate water.

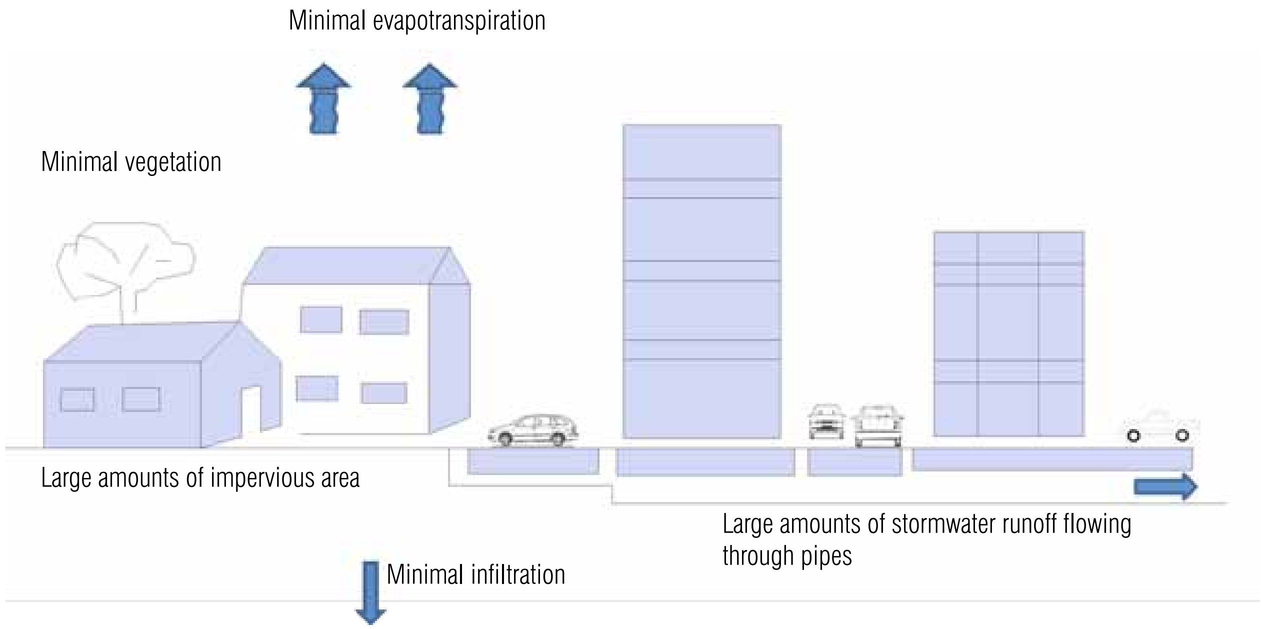
Water Quality and Habitat
Stormwater runoff from urban areas has a significant impact on nearby waterbodies. Pollutants draining from the urban landscape degrade water quality, while higher flow rates cause erosion and habitat loss.

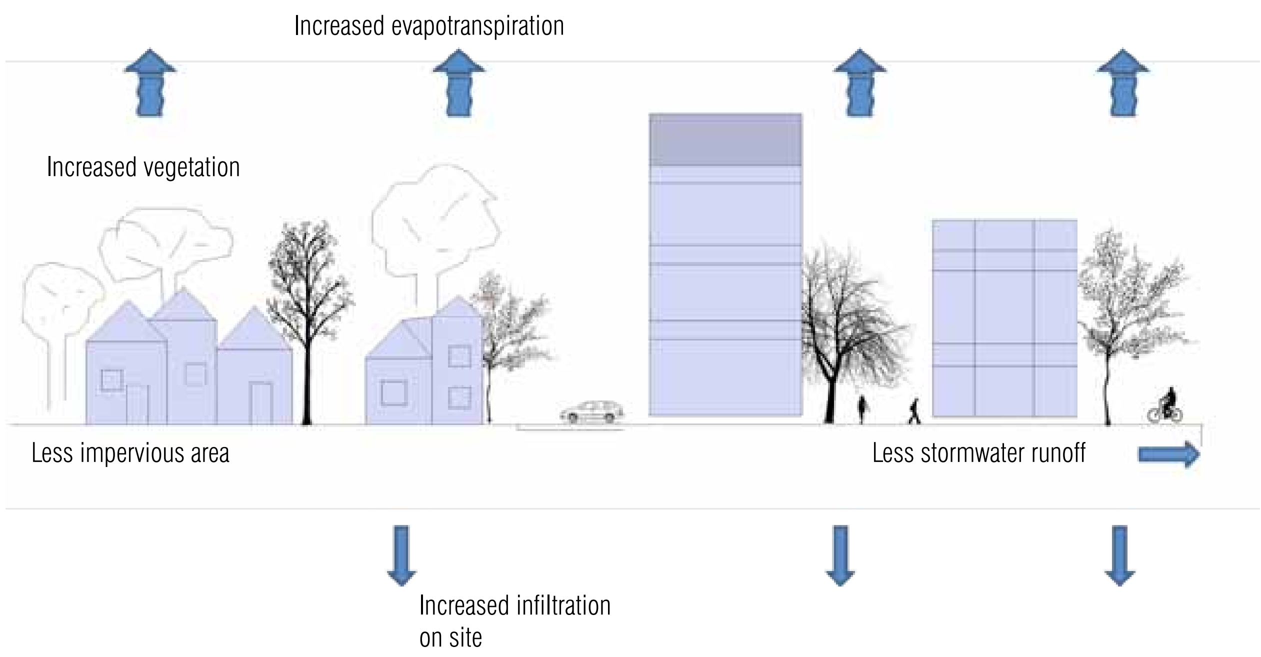
Green infrastructure can help to mitigate these impacts by retaining, slowing, and filtering runoff from small storms. Retaining and slowing stormwater runoff reduces flow rates in urban streams, mitigating the impact of sediment erosion on water quality and aquatic habitat. In addition, the first flush of runoff carries a higher concentration of pollutants, so filtering the runoff from small storms allows green infrastructure to treat the most polluted runoff before it reaches the groundwater or nearby streams.

Groundwater Recharge
In the State of New Jersey, any development project disturbing at least 1 acre of land or creating at least 0.25 acres of new or additional impervious surface must include non-structural and/or structural stormwater management measures that prevent the loss of groundwater recharge at the project site (see NJAC 7:8). While the primary focus of green infrastructure is typically to slow and clean stormwater runoff, green infrastructure practices that direct runoff to vegetated areas or areas with porous materials can also help recharge groundwater supplies – particularly where drought-tolerant plants and trees are incorporated into the design.[11] In New Jersey, this requirements is included because of the adverse impact that the loss of groundwater recharge can have on water supplies and on the health of streams and wetlands.[12]

Expected Social Benefits

Community Reference Point
The phrase community reference point refers to the ability of a feature to serve as a signature or destination for community residents or visitors, and/or serve as a model for development or redevelopment.[13] Green infrastructure features can contribute to a community reference point, enhancing the attractiveness of a site or neighborhood and serving as a source of pride for the community. The benefits of a community reference point are difficult to quantify, but may include an increase in visitors to the project location, an increase in ceremonies held at the location, and/or an increase in sales by nearby merchants.





Traditional (top image) versus green (bottom) design. Greener approaches serve to treat a greater amount of stormwater on-site, providing multiple benefits along the way.

Above: Incomplete sidewalks and crosswalks force pedestrians to walk in travel lanes.

Recreational Opportunities
Through adding green spaces and wooded vegetation, green infrastructure can increase publicly available recreation and gathering areas. Recognizing this connection, the City of Lenexa, KS, developed an award-winning “Rain to Recreation” program in 2000 to reduce flooding and protect water while preserving natural habitat and providing educational and recreational opportunities for residents. Similar opportunities are available for Camden to build upon its waterfront area by linking its development efforts with low impact development practices.

