



NEW JERSEY **DEVELOPERS** Green Infrastructure GUIDE 2.0



Special thanks to the Developers Green Infrastructure Task Force and the Green Infrastructure Guide Review Committee for their insight, constructive input and time in the preparation of this Developers Green Infrastructure Guide.

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Purpose of Task Force

The Developers Green Infrastructure Task Force helps New Jersey's developers and their design professionals learn about green infrastructure, understand related costs and savings, and build high-quality, cost-effective green stormwater infrastructure into their projects.

About New Jersey Future

New Jersey Future is a nonprofit, nonpartisan organization that brings together concerned citizens and leaders to promote responsible land use policies. The organization employs original research, analysis, and advocacy to build coalitions and drive land use policies that help revitalize cities and towns, protect natural lands and farms, provide more transportation choices beyond cars, expand access to safe and affordable neighborhoods, and fuel a prosperous economy.

About NJBA

The New Jersey Builders Association (NJBA) is the leading trade association for the shelter industry in New Jersey. Members include residential, and commercial builders, developers, remodelers, subcontractors, suppliers, engineers, architects, consultants and other professionals. NJBA serves as a resource for its members through continuing education and advocacy. NJBA and its members strive for a more vibrant, greener, and affordable housing market in New Jersey.



NEW JERSEY **DEVELOPERS** Green Infrastructure GUIDE **2.0**



**New Jersey
Builders Association**

MAY 2020

THANKS TO OUR CONSULTANT TEAM:



Since the first edition of the Developers Green Infrastructure Guide was published in 2017, much has changed. Green stormwater infrastructure is becoming more common and better understood in New Jersey, and traditional ways of managing stormwater are going the way of the dinosaur.

Why? Because green is the new gray.

Through a collaborative approach involving both the regulated community and environmental advocacy groups, NJDEP has adopted new stormwater management rules that require the use of green infrastructure. This new approach is a paradigm shift in New Jersey stormwater management. Developers who have long been frustrated by having to design to a subjective “maximum extent practicable” standard that is open to interpretation by regulators, now have an objective standard that replaces pipes and storage basins with landscaping techniques that create multiple infiltration points, which mimic how nature deals with stormwater. The new rules present a rare opportunity to add value to your project while doing more for the environment.

The Guide shows you how to make the new rules work for you.

Understanding the details in the stormwater rules and in its companion “how to” document, the BMP Manual, is the purpose of this Developers Green Infrastructure Guide. But first, let’s describe a few broad, positive changes you should understand about how stormwater requirements are changing. Here is what is “out” and what is “in”:

MESSAGE FROM THE DEVELOPERS GREEN INFRASTRUCTURE TASK FORCE CO-CHAIRS

✗ WHAT'S OUT Gray and exclusively end-of-pipe stormwater management

✓ WHAT'S IN Decentralized green infrastructure, distributed around a site

✗ OUT Subjective, time-consuming project review standards

✓ IN Objective, clear mathematical standards

✗ OUT Assumption that stormwater systems will fail and require redundant systems

✓ IN Green infrastructure “counts”, including infiltration

✗ OUT Less efficient and effective stormwater management

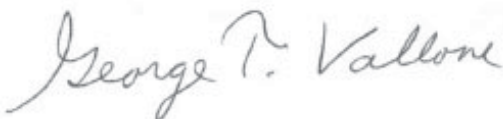
✓ IN Additional project yield and value with superior stormwater treatment

This Guide will help ensure that you and your design team can fully capitalize on these landmark changes.

As always, we want your feedback. Tell us what you like about the Developers Green Infrastructure Guide and what questions you still need answered. Share your experiences with us. We would love to learn from your trials and highlight your successes.

George Vallone

President, Hoboken Brownstone Company
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The image is a composite. The top half shows a street intersection with traffic lights and street signs. A blue semi-transparent banner is overlaid on this section, containing the title text. The bottom half shows a bioswale, which is a landscaped area designed to manage stormwater. It features a large, dense green bush in the foreground, a concrete curb, and a metal grate covering a storm drain. The background shows residential houses and trees.

NEW JERSEY'S STORMWATER RULES AND REQUIREMENTS



NEW JERSEY'S STORMWATER RULES AND REQUIREMENTS

The New Jersey Department of Environmental Protection (NJDEP) has adopted a revised set of stormwater regulations under N.J.A.C. 7:8 that will affect land development practices within the state. **The revisions, which take effect on March 2, 2021, require the use of decentralized green infrastructure practices and provide a more objective review process for projects.** Previous regulations required the use of nonstructural stormwater management strategies to “the maximum extent practicable.” The new rules eliminate this subjective language and instead provide a clearly articulated, mathematically-based set of standards for stormwater design compliance. The previous nonstructural strategies have been relocated within the rule to function as planning principles instead of conformance review criteria.

A second, but equally important, change relates to permitted stormwater modeling criteria. As explained in Chapters 5, 9, and 13 of the BMP Manual, infiltration of captured stormwater through best management practices (BMPs) is now permitted in engineering calculations. This change will result in smaller stormwater BMPs, thus maximizing developable area on a site.

Beyond the use of green infrastructure and the impact of receiving credit for stormwater infiltration, the rules introduce additional changes that will impact development. Guidance is provided on both small and large scale BMPs. New tables clarify the applicability of different BMPs when used to meet the requirements for groundwater recharge, water quality, and quantity standards. Additional engineering calculation methods relevant to green infrastructure design are also incorporated.

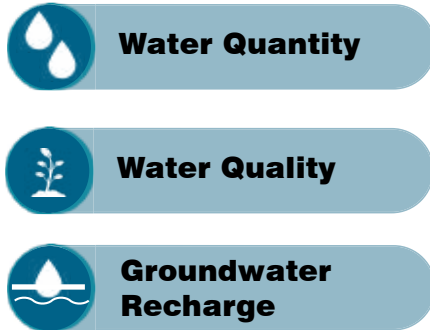
This chapter covers the main takeaways from the new rule while also indicating where further reading may be desirable for both developers and engineering consultants. Overall, thoughtful application of the new tools and methods in the rule change will result in projects that benefit developers, engineers, and communities.

Bioretention Basin
Image Credit: AKRF, Inc., 2018



GREEN INFRASTRUCTURE STANDARD

Effective March 2021, green infrastructure BMPs must be used to satisfy:



In order to assist design professionals in selecting the right BMPs to meet these standards, the new rule separates BMPs into three (3) tables:

- **Table 5-1 (p. 16) consists of green infrastructure BMPs that can be used to meet water quality, water quantity, and groundwater recharge requirements.** Table 5-1 presents options for the use of local, decentralized green infrastructure in order to maximize treatment and groundwater recharge.
- **Table 5-2 (p. 17) consists of green infrastructure BMPs that can be used to meet water quantity standards.** BMPs in this table provide alternatives for meeting water quantity requirements for larger sites. These BMPs cannot be used for water quality or groundwater recharge without a waiver/variance. When a development must meet all three (3) requirements, these systems can be used in conjunction with Table 5-1 BMPs.
- **Table 5-3 (p. 17) consists of systems that may be used only with a waiver or variance.**



Bioretention Basin
Image Credit: Maser Consulting, 2020

CHANGES TO THE BMP MANUAL

Engineering Tip

The updated BMP Manual permits a number of accepted engineering computational methods to be used in stormwater design that were not previously recognized. Detailed information about the McCuen Curve Number Reduction Method, the Hantush Model for groundwater mounding, and other computation formulas can be found in appropriate chapters of the BMP Manual.

The NJDEP BMP Manual is an essential companion document to the State stormwater rules. With the adoption of the rule change, several important updates will be implemented in the BMP Manual:

- Engineers will be able to “count” infiltration in managing water quantity. Related chapters will be updated accordingly.
- Chapter 13, Groundwater Mounding, has been added to the BMP Manual. Engineers will need to meet groundwater mounding modeling requirements, as applicable.
- Soil Testing Criteria, which has been Appendix E in the BMP Manual, will now have its own chapter: Chapter 12.
- An updated Model Stormwater Control Ordinance for Municipalities has been published in Appendix D of the BMP Manual.
- The BMP Manual will be organized to reflect the structure of Tables 5-1, 5-2, 5-3. Chapter 9 will focus on small scale green infrastructure BMPs. Chapter 10 will include larger-scale green infrastructure BMPs. Chapter 11 will address BMPs that are not considered green infrastructure but may be used with a waiver or variance.

Infiltration Will “Count”

The previous version of the BMP Manual did not allow engineers to account for the volume of water infiltrated, thereby requiring larger stormwater systems to compensate. By allowing engineers to model BMPs with infiltration, the capacity of BMPs may increase. This will reduce the size of BMPs on a site.

Effective March 2021, Chapter 5, “Computing Stormwater Runoff Rates and Volumes,” will be revised to allow infiltration to be used in water quantity control calculations. Chapter 9 will be updated to reflect how infiltration in BMPs can be used to meet water quantity standards.

The use of infiltration in water quantity control will be subject to testing and modeling. Chapters 5, 12, and 13, “Computing Stormwater Runoff Rates and Volumes,” “Soil Testing Criteria,” and “Groundwater Table Hydraulic Impact Assessments for Infiltration BMPs,” will provide further guidance.

Infiltration testing is required for stormwater systems in order to determine the seasonal high water table and the infiltration rate of existing soils.

Image Credit: Maser Consulting, 2020



Groundwater Mounding

Groundwater mounding occurs when stormwater design has a hydraulic impact on the groundwater table. Designs that do not account for groundwater mounding can lead to flooding of basements, surface ponding, and other undesirable outcomes. If groundwater mounding reaches the bottom surface elevation of a BMP, infiltration could cease and the BMP would become ineffectual.

Chapter 13 of the BMP Manual provides guidance and requirements for groundwater mounding assessment. A spreadsheet detailing the Hantush Method is provided by NJDEP to help engineers model groundwater mounding correctly.