Improved Safety
All too often, roads are built without sidewalks or proper crosswalks. Where they do exist, they are often inadequate, with crosswalks spaced too far apart, or sidewalks not connected.[14] Green infrastructure in the form of curb extensions help to slow down traffic and reduce crossing distances while increasing awareness of places where people cross. Adding sidewalks and bike lanes can further add to public safety.

In addition, studies have shown that increased vegetation and green spaces within urban areas can reduce crime and promote safer communities.[15,16] Outdoor spaces with natural landscapes have less graffiti, vandalism, and littering than in comparable plant-less spaces.[17] In a study of community policing innovations, there was a 20% overall decrease in calls to police from the parts of town that received location-specific treatments. Cleaning up vacant lots was one of the most effective treatment strategies.

Expected Economic Benefits

Avoided Capital Costs
Green infrastructure often costs less than gray stormwater infrastructure to install, which is a benefit to developers.[18] Development projects that incorporate green infrastructure may have lower costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping. When properly placed, such features can also reduce inflow and infiltration into sewer lines otherwise burdened by increased wear, tear, and repair. Over time, these practices can reduce pressures to increase storm drain capacity.

Increased Property Values
Green infrastructure features such as increased plantings and street trees lead to more attractive neighborhoods, which serves to increase nearby property values. A study in Portland, Oregon, for example, found that street trees added an average of $7,020 to the price of nearby houses.[19] In addition, studies have shown that access to green spaces and parks can inflate the value of property in a three-block

radius, while also providing valuable recreation opportunities that boost communities.[20] Such benefits can also translate into increased annual property tax revenue for local communities.

Stormwater Design Toolbox

Overview

The City of Camden was originally incorporated in 1828 and is the county seat of Camden County. At approximately 6,600 acres in size, it is an urban community situated along the scenic Delaware River, with its waterfront just one mile from Philadelphia's historic district.

While the City's overall population density is still high, Camden's population has been in decline for the last several decades, falling from a peak of about 125,000 residents in 1950 to 77,334 in 2010.[21] For many years, Camden has struggled against the impacts of urban decay: the closing of major manufacturing industries, a thinning population, crumbling infrastructure, abandoned parcels, a high rate of poverty, a high rate of crime, and struggling communities. Through this, however, the City of Camden's residents have showed a sense of resiliency and determination. Significant new public and private resources – coupled with tremendous community willpower– are leading to a new vision for the City of Camden, where neighborhoods are built up holistically, and green and grey infrastructure are considered together as part of the solution.

Integrating green infrastructure throughout the City of Camden will not only help to alleviate flooding and pressures on the City's combined sewer infrastructure, but is a necessary step in the City's revitalization. The City of Camden, its partners, and its residents have already recognized the role that green infrastructure can play in its reinvestment. Through extensive community Green Up efforts and the Neighborhood Improvement Program, blighted vacant lots have been turned into green havens. With the help of the New Jersey Tree Foundation Urban Airshed Reforestation Program, citywide tree planting efforts have taken root. Numerous greenway efforts and bike trails have been established. The Camden SMART initiative is furthering these efforts by developing a comprehensive network of green infrastructure programs and projects for the City of Camden. The purpose of the green infrastructure stormwater toolbox is to help further this effort by identifying practices that are applicable within the city.

Green Infrastructure Toolbox

Green infrastructure, when incorporated into new construction, can be designed to handle significant amounts of runoff. In retrofit scenarios, opportunities may be more limited, but green infrastructure can generally be designed to handle the small storm events that convey the most pollution, while allowing runoff from larger storms to overflow into the storm sewer system.

From green roofs to permeable pavements, the tools identified in this chapter showcase some of the many green infrastructure practices available within the development and redevelopment process. Technical specifications for many of these and other green stormwater infrastructure practices can be found in the New Jersey Stormwater Best Management Practices Manual,[12] the New Jersey Department of Agriculture's Soil Erosion and Sediment Control Standards, and the Rutgers Cooperative Extension Water Resources Program.

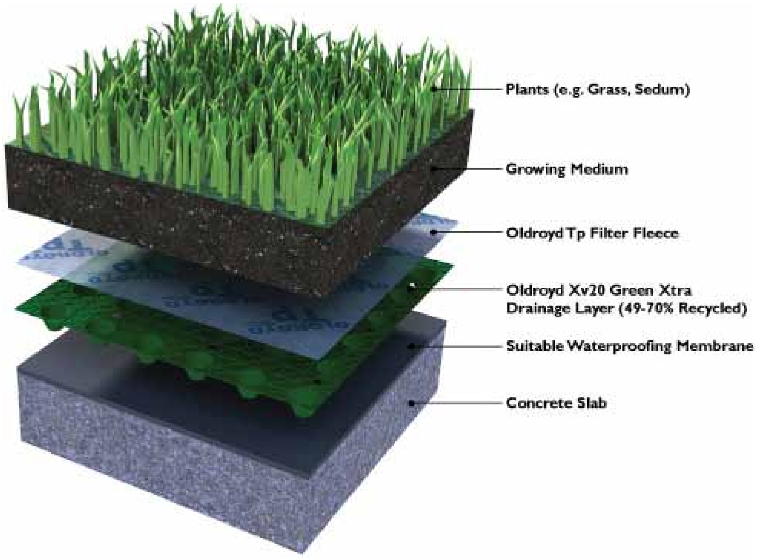
Above: A rendering of the proposed design for the Haddon Avenue Transit Village in Camden depicts how "green" is already being integrated into Camden's design concepts.

Green Roof

Above: The 31st Street Harbor green roof rests atop the harbor services building in Chicago. The development, which includes a 1,000-slip marina and a park with newly configured bike and walking paths, transformed an under-used portion of Lake Michigan's shoreline into a public amenity. The consideration of social and economic components was critical to its development. The area serves as one of the Chicago Park District's largest revenue generators, and has helped to revitalize surrounding neighborhoods.

Green roofs -- also commonly referred to as living roofs or eco roofs -- use soil and plants in place of traditional roof materials. Green roofs provide multiple economic, environmental, and social benefits. In addition to water quality benefits, green roofs reduce the life cycle costs of roofs, provide energy savings and greater fire protection, remove airborne particulate matter, create wildlife habitat, provide space for food production, and can create usable green space in urban environments.

Green roofs come in two general types: extensive and intensive. Extensive green roofs typically have a growing medium of 3-4", are usually planted with sedum, require less irrigation, and have low maintenance requirements. Intensive green roofs have up to 12" of growing medium and can support shrubs and trees. The ability to maintain larger



Above: Details from a typical extensive green roof installation, consisting of a vegetative layer, a specially-designed soil layer, and a drainage layer.

plant material also introduces a need for constant irrigation and a more regular maintenance schedule.

Research conducted on green roof installations in the Northeast indicates that they retain 50% or more of annual rainfall,[22] and can add 3 hours to the time it takes runoff to leave a roof.[23] An intensive 7,000 square-foot green roof on top of Hackensack UMC's John Theurer Cancer Center in Hackensack, NJ, retains up to 90% of summertime precipitation and 40% of wintertime precipitation.[24]

In addition, green roof installations can help neutralize the effects of acid rain, which is a problem in Northeastern states such as New Jersey.[22] Recent research has also shown that green roofs have the capability to sequester large amounts of carbon. Replacing traditional roofing materials in an urban area of about one million people, for example, would capture more than 55,000 tons of carbon -- the same effect as removing more than 10,000 mid-sized SUVs or trucks off the road a year.[25]

Several factors can influence the costs of green roofs. These include whether the project involves a retrofit or is new construction, the type of green roof (extensive versus intensive), accessibility, maintenance requirements, and market maturity. The installation cost for extensive green roofs range from $10.30 to $12.50 more per square foot than a conventional black roof, while intensive green roof costs range from $16.20 to $19.70 more per square foot than a conventional black roof. Annual maintenance costs are generally $0.21 to $0.31 more per square foot than a conventional black roof. However, the average life expectancy of a green roof is more than twice that of a traditional one. And, when adding in the monetary benefits derived from stormwater runoff reductions, energy savings, improved real estate values, and community improvements, a recent report by the General Services Administration determined that the money invested into installing a green roof of 3-6" in depth can be recouped within about 6.4 years for a 5,000 sq. ft. installation, and 6.2 years for a 10,000 sq. ft. installation.[23]

Above: Close-up of an extensive green roof atop of the newly constructed Rutgers dorm. Such systems can significantly extend the amount of time it takes for water to leave a site.