STORMWATER RULES AND BMP MANUAL SCHEDULE

DECEMBER 3, 2019	NEW RULE AMENDMENTS FILED WITH OFFICE OF ADMINISTRATIVE LAW REVIEW
MARCH 2, 2020	NEW RULE AMENDMENTS PUBLISHED IN THE NEW JERSEY REGISTER AND FORMALLY ADOPTED
MARCH 2, 2020	NEW GROUNDWATER MOUNDING CHAPTER AND DRAFT MUNICIPAL ORDINANCE PUBLISHED. DRAFT SOIL TESTING CRITERIA CHAPTER AND DRAFT STORMWATER RUNOFF RATES CHAPTER PUBLISHED FOR PUBLIC COMMENT.
SPRING/SUMMER 2020	REVISED SUBCHAPTERS OF BMP MANUAL CHAPTER 9 ISSUED FOR PUBLIC COMMENT
ON OR BEFORE MARCH 2, 2021	ALL DRAFT REVISED CHAPTERS OF THE BMP MANUAL ARE FINALIZED AND ADOPTED
MARCH 2, 2021	RULE AMENDMENTS BECOME OPERATIVE

BY MARCH 2021:

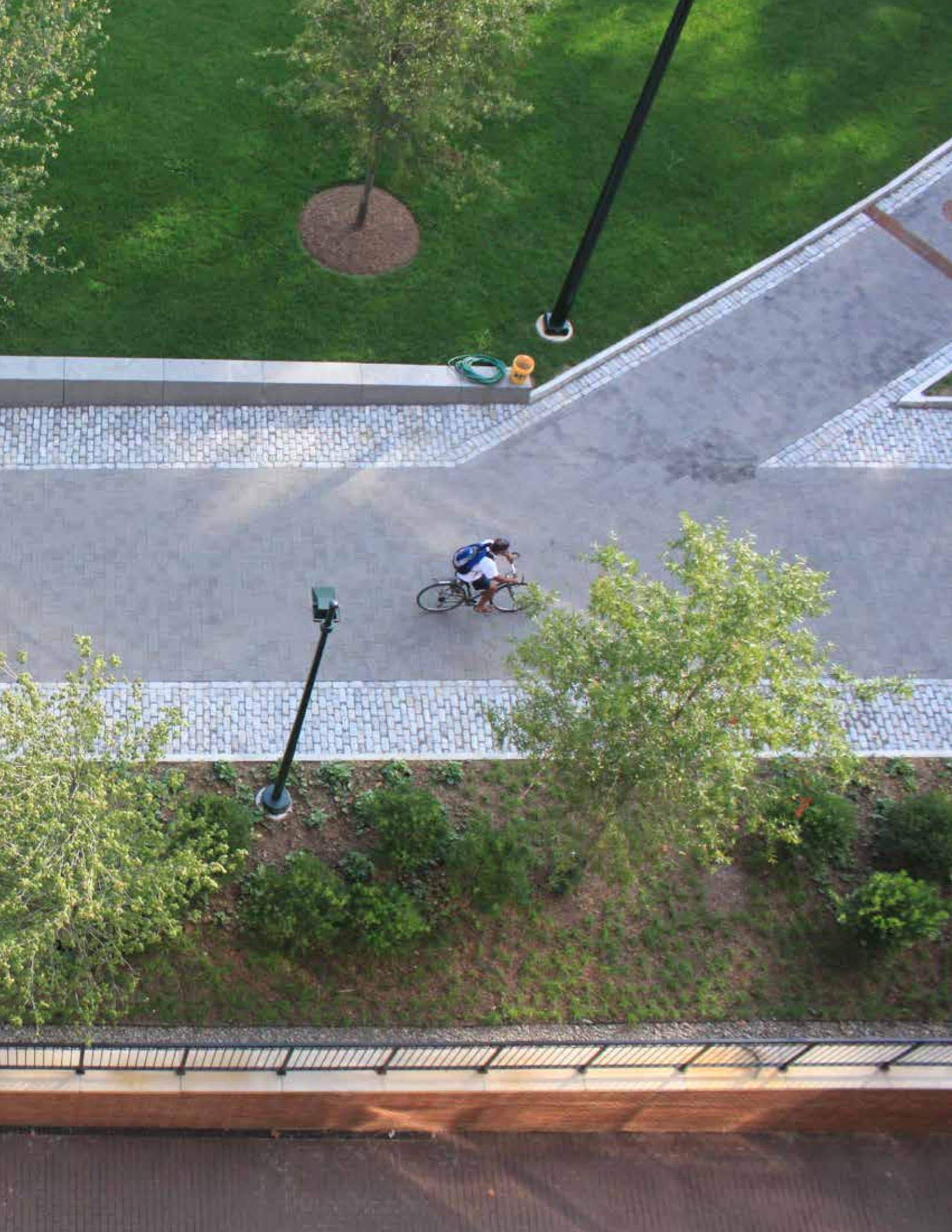
Municipalities have until March 2021 to modify their stormwater control ordinances. Appendix D of the BMP Manual provides an updated model ordinance.

Applicants must adjust to the new rule requirements and anticipate changes in the way stormwater systems are developed. A team approach that starts at the conceptual planning stage is important and will yield the best results. The one-year operative delay, ending March 2021, allows for grandfathering of projects already substantially designed.

Design Professionals (engineers and landscape architects) that are unfamiliar with green infrastructure need to adopt a new mindset and acquire a new skill set. The one year operative delay, ending March 2021, will allow NJDEP and other groups to provide training for professionals that design and/or review stormwater management systems.

TYPES OF **GREEN** INFRASTRUCTURE





TYPES OF GREEN INFRASTRUCTURE

WHAT IS GREEN INFRASTRUCTURE?

“These are the go-to practices for meeting regulatory requirements. Used strategically, they increase return on investment while adding aesthetic value.”

- Ed Confair, PE, PLA,
E&LP Associates

Developers understand that land development projects in New Jersey must be designed to “manage” stormwater runoff. However, new NJDEP regulations are changing the way developers accomplish this by requiring the use of decentralized green infrastructure. [This Developers Green Infrastructure Guide Version 2.0](#) is a resource to help you navigate decision-making and incorporate green infrastructure into your projects for maximum benefit.

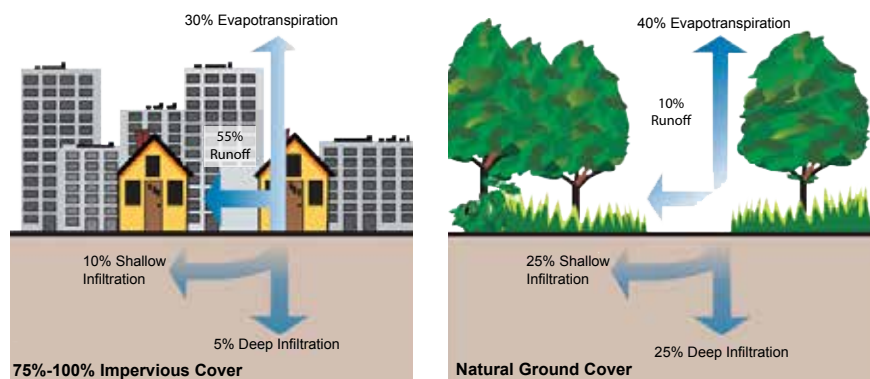
What does the term “green infrastructure” mean?

The term “green infrastructure” or “green stormwater infrastructure” refers to a set of stormwater management practices that use or mimic the natural water cycle to capture, filter, absorb, and/or reuse stormwater. The NJDEP defines it more technically as a stormwater management measure that manages stormwater close to its source by: 1) Treating stormwater runoff through infiltration into subsoil; 2) Treating stormwater runoff through filtration by vegetation or soil; or 3) Storing stormwater runoff for reuse. Unlike traditional gray infrastructure, green infrastructure integrates high-performance landscapes and hardscapes to meet stormwater requirements while also improving the appearance and value of your project. Though most commonly understood as garden-like landscapes, green infrastructure can also be installed on roofs or in paved areas. The NJDEP refers to approved green infrastructure techniques as “Best Management Practices,” or “BMPs.”

The Hydrologic Cycle
Image Credit: Environmental Protection
Agency, Washington D.C., 2018

Effect of Impervious Cover on Stormwater Runoff

In a natural environment, rainfall is cycled through the process of evaporation, uptake by plants, and infiltration into the ground. Development (roofs, pavement, etc.) disrupts this process and leads to runoff and water pollution.



What does green infrastructure do?

Green infrastructure can be used to meet Water Quantity, Water Quality, and Groundwater Recharge requirements. When selecting green infrastructure practices for a site, developers should consider the different functions of each BMP. Each requirement varies based on specific site conditions and the intensity of development.

- Water quantity requirements involve capturing, storing, slowing, and/or infiltrating stormwater runoff.
- Water quality requirements involve removing pollutants conveyed by stormwater runoff.
- Groundwater recharge requirements ensure that underground aquifers are replenished through deep infiltration.

The following symbols will be used through the Guide to identify which BMPs provide these functions:



Water Quantity



Water Quality



Groundwater Recharge

What are some key considerations?

- **Separation from Groundwater** is an important design consideration. Before proceeding with design, soil testing is required to determine if selected locations have the required separation from the seasonal high water table. If separation is not maintained, groundwater can interfere with proper drainage, resulting in system failure. Each BMP has specific requirements for separation.
- **Soil Conditions** are crucial to green infrastructure design. Soil hydraulic conductivity testing should be performed early in the design process to determine that infiltration is possible.
- **Drainage Areas** for each BMP should also be considered. The new NJDEP stormwater rules codify a decentralized approach to stormwater management, so that stormwater BMPs are distributed around a site. The rules assign maximum contributory drainage areas to the BMPs, as shown in the three tables discussed in the following section. If the proposed BMP would collect runoff from a drainage area larger than NJDEP regulations allow, a different BMP may be necessary.
- **Maintenance** should be considered early in the design process. Developers must think about maintenance requirements for the selected BMP and how that maintenance will be ensured. Engineers must provide access to BMPs in their designs to facilitate these efforts.



Rain garden in a public park planted with grasses and flowers.
Image Credit: AKRF, Inc., 2018

How do you measure Water Quality?

The NJDEP measures Water Quality through reductions in Total Suspended Solids (TSS). TSS in stormwater are commonly found in the forms of rock and soil fragments and debris. Green infrastructure can remove these and improve Water Quality for local ecosystems.

How do you know which green infrastructure practices are approved?

The new NJDEP stormwater rules organize Best Management Practices (BMPs) information into three tables: 5-1, 5-2, and 5-3. Table 5-1 includes BMPs that can be used to meet water quality, recharge and quantity requirements. Table 5-2 includes BMPs that are approved for water quantity management and, with a waiver or variance, for water quality and recharge. Table 5-3 includes BMPs that can be used to meet all three standards (quality, quantity, and recharge), but only with a waiver or variance. To avoid the costs and headaches of seeking a variance, developers and engineers should endeavour to meet stormwater requirements using BMPs from Table 5-1 and, if necessary for overflow quantity, Table 5-2.

Various exceptions to the use of different BMPs are outlined in the new stormwater rules. Asterisks (*) in the table indicate that exceptions or limitations exist. BMPs that appear in multiple tables are differentiated by specific design requirements or site conditions. See N.J.A.C. 7:8 for further information.

Symbols will be used in the following section to identify which table each BMP belongs to:

5-1

5-2

5-3

Table 5-1

Green Infrastructure BMPs for Groundwater Recharge, Stormwater Runoff Quality, and/or Stormwater Runoff Quantity

Best Management Practices	Stormwater Runoff Quality TSS Removal Rate (%)	Stormwater Runoff Quantity	Groundwater Recharge	Minimum Separation from Seasonal High Water Table (ft)
Cistern	0	Yes	No	-
Dry Well *	0	No	Yes	2
Grass Swale	50 or less	No	No	2 * 1 *
Green Roof	0	Yes	No	-
Manufactured Treatment Device *	50 or 80	No	No	Dependent upon the device
Pervious Pavement System *	80	Yes	Yes * No *	2 * 1 *
Small-Scale Bioretention System *	80 or 90	Yes	Yes * No *	2 * 1 *
Small-Scale Infiltration Basin *	80	Yes	Yes	2
Small-Scale Sand Filter *	80	Yes	Yes	2
Vegetative Filter Strip	60-80	No	No	-

Table 5-2

Green Infrastructure BMPs for Stormwater Runoff Quantity (or for Groundwater Recharge and/or Stormwater Runoff Quality with a Waiver or Variance)

Best Management Practices	Stormwater Runoff Quality TSS Removal Rate (%)	Stormwater Runoff Quantity	Groundwater Recharge	Minimum Separation from seasonal high water table (ft)
Bioretention System	80 or 90	Yes	Yes *	2 *
			No *	1 *
Infiltration Basin	80	Yes	Yes	2
Sand Filter *	80	Yes	Yes	2
Standard Constructed Wetlands	90	Yes	No	N/A
Wet Pond *	50-90	Yes	No	N/A

Table 5-3

BMPs for Groundwater Recharge, Stormwater Runoff Quality, and/or Stormwater Runoff Quantity only with a Waiver or Variance

Best Management Practices	Stormwater Runoff Quality TSS Removal Rate (%)	Stormwater Runoff Quantity	Groundwater Recharge	Minimum Separation from seasonal high water table (ft)
Blue Roof	0	Yes	No	N/A
Extended Detention Basin	40-60	Yes	No	1
Manufactured Treatment Device *	50 or 80	No	No	Dependent upon the device
Sand Filter *	80	Yes	No	1
Subsurface Gravel Wetland	90	No	No	1
Wet Pond	50-90	Yes	No	N/A

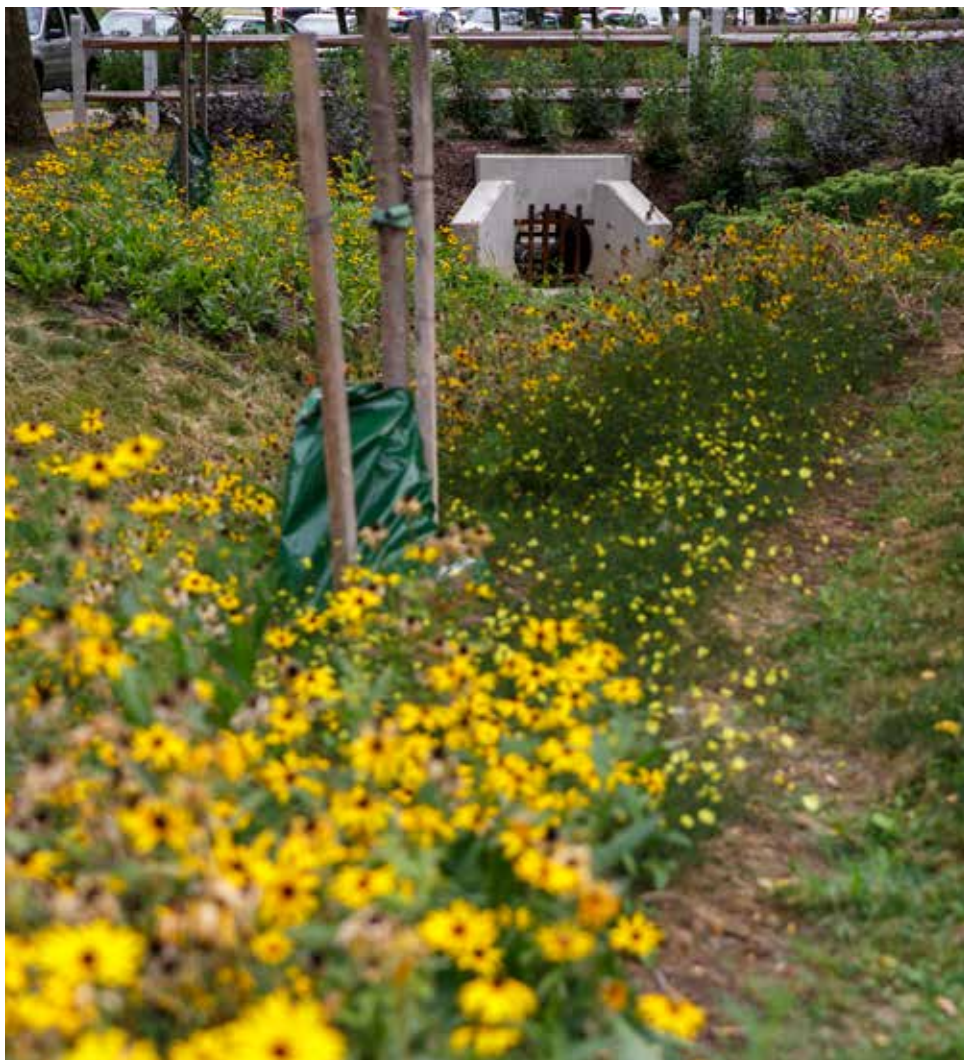
BEST MANAGEMENT PRACTICES

The following section provides descriptions of the different “Best Management Practices,” or BMPs, outlined in the new NJDEP stormwater rules. Most, but not all, of these BMPs qualify as green infrastructure. Those that are not green infrastructure may be used only with a variance. Each practice has its own design, cost, and maintenance requirements. For additional guidance, see the NJDEP BMP Manual.

The following BMPs are included:

- Bioretention System
- Blue Roof
- Cistern
- Dry Well
- Extended Detention Basin
- Grass Swale
- Green Roof
- Infiltration Basin
- Manufactured Treatment Device
- Pervious Pavement System
- Sand Filter
- Standard Constructed Wetlands
- Subsurface Gravel Wetlands
- Vegetative Filter Strip
- Wet Pond

Bioswale
Image Credit: AKRF, Inc., 2018

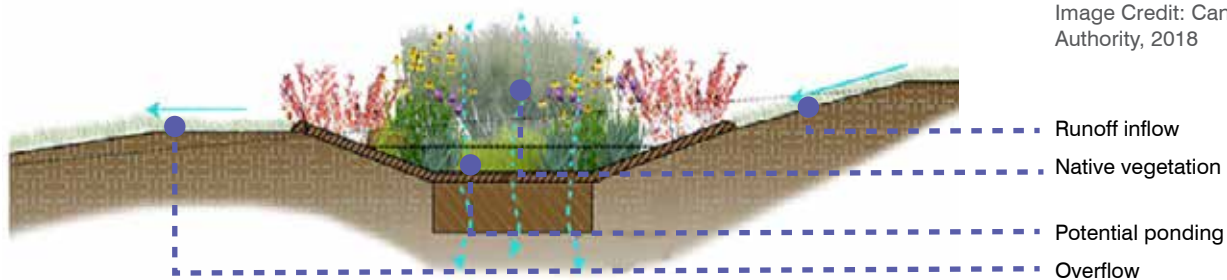


Bioretention System



Bioretention basin at time of installation.
Image Credit: Bluegrass Landscaping & Maintenance, 2018

Bioretention systems are vegetated depressions in the landscape designed to infiltrate stormwater into the subsoil, and/or hold it for a period of time to settle out pollutants and allow some uptake by plants. Bioretention basins can be sited in a wide range of different locations and settings. The terms “rain gardens” and “stormwater bumpouts” are often synonymous with bioretention systems. By co-locating stormwater management with visually appealing landscaped areas, designers can maximize the remaining area available for building.



Bioretention basin section view.
Image Credit: Canyon Region Water Authority, 2018

Considerations: The size of the area draining to the system can influence its effectiveness at providing water quality treatment and groundwater recharge. Small-scale bioretention systems are preferred for meeting these standards.

Cost: Bioretention systems require regular maintenance to maintain their functional and aesthetic value. Designers can lessen the degree and complexity of the required maintenance regime through careful consideration of the soil specification and use of native plants. Maintenance costs can be offset by lower upfront construction costs as bioretention systems are typically smaller than equivalent traditional detention systems.

Maintenance: Bioretention systems require frequent inspections, debris and sediment removal, and landscape services for vegetation management.

Blue Roof



Blue Roof
Image Credit: NYC Department of
Environmental Protection, 2018



Blue roofs are non-vegetated systems that hold stormwater. They can be designed as modular trays with loose stones, specialized permeable pavers, or just a waterproof membrane.