Green Wall

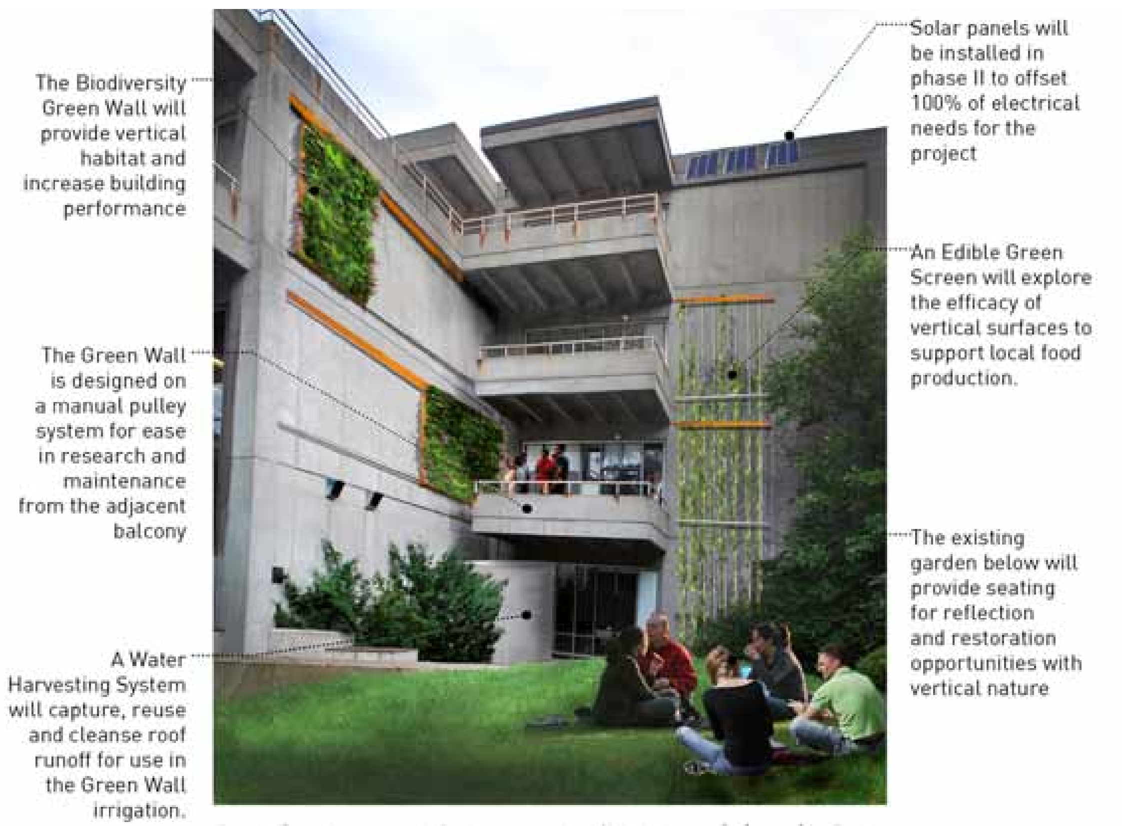
Green infrastructure technology is continuously evolving as engineers, designers, and landscape architects find new, creative ways to integrate the concepts of sustainability into urban landscapes. Green walls, also know as biowalls, living walls, and vertical gardens, are one such evolving technology.

While the idea of having greenery growing up a building or retaining wall is not new, coupling it with ways to ensure improved stormwater uptake, improve air quality, and provide additional community benefits is. Researchers such as those at the University of Washington (see image below) are experimenting with ways to improve their utility and ease of maintenance.

Green walls can be designed to help slow down and absorb stormwater, clean the air, modify micro-climates, and add beauty to a garden or living space. When designed without soil, cisterns placed higher than the top of the growing medium can help provide a constant supply of water.

Just as green roofs can reduce the strains on combined sewer systems by slowly releasing stormwater over time, this delay in runoff is also considered a benefit of green wall technology. Research has yet to quantify the runoff reduction benefits of green walls,[26] but preliminary studies suggest that these systems can retain as much as 45 to 75% of a given rain event.[27]

Recently published research on the air quality benefits of green walls in urbanized areas is also very compelling. In high-density areas, it is not uncommon for the height of buildings on either side of a street to be twice the width of a road or more. When this happens, air flow is restricted, and air pollution can become trapped in the “street canyon.” The strategic placement of green walls with street trees and other greenery, however, can reduce air pollution (e.g., nitrogen oxide and particulate matter) by up to 30%, proving to be a more cost-efficient measure than other strategies that are currently employed.[28]



Left: A concept design for a recently unveiled green wall at the University of Washington College of Built Environment’s Green Futures Lab to study more efficient methods in plant growth, water circulation, and biodiversity. The upper wall was planted with 80 to 85% native species, and the lower wall with about 50% native plants. Temperature systems were installed to track the wall’s temperature and measure energy efficiency, and throughout winter months, the wall will be irrigated via a rooftop water cistern. A crank-and-pulley system allows for easier maintenance.

Above: A temporary green wall was installed by the popular Shake Shack as their recently-opened Philadelphia Shack was undergoing construction in its Rittenhouse Square neighborhood. In addition, several permanent green walls can be spotted throughout Philadelphia.

In general, the cost to design and install a green wall can range from $100 to $175 per sq. ft., depending on the complexity of the system and plant materials chosen. Maintenance requirements and costs also vary by system. However, these costs must be weighed against the monetary benefits associated with improved air quality, reduced energy consumption (green walls can reduce surface energy use by 23% in the summer), reduced noise pollution, and reduced stormwater runoff.[29]

These systems are equally viable for use in interior settings in combination with a rainwater capture and filtration system, and can serve to add greenery without taking up valuable floor space. In the U.S., where retail and office space average $25.50 per sq. ft., dedicating 35 sq. ft. of wall space is much cheaper on an annual basis than dedicating the same amount of floor space to indoor plants,[30] while also providing a more stunning backdrop and allowing for the integration of stormwater reuse systems.

Downspout Disconnection

A downspout is a pipe that carries rainwater off of rooftops. Some downspouts drain into yards or other vegetated surfaces. Other downspouts drain directly onto paved surfaces or are piped into stormwater inlets. Even during very short rains, downspouts that flow onto pavement and/or directly into stormwater inlets contribute to sewer overflows. When the sewer system fills up with rainwater, sewage overflows into the nearest local waterway.

Downspout disconnection reconfigures rooftop drainage to flow into vegetated areas, rather than flowing into pipes or paved areas. Discouraging or eliminating direct connections of impervious areas to stormdrains is a simple yet effective green infrastructure practice that is applicable to a wide variety of site conditions and development designs. By directing downspouts into rain barrels, water can be stored and used later for irrigation. When directed to rain gardens or other pervious areas, increased infiltration will result. To ensure effectiveness and to minimize possible problems such as building or street flooding, close attention must be paid to site drainage patterns. This practice is not well suited to properties when cracks exist in basement walls and/or lawn area is not available or properly graded. In these instances, other toolbox practices, such as rain barrels and cisterns, could be an alternative.