Benefits include:

- Better temperature regulation on the roof surface
- Lower building heating and cooling costs
- Minimizes land used for stormwater management, allowing for more recreational and public space area

Blue Roof with Pedestal Pavers
Image Credit: Hydropavers, Inc., 2018



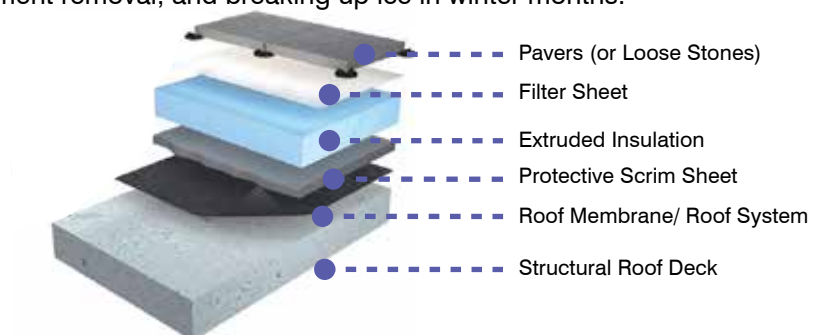
Considerations:

- Blue roofs are only suitable for flat roofs.
- Blue roofs can be modified onto existing roofs.
- Rooftops must be evaluated for structural considerations before a blue roof can be installed.

Cost: Blue roofs are generally less costly than green roofs due to the lack of soil and vegetation components. Blue roofs can reduce the size of downstream BMPs, saving cost throughout the stormwater design. No excavation or earthwork is required.

Maintenance: Regular maintenance activities include inspections, debris/sediment removal, and breaking up ice in winter months.

Deconstructed Blue Roof
Image Credit: Hudson Roofing, 2018



Cistern



Image Credit: Environmental Finance Center, 2018

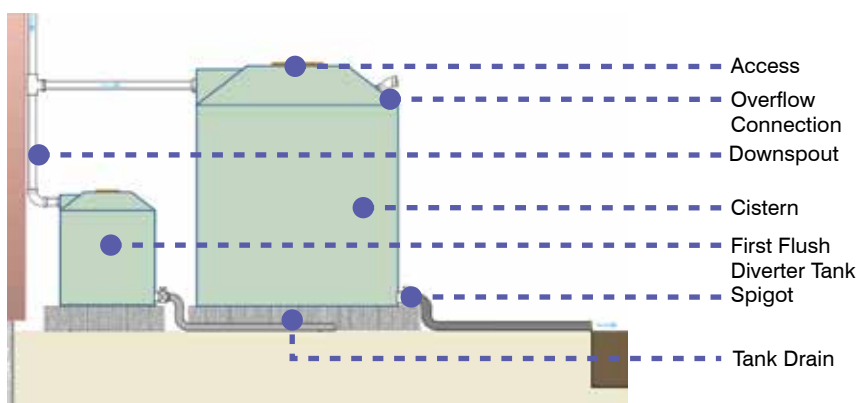
Cisterns are storage tanks designed to capture and store stormwater for non-potable uses such as irrigation, toilet flushing, or industrial processes. Stormwater runoff is typically carried from roof areas to cisterns through roof gutters, downspouts, drains, and/or pipes. Screens on gutters and downspouts filter large sediment and debris from stormwater runoff before it enters the rain barrel or cistern.

Considerations:

- Ensure a stable path for overflows since cisterns are not typically designed for large storms.
- Underground cisterns may need special permits, and the location for overflows may also need approvals. Check with your local municipality.
- A number of pollutants can be deposited on roofs and in parking lots. Therefore, cistern water should never be consumed without proper treatment.

Cost: Cost varies by size of cistern. Cisterns are generally more expensive per gallon of water captured compared to other BMPs. They are ideal for smaller projects where roof capture is desired. Depending on their size, cisterns can provide a significant opportunity to use recycled rainwater in place of potable water, which can help save on your project's long-term water use costs.

Maintenance: Regular maintenance activities include flushing, filter cleaning, and debris removal. See manufacturer guidelines for specific procedures.



Aboveground Cistern Schematic
Image Credit: NJ BMP Manual, 2020

Dry Well



HDPE modular storage unit.
Image Credit: Earth Stone
and Water, 2018



A dry well is a subsurface stormwater facility consisting of either a structural chamber or stone filled excavation that is used to collect and temporarily store stormwater runoff from rooftops. The dry well inflow is connected by roof leaders. The sides and top of the dry well are completely lined with filter fabric to avoid fines clogging the system.

Dry well detail.
Image Credit: Montgomery County,
Maryland, 2018

Maintenance Access
Stormwater Inflow

Dry Well

Outlet and/or Overflow



Considerations:

- Dry wells are only intended for small storm events, and all excess stormwater must be designed to bypass the structure.
- Designers must ensure that soil conditions are suitable for infiltration.

Cost: Dry wells can be less expensive than other BMPs. However, under the new rules, dry wells may only be used to satisfy groundwater recharge requirements. If the project must meet water quality and water quantity standards, a BMP with the capacity to provide multiple benefits should be considered.

Maintenance: Regular maintenance activities include inspections for clogging and structural damage and sediment and debris removal. Roof drains should be checked and cleared regularly to prevent upstream clogging and to ensure that water reaches the system.

Extended Detention Basin

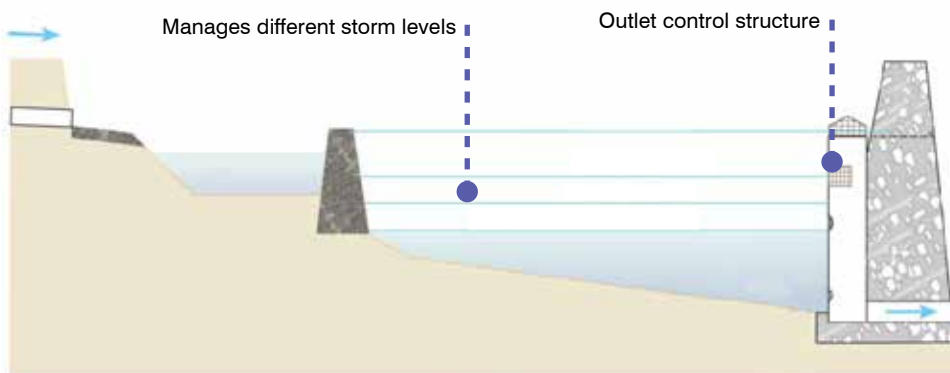


Educational signage.
Image Credit: Princeton
Nature Notes, 2018

Extended detention basins are surface depressions that temporarily store stormwater runoff. The slower drain time allows sediment to settle to the basin bottom before water discharges. The amount of water quality treatment is dependent upon the detention time.

Myth: Green infrastructure breeds mosquitoes.

Fact: Green infrastructure practices are designed to drain in less time than it takes for mosquitoes to reach adult stage. Rain barrels and cisterns have screens to prevent females from laying eggs.



Extended detention basin detail.
Image Credit: NJ BMP Manual, 2018

Considerations: Sediment will accumulate at the basin bottom. Designing systems to accommodate more volume than required can accommodate for this volume loss.

Cost: Extended detention basins are generally less expensive per square foot than infiltration basins or bioretention basins due to the lack of planting and soil modifications/amendments. However, they have less benefit per square foot and are likely to require larger footprints to manage water quality and water quantity. Detention basins need to be paired with additional BMPs to achieve groundwater recharge on site and/or water quality rates over 60%.

Maintenance: Regular maintenance activities include inspections for structural damage related to the inlet and outlet structures, ponding within the basin, and the structural integrity of the berm and spillway. Frequent mowing and clearing of debris/sediment is also required.

Grass Swale



Grass Swale
Image Credit: Keltic
Engineering, Inc., 2018



A grass swale is a long, narrow grassy channel used to convey stormwater to a downstream green infrastructure practice or storm drain. Grass is typically kept to a height of about three to six inches to slow down the runoff and allow any debris or sediment to settle out without interfering with the direction of flow. Depending on site conditions, additional features such as check dams and underdrains may be required to comply with New Jersey Soil Erosion and Sediment Control Standards.

Grass Swale Diagram
Image Credit: NJ BMP Manual, 2018

Runoff depth 2" max.



Considerations: The stability of grass swales needs to be considered during the design process. High velocities and steep slopes can lead to erosion issues.

Cost: Grass swales are typically more affordable than traditional piping. Maintenance costs are relatively low.

Maintenance: Grass swales are easily maintained through regular mowing and debris removal.

Green Roof

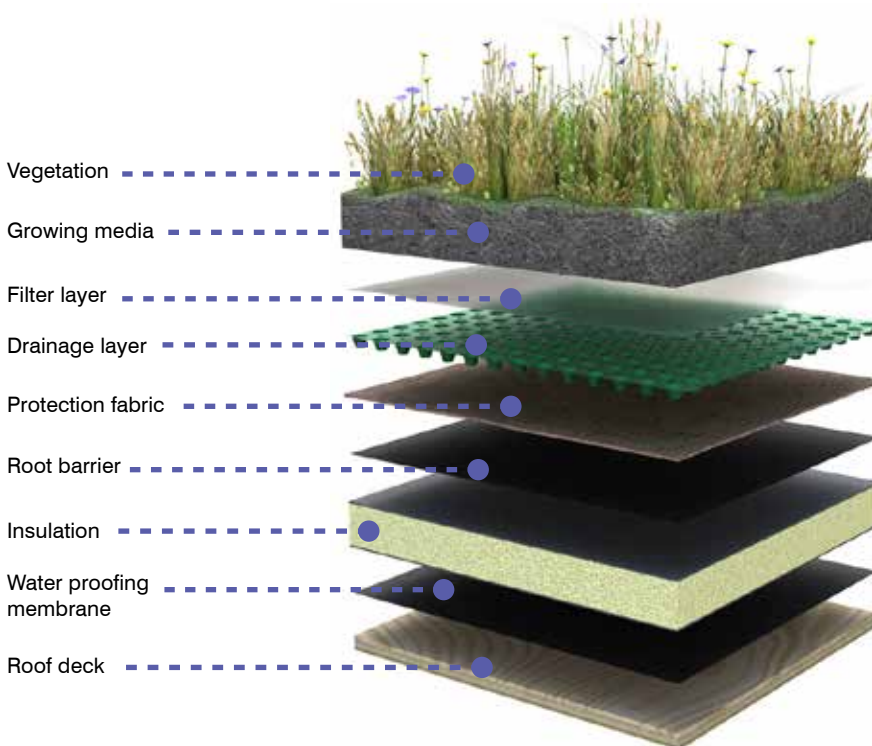


U.S. Coast Guard Headquarters
Green Roof
Image Credit: Andropogon, 2020

A green roof is a system of lightweight soil and plants. The plants absorb some of the rain that falls on the roof, and any excess is stored in a soil layer below. Layers of soil and plants are as thin as just a few inches or as thick as several feet depending on the structural capacity of the roof and the types of plants that are specified. Roofs with a thin soil layer are lighter and easier to install, and are usually planted with succulents that need minimal water and nutrients to survive. Green roofs with thicker soil profiles can support a greater variety of plants, including trees and shrubs, but are more expensive.