Above: A disconnected downspout flows into a stormwater planter. Left: Due to the relative ease in which a downspout disconnection program can be developed, several cities like Gresham, OR, have encouraged downspout disconnections as part of a community outreach campaign to promote better on-site stormwater management.

Typically costing less than $15 per downspout, downspout disconnections are very inexpensive and can be implemented on a large-scale relatively easily. In Portland, OR, the city disconnected downspouts on more than 26,000 properties, removing more than 1.2 billion gallons of stormwater from its combined sewer annually.[31] In Detroit, MI, modeling extrapolated from a pilot project indicate that a city-wide downspout disconnection program there would result in reducing annual combined sewer volumes by 2 billion gallons.[32]

Cistern/Rain Barrel

Rain barrels and cisterns are cost efficient, easy to maintain features that have applications in residential, commercial and industrial settings. By capturing stormwater from the rooftop and storing it on site, large-scale systems can help reduce runoff volumes and velocity, protecting delicate watersheds and aquatic life. To be most effective, they should be completely dewatered between rain events.

Rain barrels and cisterns hold water that is free of most sediment and dissolved salts, making the stored water perfect for landscape irrigation. These systems help reduce a building's overall potable water usage while capturing rain water for reuse.

An average-sized rain barrel can hold 55 gallons and costs between $90 - $120. However, for a 20x25 sq. ft. roof, a 1" rain may produce more than 300 gallons of water, which would fill most barrels 4-5 times.[33] Cisterns are typically used in more commercial applications. Cisterns can hold as much as 10,000 gallons of rainwater and can be stored either above or below grade. Because of their large size, cisterns can offset a significant proportion of a building's water use. As their use has increased, some residential builders have begun offering cisterns as well. The cost of a cistern can range from several hundred to several thousand dollars, depending on the size and type.[34]

Above: A rain barrel installed in the City of Camden. Left: Rendering of a cistern in an upcoming mixed use development in Seattle, WA. The water collected will be used for irrigation, and is expected to reduce the building's water usage by 35%, as compared to a typical building.

Bioretention System

Bioretention systems are green infrastructure practices that use a combination of vegetation, such as trees, shrubs, and grasses, planted in a specialized soil bed to slow down, collect, and filter stormwater runoff. Runoff is directed into bioretention systems either as overland flow or through a stormwater drainage system. When configured as a *basin*, bioretention systems are most commonly referred to as rain gardens. Bioretention basins are designed to collect water and give it time to infiltrate into the ground or evapotranspirate into the air. Alternatively, a bioretention system can be constructed directly in a drainage channel or swale. *Bioretention swales* differ from basins in that they are designed more as conveyance treatment devices, not storage devices.

Because of their relatively small footprint and flexible design features, bioretention systems can easily fit into an urban landscape or other areas where space is limited. Bioretention basins are just as applicable in residential settings as they are in commercial, industrial, and street settings. Bioretention swales, are less likely to be found in residential settings, unless used in the design of a large, multi-family dwelling, and more likely to be found in parking lots or along streets or sidewalks.

Above: Bioretention basins (i.e., rain gardens) allow rain and snowmelt to seep naturally into the ground while also providing visually appealing landscaping. Below: Water from the roof of a rowhouse in downtown DC is directed towards a backyard rain garden/bioretention basin.

Bioretention systems can remove a wide range of pollutants from stormwater runoff, including suspended solids, nutrients, metals, hydrocarbons, and bacteria. They can also be used to slow water down to reduce peak runoff rates.[12] In areas where infiltration is not desired due to a high water table or where adjacent soils are contaminated, both systems can be designed with an underdrain to move excess water into a conventional storm sewer pipe.

In addition to their numerous stormwater management benefits, other benefits associated with bioretention systems include reduced urban heat island effect, reduced downstream erosion and sedimentation, and improved community aesthetics. Many other green infrastructure techniques such as vegetated curb extensions and tree planters are based off of this structural best management practice.

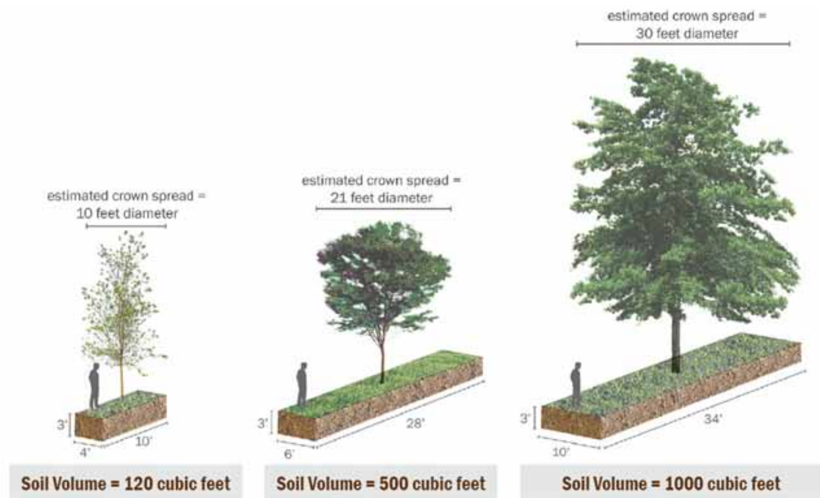
Installation and maintenance costs for bioretention systems vary depending on the site preparation required and the plants selected. Residential systems generally average $3 to $4 per sq. ft., depending on soil conditions and the density and types of plants used. Commercial, industrial, and institutional site costs can range between $10 to $40 per sq. ft., based on the need for control structures, curbing, storm drains, and underdrains. Those landscaping expenses that would be required regardless of the bioretention installation should be subtracted when determining the net cost. Additionally, the use of bioretention systems can decrease the costs required for constructing traditional storm water conveyance systems at a site and reduce the public burden to maintain large centralized facilities.

Above: A bioretention swale filters rainwater in a shopping center parking lot. Below: A bioretention swale in an urban park setting.

Stormwater Design Toolbox

Street Trees

Street trees are one of the most economical green infrastructure practices available. In a study of urban street trees in Minneapolis, MN, it was estimated that the average street tree intercepts 1,685 gallons of stormwater.[35] Urban trees intercept stormwater in their canopies, improve air quality, reduce the urban heat island effect, and improve neighborhood aesthetic. In addition, a study of street trees in nearby Philadelphia found that they can raise a house's value up to 9% and increase the time shoppers spend in stores by 12%.[36]



Above: As the potential growing medium increases (soil volume), the tree size over time can be greatly enhanced.

More important than the number of street trees is the size and composition of the soil area which allows for proper tree growth. In urban areas, the size potential and stormwater benefit of trees are often limited by densely compacted soils and confined growing areas.

For urban trees to reach their full maturity, trees need 1 to 2 ft^3 of soil volume for every square foot of crown area spread. However, a typical urban street tree only has about 120 cubic feet of available soil, restricting its tree canopy spread to 10 ft. before it begins to decline. By expanding tree spaces to allow for 500 ft^3 of soil, the same tree canopy can grow more than 20 ft. Even larger soil volumes will yield larger trees.[37]

While costs vary, an average Camden street tree costs approx. $500 to plant. Triple bottom line analyses show that the value of the benefits provided by street trees compares favorably to their cost. For example, a Los Angeles, CA, study found that one tree produces a $2.80 return on investment in energy savings, pollution reduction, stormwater management, and increased property values .[38]

Left: Street trees along Riverside Dr. near the Aquarium in Camden provide multiple benefits. However, the root growth area (RGA) is limited. Increasing RGAs will allow for trees to reach a larger size at maturity, further increasing benefits.

Stormwater Planters

Stormwater planters, also known as infiltration or flow-through planters, are a type of bioretention system that is adapted to fit into "containers" within urban landscapes. Integrated into tree boxes or urban landscaping planters, stormwater planters collect stormwater from pavement (mostly sidewalk and roads) and filter it through a bioretention system to treat pollutants such as excess nutrients, heavy metals, oil, and grease. Treated stormwater is then either infiltrated into the ground (infiltration planters) or discharged into a conventional storm sewer pipe (flow-through planters), where infiltration is not appropriate.

Stormwater planters have a small footprint and are often rectangular. With their hard edges and concrete sides, they can easily be incorporated into street retrofits or built to fit between driveways, utilities, trees and other existing constraints. These systems can be used in conjunction with permeable pavement and curb extensions to create a green street that significantly reduces overall stormwater runoff. Stormwater planters also help to provide greenery, improve air quality, and reduce the urban heat island effect.

A stormwater planter can be expected to last about 25 years. Installation costs vary on the planter's size, materials and plants used, and whether or not an underdrain is required. For a 500 sq. ft. planter, however, a simple estimate would be $4,000, or $8 per sq. ft., with annual maintenance costs of $400.[39] Stormwater planters are often less expensive to install and maintain than more conventional stormwater management facilities.[40]

Above: Cross-section of stormwater planter.
Right: Stormwater planters along Rockville Pike in Rockville, MD.

Vegetated Curb Extensions

Curb extensions are a type of traffic calming device that serve to narrow the roadway width. When modified to incorporate stormwater treatment into their design, they are capable of filtering and infiltrating all of the stormwater from the street on which they are located. Stormwater flowing down the street is directed towards the curb extension, where it is filtered and infiltrated in a vegetated area.

Above: Rendering of a curb bumpout along a residential street. Left: Vegetated curb extension in Portland, OR. Below: Cut-away of a curb bumpout with permeable pavers on sidewalk.

Vegetated curb extensions are ideal retrofits for low to medium density residential or commercial areas where some loss of on-street parking is tolerable.

In addition to providing stormwater treatment and traffic calming, vegetated curb extensions also help to reduce the urban heat island effect, improve air quality, and improve community aesthetics. They can also be combined with mid-block crossings to further increase pedestrian safety when crossing streets. In areas where on-street parking is at a premium, smaller vegetated curb extensions that are spaced more frequently can minimize parking loss to any individual property.

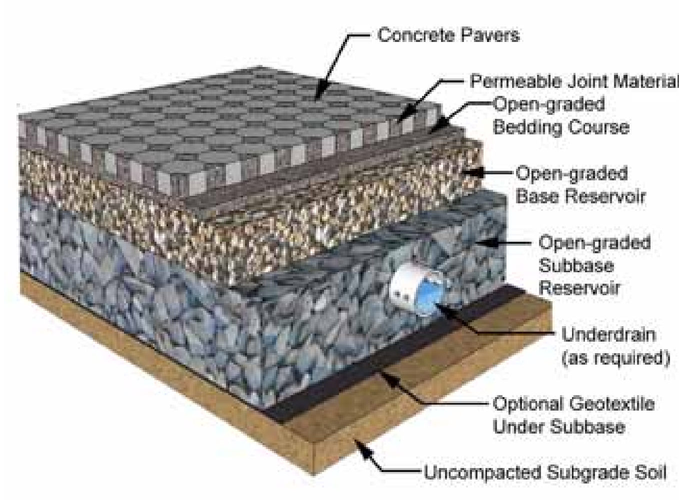
Curb extensions are appropriate where on-street parking lanes already exist. The cost of a curb extensions, which can range from $2,000 to $20,000, depends largely on the design and existing site condition, with drainage usually being most significant determinant.[41]

Permeable Paving

Permeable pavement comes in many varieties, but the most common include open grid and interlocking pavers, porous concrete, and asphalt. Permeable pavement provides the same load-bearing support as conventional pavement and is good for walking, biking, and parking areas, and for driving on low- to moderately-trafficked streets. Permeable pavement is specially designed to allow stormwater to infiltrate through the pavement to an underground storage basin or exfiltrate into the ground and recharge the water table.

Permeable pavement is ideal for planting trees in a paved environment because they allow adjacent trees to receive more air and water, while still permitting full use of the pavement. Because they are light in color and have an open-cell structure, they also help to reduce the urban heat-island effect. From a safety perspective, permeable pavements are observed to reduce hydroplaning, and are gaining popularity for use on highways and other high-traffic areas.

Permeable pavement costs vary based on the site conditions, design requirements, and type of paving that is selected. The cost per sq. ft. (installed) can vary from \$0.50 to \$10.00. When comparing the costs of permeable versus conventional pavements,



Above: System Components of Permeable Interlocking Concrete Pavement. The base layer is similar to those for permeable pavers, porous asphalt, and pervious concrete. Below: Pervious pavement in Portland, OR.

the costs of both the paving system and stormwater management system should be considered. For example, when costs for drains, reinforced concrete pipes, catch basins, outfalls and stormwater connects are included, an asphalt or conventional concrete pavement can cost two times more than its permeable alternative.[42]

Applying Green Infrastructure Practices within the City of Camden

As Camden redevelops, incorporating LID and green infrastructure techniques will allow the City to address stormwater runoff concerns while providing additional environmental, social, and economic benefits. This section provides examples of how LID and green infrastructure can be interwoven into development, redevelopment, and retrofit projects within the Central and North Waterfront area.

Three case studies were selected to represent the range of urban development opportunities considered representative of the area: Multi-Residential Developments, Commercial Developments, and Parking Lot Retrofits. First, multi-residential and commercial development are discussed by taking two case studies and identifying both structural and landscape opportunities. *Structural opportunities* focus on innovative ways to reduce stormwater, energy, and resource consumption within the building footprint. *Landscape opportunities* look at ways to reduce stormwater runoff from impervious surfaces, reduce the urban heat island effect, and increase pedestrian safety and connectivity.

Parking lot retrofits are divided into short-term and long-term proposals. Short-term proposals focus on projects that could be implemented quickly with

	Rain Barrel	Curb Extension	Downspout Disconnect	Green Roof	Bioretention System	Stormwater Planter	Street Tree	Green Wall	Permeable Pavement
Commercial	X	X		X	X	X	X	X	X
Residential	X	X	X	X	X	X	X	X	X
Parking Lot					X		X		X

little investment. These projects are designed to be implemented in parking lots slated for development in 3-5 years time. Long-term proposals look at more permanent parking lot improvements. These projects are designed for parking lots slated for development in 5+ or more years.

Three possible projects in the Camden Waterfront area were chosen as case studies. The Meadows (Phase II) at Pyne Poynt, which is an upcoming multi-family residential development; the Coopers Ferry Office development, which is an upcoming commercial development, and lastly the Federal Street surface parking lot, which is representative of the existing parking lots within the Camden Waterfront. It should be noted that these case studies were prepared solely to provide examples of how green infrastructure could be incorporated into their design. No developers were engaged in this process.

Multi - Family Residential Development: The Meadows, Phase II

Multi-family residential and mixed residential developments provide numerous opportunities to integrate green infrastructure techniques into redevelopment projects within the Camden Waterfront area. They also have the potential to target both management and residents in their greening efforts.

From the early planning stages, multi-family projects can incorporate green roofs, green walls, permeable pavements, and bioretention systems into the design. Residents can step in and incorporate additional rain gardens, rain barrels, and disconnect downspouts depending on the type of development. The following case study takes an upcoming multi-family development scheduled for the Camden Waterfront Area to showcase how green infrastructure could be incorporated into the project. The following discussion is solely conceptual in nature and is intended to provide examples of how a planned development project could be reconfigured to allow for the incorporation of green infrastructure features.