Benefits include:

- Better temperature regulation on the roof surface
- Minimizes land used for stormwater management, allowing for more recreational and public space area



Deconstructed Green Roof
Image Credit: Mekobre, 2018

Green Roof (Continued)



Paseo Verde Green Roof
Image Credit: Zelen Architecture, 2018



Considerations:

- The structural capacity of an existing or proposed roof should be considered before proposing a green roof.
- Green roofs can be combined with blue roof systems to maximize the effectiveness of stormwater storage while maintaining the aesthetic and recreational value that green roofs provide.
- Green roof plant palettes should consider seasonality, wind exposure, and drought tolerance to maximize performance year round, especially in colder weather.

Cost: Green roofs can provide cost savings for a building's heating and cooling. Construction costs of the green roof system are generally more expensive than typical roof construction and vary based on intensity and design. Maintenance costs are similar to landscape maintenance costs with occasional mechanical upkeep.

Maintenance: Regular maintenance activities include inspections, debris and sediment disposal, and frequent vegetation management.

<i>Types of Green Roofs</i>		
Name	Vegetation	Media Depth
Intensive	Supports trees and shrubs	10 or more inches
Semi-intensive	Grasses, herbaceous perennials, and shrubs	6-10 inches
Extensive	Succulents, herbs, and grasses	3-6 inches

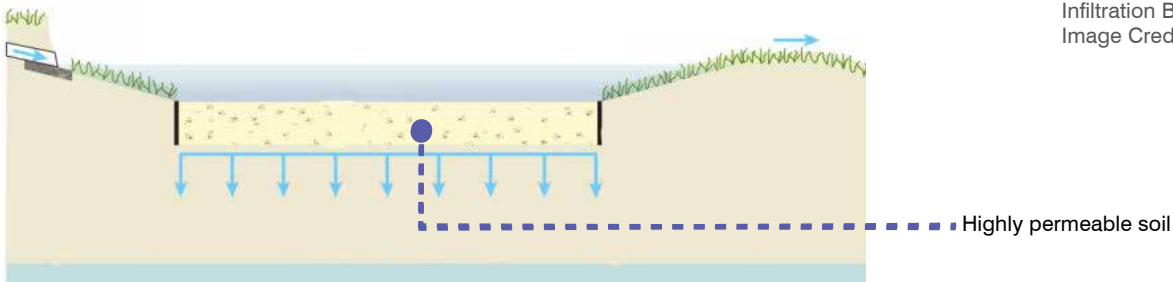
Infiltration Basin



Infiltration Basin
Image Credit: Minnesota Pollution
Control Agency, 2018

An infiltration basin captures stormwater and infiltrates it into the ground through highly permeable soil media designed to remove pollutants and promote groundwater recharge. The soils in these systems treat pollutants via settling, filtration, and biochemical activity.

Like bioretention systems and sand filters, infiltration basins are more effective at providing water quality treatment and groundwater recharge for small drainage areas. For large drainage areas, a waiver is required to use an infiltration basin for water quality and/or groundwater recharge.



Infiltration Basin
Image Credit: NJ BMP Manual, 2018

Considerations:

- The bottom surface of an infiltration basin shall be be engineered sand or other approved soil media. A minimum of six inches is required.
- No vegetation is permitted in the bottom sand surface of an infiltration basin.
- Due to the high rate of infiltration, basins are not permitted to be located in area of high pollutant or sediment loading.
- No material or equipment storage should be located within an infiltration basin during construction in order to avoid compaction.
- Upstream slopes must be stabilized before the infiltration basin is made operational.

Cost: Infiltration basins are more efficient at meeting stormwater requirements and can therefore have smaller footprints. Maintenance costs are comparable to traditional detention basins.

Maintenance: Regular maintenance activities include sediment/debris removal and inspections for structural damage, erosion, and clogging of outlet and inlet structures.

Manufactured Treatment Device



This Filterra MTD is a NJDEP-approved device for treating water quality under Table 5-1. It features elements of bioretention systems and provides pollutant removal within a small footprint.

Image Credit: Contech Solutions, 2020



A manufactured treatment device (MTD) is a structural alternative to treating water quality on a site. This approach to treatment can be used when space is limited. MTDs are designed to remove chemical contaminants and sediment from runoff through filtration, vortex separation, and/or other technologies.

MTDs can replace traditional tree pits, optimizing the use of space on a site.
Image Credit: Contech Solutions, 2020



Considerations:

- MTDs are most effective for small drainage areas.
- Separation from groundwater must be assessed. Different BMPs require varying distances to the seasonal high water table.
- The NJDEP requires developers to select from a list of certified MTDs listed on their website.

Cost: Manufactured treatment devices are typically more expensive to install and maintain than other BMPs that treat water quality. Capital costs vary based upon manufacturer, size of treatment area, and other design considerations. Cartridge replacement for MTDs is required regularly for the entire lifespan of the device.

Maintenance: Regular maintenance activities include inspection of structural components, removal of sediment and debris, and cartridge replacement. See manufacturer guidelines for specific procedures.

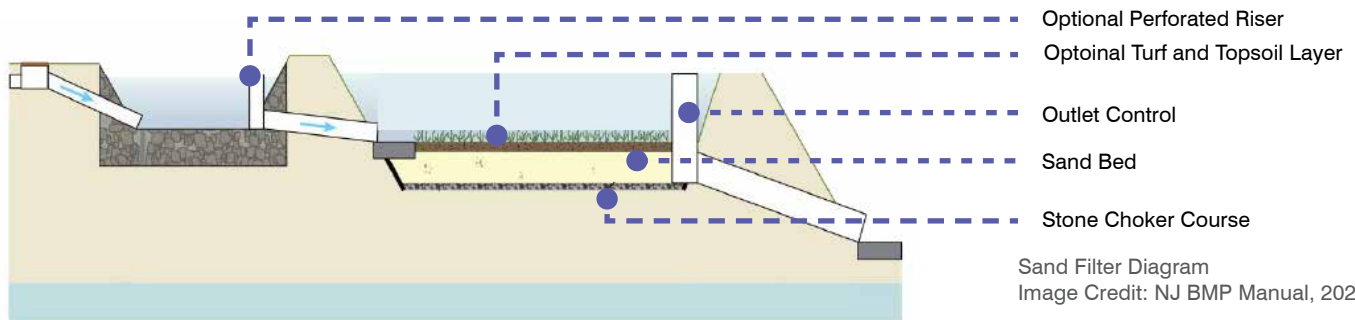
Sand Filter



A sand filter at the base of a planted slope.
Image Credit: Montgomery County, MD, 2018

A sand filter is a depression in the ground used to capture, infiltrate, and filter pollutants before discharging. Sand filters are similar to infiltration basins in design. The primary difference is that sand filters can have vegetative cover and are less aesthetically obtrusive. Sand filters can be constructed with or without underdrains.

Like bioretention systems and infiltration basins, sand filters are more effective at providing water quality treatment and groundwater recharge for small drainage areas. The NJDEP requires a variance for sand filters with large drainage areas to count for water quality and groundwater recharge.



Sand Filter Diagram
Image Credit: NJ BMP Manual, 2020

Considerations:

- Upstream slopes must be stabilized before the sand filter system is made operational
- Construction equipment should not be placed within the sand filter in order to avoid compaction.

Cost: Infiltration systems are more efficient at meeting stormwater requirements and can therefore have smaller footprints. Maintenance costs are comparable to traditional detention basins.

Maintenance: Maintenance for sand filters requires regular raking, repair of structural components, and inspections. The sand layer will need to be removed and replaced with sediment accumulation.

Standard Constructed Wetland

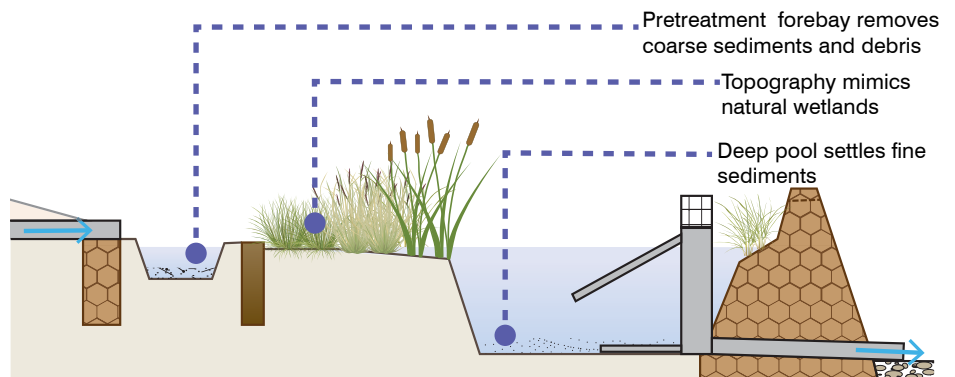


Constructed Wetland
Salyor Grove, Philadelphia, PA
Image Credit: Philadelphia Water
Department, 2020



A constructed wetland is an engineered wetland system that can be used to reduce peak flows and meet water quantity regulations. Constructed wetlands have the added benefit of removing a wide variety of pollutants through settling and vegetative filtering, providing wildlife habitat, and adding aesthetic value to a site.