Location

In 2011, an affordable housing rental development known as The Meadows at Pyne Point was developed in a city block along North Camden Waterfront area's Erie Street and bound by Fourth, Fifth and Byron Streets. Just north of this development sits a two-city block area that is expected to be the future location of Meadows Phase II. The site, which is north of Byron St. and bounded by N 4th St. on the west and N 6th St. on the east holds a prime location just south of Pyne Poynt Park and the North Camden Waterfront.

Project Description

Completed in 2011, The Meadows at Pyne Point was the first new construction component a robust redevelopment of the North Camden neighborhood. Currently, development is being planned for Pyne Point II, and includes twelve townhouses on two blocks with a community center and parking. The site is currently adjacent to open space to the north. The case study presented here considers how green infrastructure could be incorporated by moving back the current subdivision line to allow for 1-2 more blocks of development.

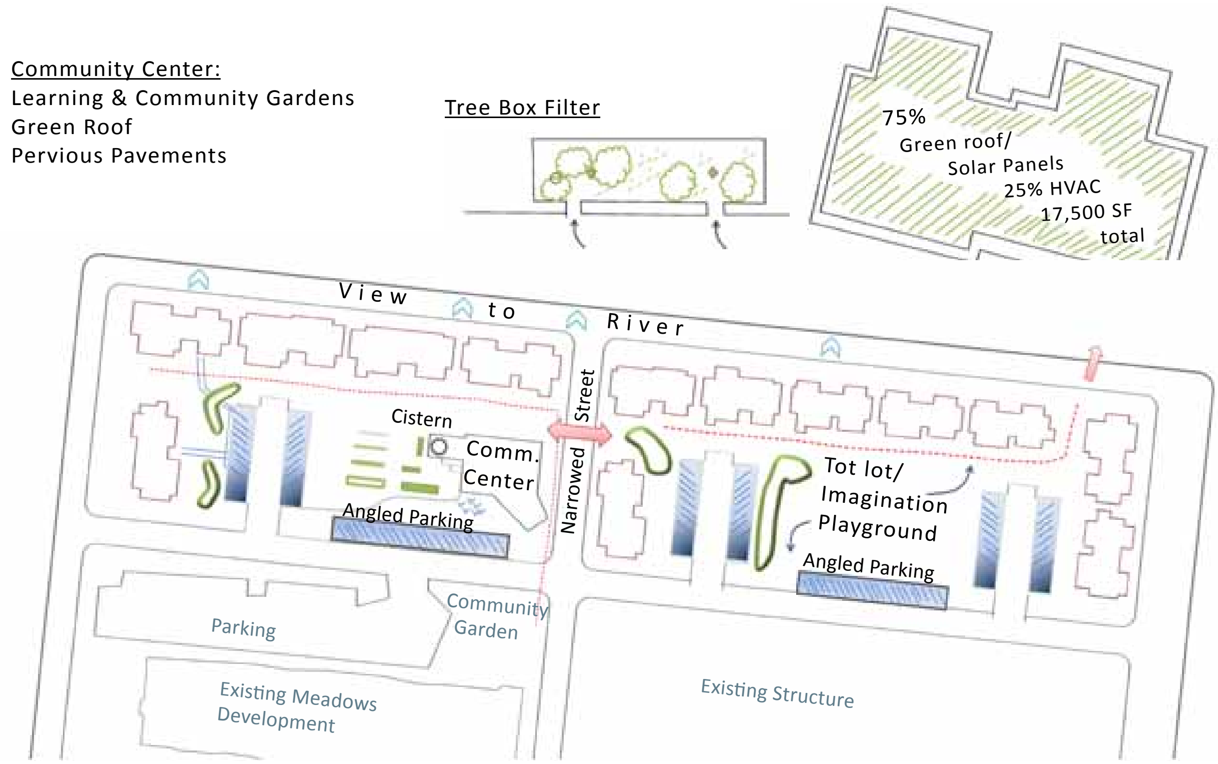
At the north end of the newly proposed subdivision line, the existing North Camden Neighborhood Waterfront Park Plan (NCNWP) outlines an up and coming new greenway trail, boat launch, fishing pier and tidal wetland restoration area. The concept design presented here envisions Meadows Phase II project using the momentum from the NCNWP to help showcase environmentally responsible development.

There are many possibilities for incorporating green infrastructure into the Meadows Phase II site. In order to break them down, the opportunities presented here are divided into two categories: structural and landscape opportunities. Structural opportunities explore the potential to add green infrastructure within the townhomes themselves; landscaping opportunities identify how green infrastructure can be incorporated into surrounding landscape, streets, and parking lots.

Multi-Family Residential Development

Structural Opportunities

The sketch at right identifies several structural opportunities to incorporate green infrastructure features within the Meadows Phase II townhomes. These include an accessible green roof and an underground cistern.



Above: Upcoming developments such as Meadows at Pyne Point II offer many opportunities to integrate green infrastructure features. This concept sketch adds green features to the existing plan. Options include adding a green roof and an cistern to the building and integrating rain gardens, permeable pavement, and vegetated curb extensions within the landscape and along the street.

Besides the many stormwater management benefits that a green roof would provide, an accessible green roof would provide additional outdoor space for residents while helping to further insulate the building, reduce the urban heat island affect, and increase long-term property values. In addition, a recent (2005) study on air toxics in the Camden Waterfront South Neighborhood recommended the vegetating of vacant lots to address the large amount of airborne particulate matter in the Waterfront area. A large, vegetated green roof would provide similar benefits.

Above: Canal Park in Washington DC connects across several streets. Using a colored paver in the roadway helps slow traffic and encourage foot traffic.

In conjunction with the green roof, excess water that would typically be piped to the storm sewer could be collected in the basement of the structures to be reused for gray water uses. These uses can include irrigation or indoor uses such as flushing, or heat reclamation.

The Meadows, Phase II

Above: Community centers such as this one in North Carolina provide multiple opportunities to showcase green infrastructure features, including a green roof, rain gardens to capture roof runoff, and permeable pavement. Incorporating features such as these in development projects adjacent to the North Camden Neighborhood Waterfront Park master plan area are vital for completing the City's vision for North Camden's future: a community reconnected to the river, with signficant volumes of housing nestled between a revitalized core and a green ribbon of parkland along its length.

Landscaping Opportunities

Outside of the townhomes, the streetscape and parking lots offer many opportunities to incorporate green infrastructure and LID. In order to enhance stormwater uptake on-site, permeable pavements should be utilized wherever possible. In parking lots and on street parking strips, permeable pavements can be installed to infiltrate and store stormwater, and light colored pavements can help reflect heat and reduce the urban heat island effect. Sidewalks and plazas can also be retrofitted with permeable pavement.

Vegetated curb extensions along North 5th Street would serve to reduce vehicle speed and crossing distance while also infiltrating stormwater and reducing demand on the storm sewer network. It is suggested that the section of North 5th Street that separates Phase II be at-grade and constructed of different material to encourage slower traffic and improve pedestrian connectivity. The community center at the corner of Erie Street and N. 5th Street should have a strong connection with the open space across N. 5th Street as well as the lots behind.

Open space between the townhomes and parking also provides opportunities for installing rain gardens. These would serve to help infiltrate stormwater that may not be captured by the green roofs, rain barrels, or permeable pavements.

Commercial Development

Above: This Green Wall at PNC's Headquarters in Pittsburgh is the largest in the US.