Constructed wetlands diagram
Image Credit: AKRF, Inc., 2018



Considerations:

- The vegetation and biological processes of constructed wetlands are vulnerable to chemicals. Use of pesticides and herbicides upstream of the BMP should be avoided or used very cautiously.

Cost: Constructed wetlands generally cost more than other basins due to the high density of plant growth and excavation. However, plants in constructed wetlands require a less manicured approach than traditional landscape practices and can therefore cost less to maintain over the life of the system.

Maintenance: Constructed wetlands require regular inspection, maintenance of water levels, debris/sediment removal, and landscape services for vegetative areas.

Subsurface Gravel Wetland



Image Credit: Native Plant Solutions, 2018



A subsurface gravel wetland is a system containing both a subsurface gravel bed and a surface marsh. Stormwater runoff is infiltrated through the marsh into the gravel bed. The gravel bed filters pollutants and conveys water to an outlet structure.

Considerations:

- NJDEP recommends allowing wetlands plants to establish prior to system operation.
- Liners may be necessary if soil conditions do not meet the degree of impermeability required by NJDEP.

Cost: Subsurface gravel wetlands are generally more expensive than constructed wetlands per square foot. The gravel layer and piping requires additional excavation.

Maintenance: Subsurface gravel wetlands are similar to constructed wetlands. However, additional measures to maintain water levels and to inspect clogged piping are necessary. Subsurface gravel wetlands require regular inspection, maintenance of water levels, debris/sediment removal, and landscape services for vegetative areas.

Pervious Pavement



Grass Paver Parking Lot
Image Credit: Maser Consulting, 2020

Myth: Pervious pavement does not work in cold weather climate.

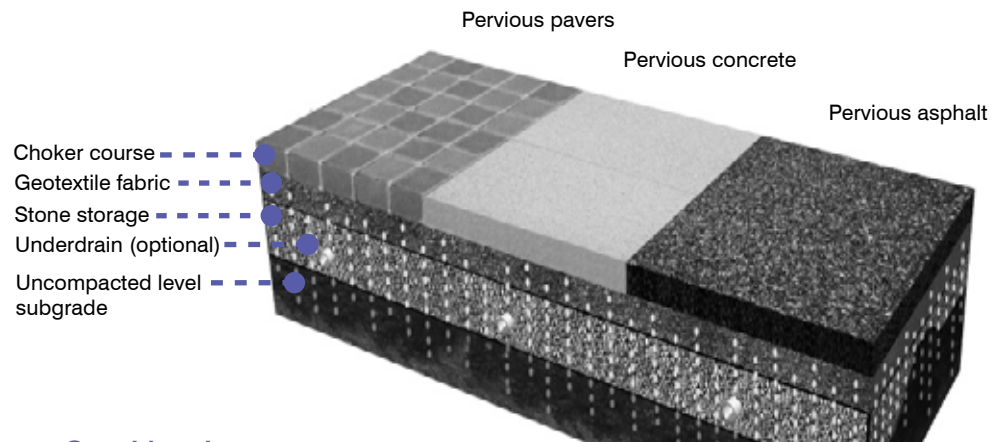
Fact: Pervious paving is not negatively affected by freezing; this pavement remains porous and does not become clogged by ice. Furthermore, pervious paving requires less deicing throughout the winter season and is more resistant to frost heave than standard pavement, thus reducing maintenance costs and salt use.



Pervious pavement is a surface that allows water to infiltrate into the ground below. Pervious pavement materials can include asphalt, concrete, interlocking concrete pavers, gravel, and resin-bonded materials such as recycled rubber, mulch, and glass. These surface courses are installed over a supporting base of crushed stone that helps to store and infiltrate stormwater.

Pervious pavements can offer a simple means of integrating green infrastructure if your development footprint is tightly constrained.

Pervious pavement systems.
Image Credit: Philadelphia Water
Department Plan Review, 2018



Considerations:

- Pervious pavement is typically used in parking lot stalls or areas of pedestrian traffic. It is not recommended for drive lanes subject to heavy traffic or where nearby land uses generate heavy sediment or organic material accumulation that could clog the system.
- Construction should not take place during rain or snow, when the subsoil is frozen, or when there is significant accumulation of sediment or debris. These conditions can permanently clog the pervious pavement.
- Snow and ice, especially from areas treated with sand, should not be stockpiled on a pervious pavement system.

Cost: Infiltration systems, such as pervious pavement, are more efficient at meeting stormwater requirements and can therefore have smaller footprints. Construction costs are similar to traditional underground detention systems.

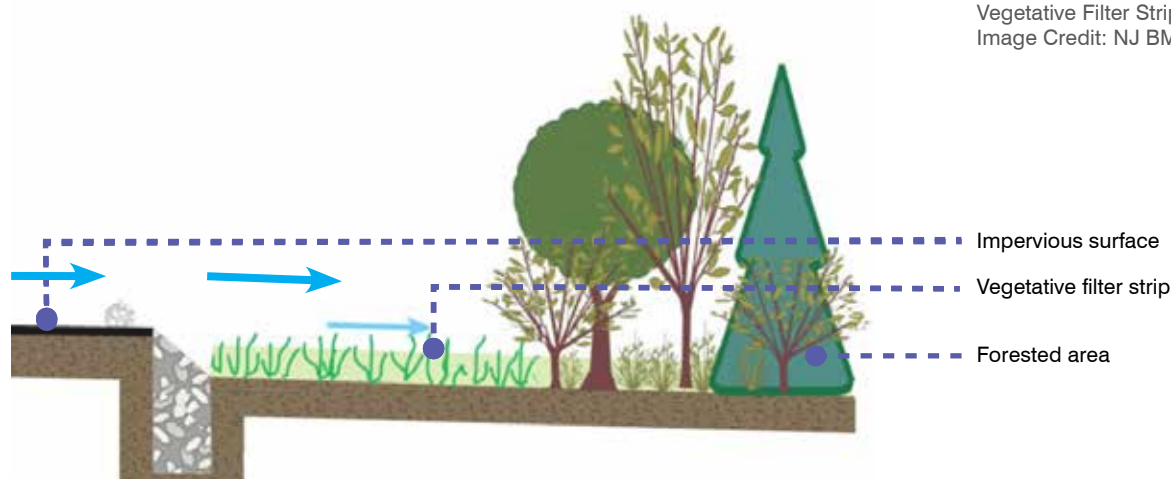
Maintenance: Regular maintenance activities include inspections and sediment/debris removal, typically with a regenerative air vacuum.

Vegetative Filter Strip



Vegetative Filter Strip
Image Credit: Adams County
Stormwater BMPs, 2018

A vegetative filter strip is a gently sloping landscaped area that provides pretreatment to an adjacent stormwater management facility. The BMP slows the upstream runoff rate, reducing the risk of erosion and allows for quicker infiltration before the water leaves the site. Vegetative filter strips add visual buffer from impervious areas such as parking lots.



Vegetative Filter Strip Diagram
Image Credit: NJ BMP Manual, 2018

Considerations:

- Vegetative filter strips are not bioswales. Runoff must be flowing in the form of sheet flow (not concentrated flow like in a swale or pipe) across the vegetative filter strip in order for this green infrastructure practice to be effective.
- The type of vegetative groundcover specified affects the level of water quality treatment which can be achieved. For instance, woodland plant species provide 70% TSS removal while turf grass provides 60% removal.

Cost: Vegetative filter strips are relatively inexpensive compared to other BMPs. A filter strip can be designed using existing vegetated areas or newly proposed planted areas.

Maintenance: Maintenance varies based upon composition of the filter strip. Regular maintenance activities may include debris/sediment removal, mowing, and landscape services.

Wet Pond



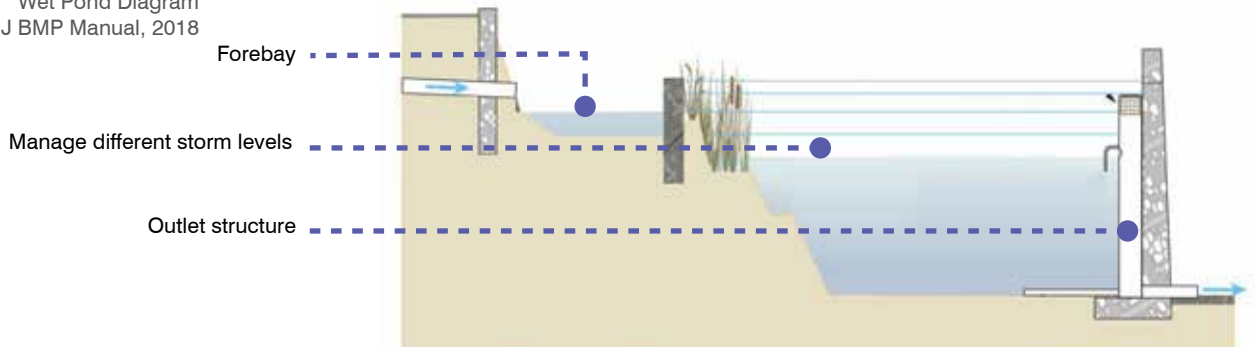
Wet Pond
Image Credit: Native Plant
Solutions, 2018



A wet pond is a permanent pool where stormwater is captured and regulated by an elevated outlet structure. Native vegetation should be used to provide a permanent buffer around the pool. Water from the pond should be used for irrigation or some other beneficial use.

Wet ponds are used to accommodate runoff and provide stability from larger design storms. They can also be used when wildlife habitats, recreational benefits, or water supply for irrigation or fire protection need to be enhanced. Wet ponds may look similar to constructed wetlands, but their plantings, soil, and subsurface systems are very different.

Wet Pond Diagram
Image Credit: NJ BMP Manual, 2018



Considerations:

- Use of wet ponds under Table 5-2 requires a 10-foot-wide area of native vegetation along at least 50% of the shoreline.
- Safety ledges are required around wet ponds deeper than 3 feet.

Maintenance: Regular maintenance activities include inspections, sediment/debris removal, and landscape services for vegetated areas. The forebay must be cleaned once 6 inches of sediment have accumulated.





DECIDING WHICH TYPES OF GREEN INFRASTRUCTURE ARE RIGHT FOR YOUR PROJECT

Each project has its own specific stormwater needs and constraints. Each Green Infrastructure Best Management Practice has unique benefits and functions. The Decision-Making Tree shown on the right can be used to help choose the best BMPs for your site.

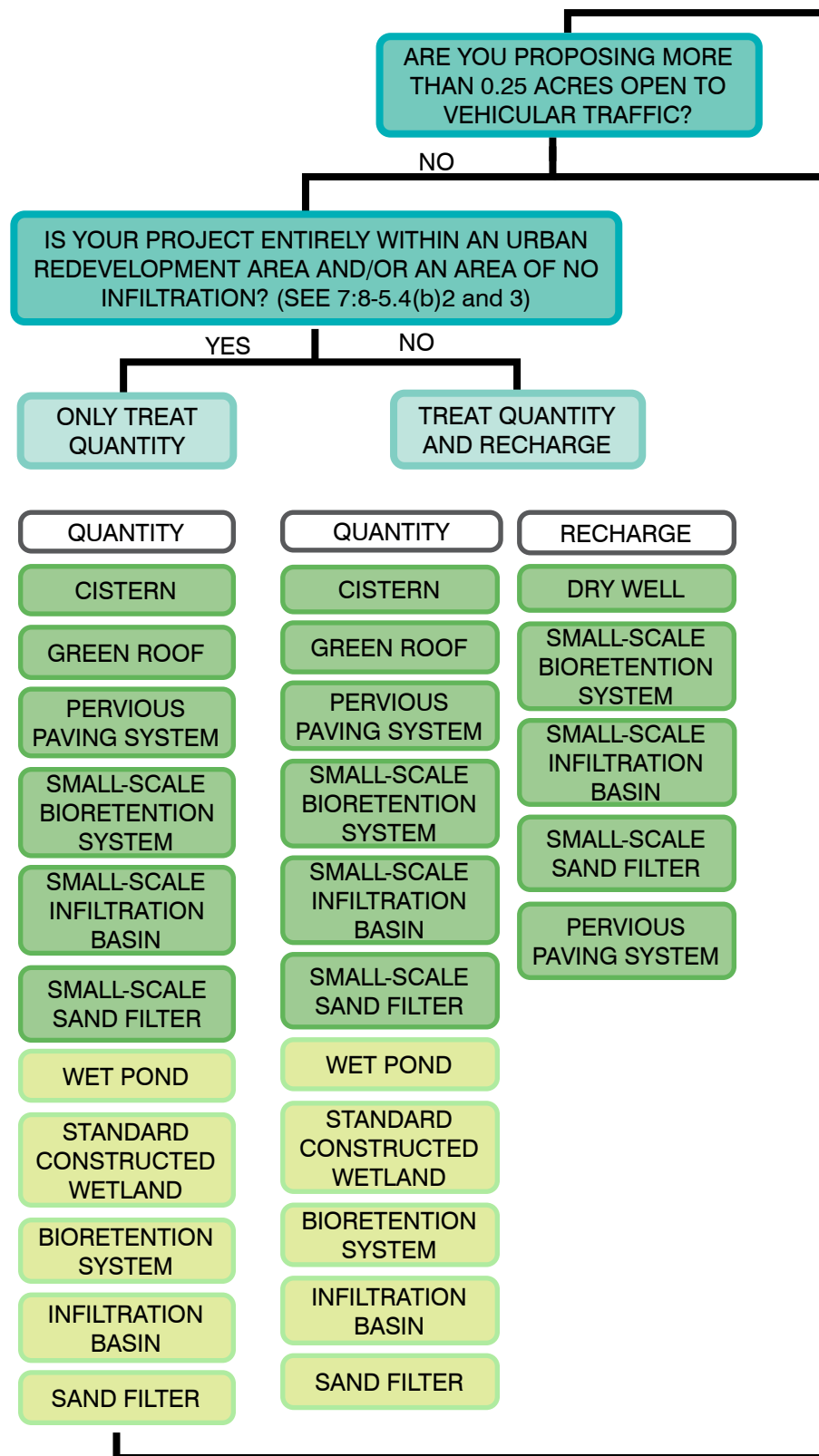
The new amendments to N.J.A.C. 7:8 place much greater emphasis on distributed green infrastructure. Design professionals will consult Tables 5-1 and 5-2 to determine which BMPs may be used to meet standards for runoff quality, groundwater recharge, and runoff quantity. Table 5-3 shows options available with a waiver or variance. This graphic illustrates design options available without variances or waivers.

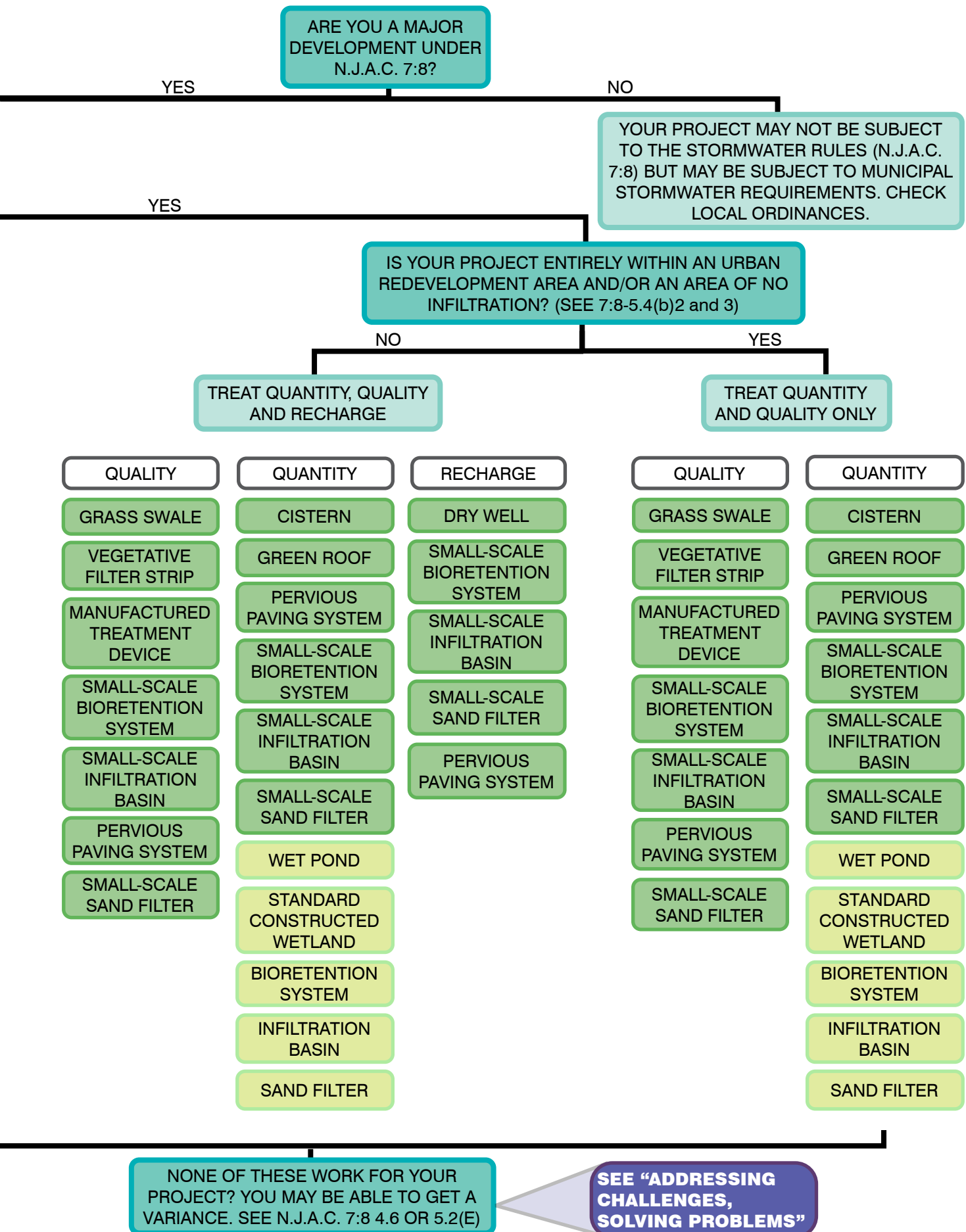
LEGEND

	TABLE 5-1, N.J.A.C. 7:8-5.2 BMPs for groundwater recharge, stormwater runoff quality, and/or stormwater runoff quantity
	TABLE 5-2, N.J.A.C. 7:8-5.2 BMPs for stormwater runoff quantity

What is a “major development”?

As of March 2021, “major development” means (a) an individual development or multiple developments that, individually or collectively, result in the disturbance of one or more acres of land since Feb. 2, 2004; or (b) the creation of one-quarter acre or more of “regulated impervious surface” since Feb. 2004; or (c) the creation of one-quarter acre or more of “regulated motor vehicle surface” since March 2021; or a combination of new regulated impervious surface or motor vehicle surface (b) and (c) above that totals one-quarter acre or more.