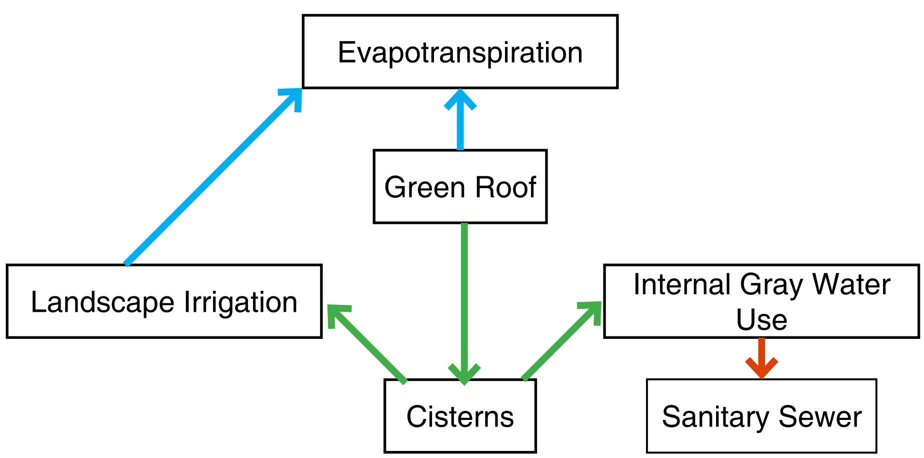
Like multi-family and mixed residential developments, commercial provide numerous opportunities to integrate green infrastructure techniques into development , and are a common land use in the Camden Waterfront area. Conventional commercial developments are rarely designed with rain capturing islands or other low impact features in mind. The following case study shows how such features could be incorporated into an upcoming development to improve stormwater uptake and provide additional triple bottom line benefits.

Project Description

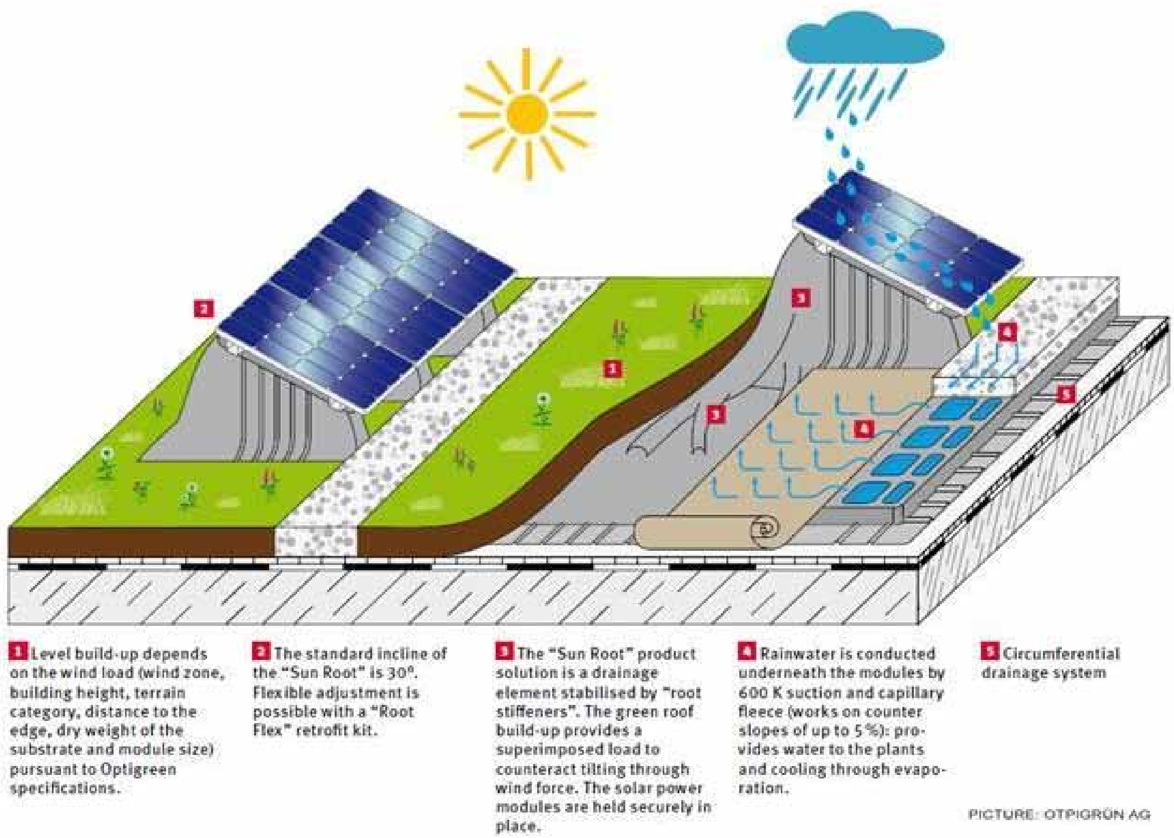
Located among the waterfront's many cultural destinations and a growing center of commerce, the existing building proposal does a good job integrating green features into its design. Opportunities for integrating additional green infrastructure practices into the building proposal are broken into structural and landscape opportunities. Structural opportunities are focused on recommendations to incorporate green infrastructure techniques into the office complex building design. Landscape opportunities focus on additional streetscape elements for the office complex site, as well as opportunities to incorporate green infrastructure within the larger development. Based off the architectural standards guide developed by Urban Design Associates, the existing designs could easily be retrofitted to allow for green infrastructure to be seamlessly integrated.

Location

This case study focuses on an upcoming Coopers Ferry Partnership Office (CFPO) development in the Waterfront Area. The proposed CFPO building sits inside of Aquarium Loop, off of Riverside Drive, between an entertainment attraction and vacant development site.



Coopers Ferry Office



Structural Opportunities

The current designs for the office complex provide outdoor seating, balconies and ample light to the office space. The following structural opportunities identify ways to improve stormwater uptake while providing additional benefits. Additionally, the project could consider incorporating green energy concepts such as photovoltaic cells or solar panels to supplement building power usage and further the goal of improving the overall environment of the Camden Waterfront while serving as a leader in promoting innovative technologies.

Above: The existing proposal includes ample outdoor space, providing multiple opportunities to incorporate GI and LID.

Green Roof and Underground Cisterns

The location of the office complex lends itself to dramatic views of the Delaware River, Philadelphia, Benjamin Franklin Bridge, and downtown Camden. Economic benefits associated with green roofs include real estate benefits (higher rent, value), reduced energy costs, and reduced roof replacement period.

The proposed roof system will provide open space for seating, as well as green space. Sloped up to the edges of the roof, the landscape will hide the walls, giving the illusion of open space.

Above: Infiltration tree boxes at Canal Park in Washington DC blend in with the existing streetscape. Security edging and curb cuts blend seamlessly into the street profile.

The decking will sit above the green roof allowing water to pass through to roof drains that will collect the excess runoff and fill cisterns located in the basement of the building. The water captured in these cisterns could be used to irrigate the surrounding landscape or flush toilets and other internal gray water uses. A small rain barrel on the roof could capture water from the building core (elevators, stairs, etc.) and be used to water plants located on the roof.

Landscape Opportunities

Landscape features include everything outside the building envelope. From sidewalks to parking spaces, the landscape provides the most opportunity for LID and GI.

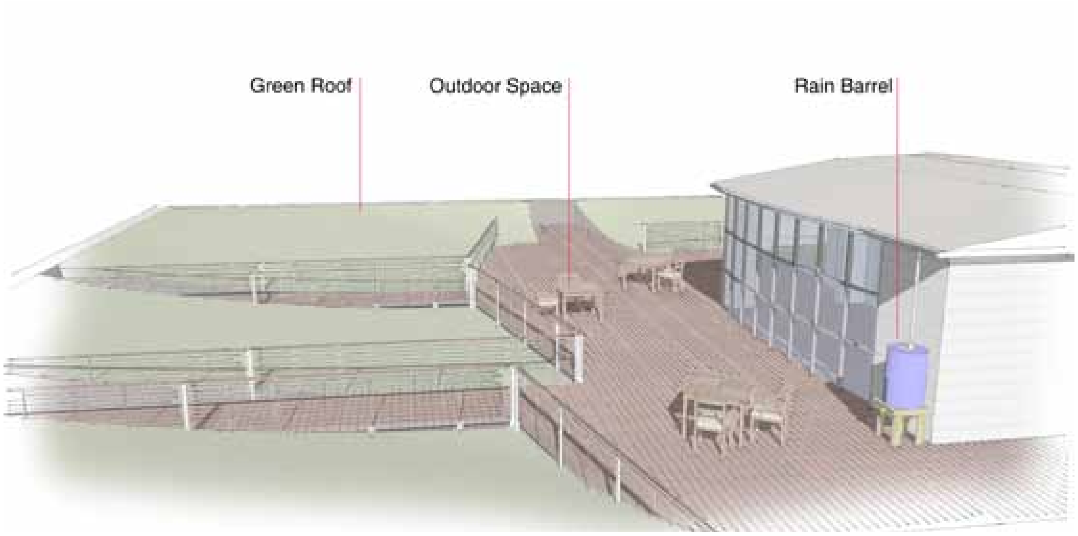
The Aquarium Loop provides a great case study for GI and LID in the Camden area. The street provides curb

Above: Permeable pavers blend in with existing brick. A thick grout/gravel line is the only discernible difference.

extensions, parallel parking, low traffic lanes, sidewalk, open space, and street trees; all of which can be retrofitted to address stormwater runoff.

Vegetated curb extensions and infiltration planters are easy retrofit projects that can blend with the proposed street character. In the Coopers Crossing Pattern Book, security edges are already proposed for street tree planters.

Above: Proposed tree boxes outlined in the Cooper's Crossing Pattern Book already provide security edging.



Above: Rendering of a green roof atop the proposed Cooper's Ferry Partnership Office.

In locations where infiltration planters or vegetated curb extensions are not needed, street trees should be provided to increase the urban tree canopy, reduce the urban heat island effect, and to provide a more hospitable street environment. Ample soil space (volume) should be given so that trees can grow quickly, and to a sizable canopy. Street trees can infiltrate stormwater even when not fed through a curb extension.

Permeable pavements can be utilized in the street and the sidewalk to improve stormwater infiltration. Permeable pavement systems include permeable concrete, asphalt, and permeable concrete pavers.

Permeable concrete pavers come in many sizes, shapes, and colors, making them the perfect fit for this project. The sidewalks in the Cooper's Ferry development are brick and, in places where infiltration is possible, red colored permeable pavers could be used so that the street character remains consistent throughout.

Crosswalks in conjunction with curb extensions provide space where permeable pavements can be used. Providing a different colored material and/or a raised surface in crosswalks reduces crossing distance and vehicle speed, improving pedestrian safety.

Parking Lot Retrofit

Numerous surface parking lots exist within the Central Camden Waterfront. In the long-term, these provide the City with tremendous redevelopment opportunities. However, it is not expected that surface parking would ever be removed completely. The following examples provide both short-term and long-term opportunities to incorporate green infrastructure practices into surface parking areas.

Location

The Federal Street parking lot is located between Federal Street and Dr. Martin Luther King Boulevard. The parking lot is only accessible from Federal Street and is a private lot.

Project Description

The Federal Street Surface Parking lot was chosen to explore potential short- and long-term solutions to reduce runoff from Camden's surface parking lots. As redevelopment continues, it is expected that some will convert to buildings in the next 10 years. For these, only less expensive LID techniques are recommended. Other parking lots will likely remain. Potential solutions are broken down into less expensive, short-term fixes and more expensive, long-term solultions.

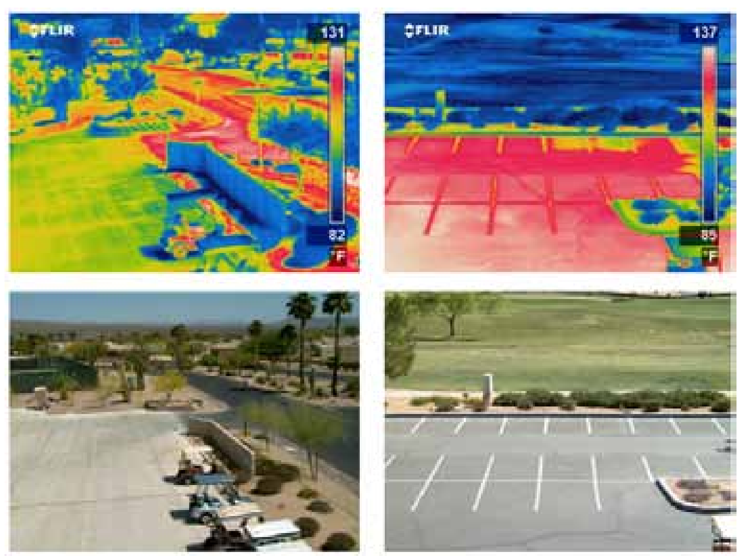
Above: The Federal St. surface parking lot, in its current layout. Short and long-term options include taking advantage of the lot's size and wide yard fronting the street.

Above: This parking lot in Berkley, CA provides solar panels, permeable pavements and landscaping.

Short-term solutions focus on low cost projects that improve stormwater runoff, increase efficiency and reduce impervious surface within 3-5 years. Long-term solutions provide increased benefits and are designed to last for 10+ years.

Short Term

There are multiple opportunities for increasing the stormwater benefits of existing lots while reducing the



Above: These thermal camera shots shows the temperatures on a light colored pavement parking lot vs. asphalt and surrounding landscapes.

Federal Street Surface Parking Lot

operational cost of the parking lot. In lots that are underutilized, one cost effective measure is to remove excess parking spaces. This helps improve stormwater conditions by reducing the amount of impervious surface. This could be combined with re-striping the lot to allow for angled parking that maximize efficiency of the existing spaces.

Another alternative is to add green infrastructure features along the street. For example, for the Federal Street lot, where development is set back from Dr. Martin Luther King Boulevard, rain gardens or bioswales could be installed along the boulevard to intercept stormwater. These features could also include vegetated curb extensions, infiltration planters or permeable pavements in the sidewalk.

Long-Term

Long-term solutions encompass all of the short term solutions but incorporate some practices that demand more robust design and construction. Parking lots can provide multiple community services. Long-term surface parking lots, for the purposes of this report, are defined as lasting 10 years or more.

One of the most dramatic ways to reduce impervious surface and treat stormwater in a surface parking lot is to convert asphalt to permeable pavers.

Above: Parking lot stormwater system utilizing permeable pavement, street trees, and bioretention.

Above: Permeable parking spaces at the Navy Yard in Washington DC.

There are several ways that this can be done. Permeable parking bays, permeable strips, or whole lot permeable pavers are just a few. Based on the size of the Federal Street parking lot (roughly two acres), it is recommended that the parking bays be converted to permeable pavement. Leaving the aisles as asphalt would reduce rutting and provide a clear distinction between drive ways and parking spaces.

Much like the streetscape, strategically placing shade trees in a parking lot is an effective green infrastructure measure. Parking lots in the City of Camden produce tremendous amount of runoff and heat. It is recommended that, after every ten car spaces, there be a street tree and landscape island.

Lastly, in lots where tree cover is not an option, solar systems can be installed as car canopies to reduce in-car temperatures and produce energy for local businesses or to power street lighting.

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Camden SMART Initiative

Stormwater Management and Resource Training

City of Camden New Jersey

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