BEFORE VS. AFTER THE RULE CHANGE: **SIDE-BY-SIDE COMPARISONS**

Molly Dodd Anderson Library, George School,
Newton Square, PA Waterway restoration and rain gardens.
Image Credit: Viridian Landscape Studio, 2020





A green infrastructure streetscape enhancement in Portland, Oregon uses planters, trees, and permeable concrete pavers to capture and manage stormwater from the street and gutter. Image Credit: City of Portland, Environmental Services, 2018

BEFORE VS. AFTER THE RULE CHANGE: SIDE-BY-SIDE COMPARISONS

The purpose of this chapter is to illustrate the practical effect and implementation of the amended stormwater management rules and BMP Manual. There are two fundamental concepts to understand:

1. **Decentralization is key.** Stormwater management BMPs should be distributed around a site near where stormwater runoff is generated in order to minimize the accumulation of stormwater prior to treatment and mitigation. Groundwater recharge and water quality standards must be met using these distributed BMPs (as demonstrated under Table 5-1). The prior nonstructural strategies in the performance standards attempted to achieve this, but they were ultimately subjective and difficult to enforce.
2. **Infiltration through green infrastructure now “counts.”** The prior BMP Manual guidelines prohibited counting infiltration in demonstrating compliance with the quantitative standards. Under the prior rule, the only standard accepted method to account for BMP volume was by hydraulically routing each BMP. Under the new rule, all stormwater BMPs can account for infiltration during a storm event, thereby increasing a BMPs ability to reduce water quantity and reducing the land area used for stormwater management.

The following side-by-side comparisons illustrate how decentralized green infrastructure could affect site design. **As shown, the use of decentralized BMPs in combination with the new approach to infiltration calculations can provide additional development yield. This could offset some or all of the cost of the green infrastructure approach.** While the more varied stormwater design may look more complicated, this rule change makes designing for and verifying the stormwater management rule compliance a mathematical exercise. This creates a purely objective design and review climate that should streamline the time required for both.



Green roofs reduce surface area used to manage stormwater, thereby increasing developable area.
Image Credit: Viridian Landscape Studio, 2020

BEFORE RULE CHANGE: RESIDENTIAL PROPERTY

This comparison shows a typical small lot single-family subdivision designed to meet the stormwater management rules effective prior to March 2021, with compact development, implementation of some grass swales, and a typical stormwater management wet pond.



Engineering Tip

“End-of-pipe” refers to traditional large-scale stormwater BMPs, like detention basins, which are located at the edges of a site. All stormwater is collected and conveyed to this one location.

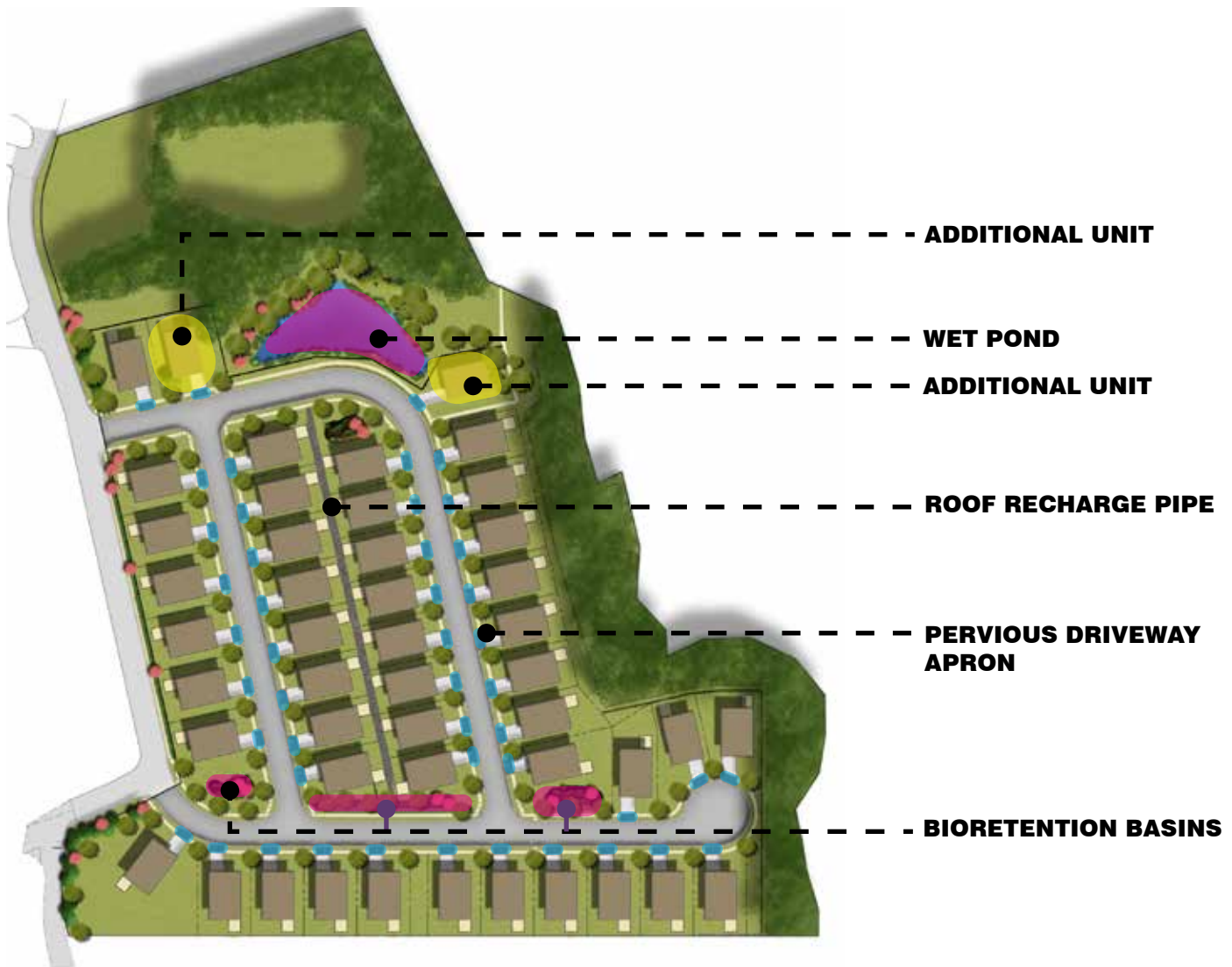
There is little to no developable area at the upper end of the site due to preservation of existing wooded areas and the large amount of area needed for the wet pond. The size of the wet pond is driven by the design approach of using an “end-of-pipe” system. All drainage areas on site are captured via storm sewer or overland flow and conveyed to the wet pond which acts as a single point of management.

AFTER RULE CHANGE: RESIDENTIAL PROPERTY

The theoretical design of the same subdivision applying the amended stormwater rules adds several decentralized green infrastructure BMPs and **yields two additional building lots**. This is achieved by intercepting and infiltrating a significant portion of the overall stormwater runoff within the developed portion of the site as opposed to conveying the majority of the runoff to the end-of-pipe wet pond.

Key Takeaway:

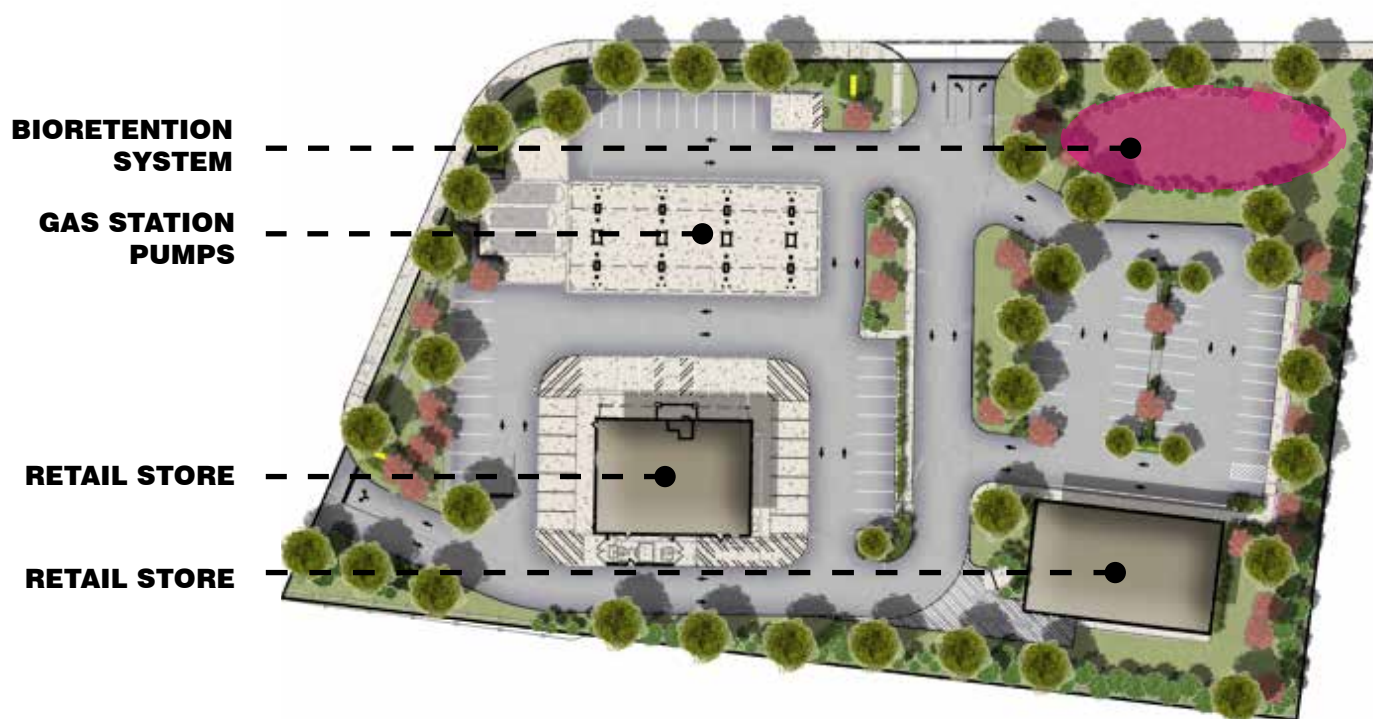
A decentralized stormwater management approach under the new rules would provide **increased lot yield**.



Pervious driveway aprons treat and infiltrate both driveway and roadway runoff; multiple rain gardens treat and infiltrate yard, roof, and roadway runoff; a roof recharge pipe in the center of the subdivision infiltrates roof runoff. This reduces the peak flow and volume of runoff to the end-of-pipe wet pond, allowing the wet pond to be designed with a smaller footprint. Note that a naturalized pond edge has also been added to the wet pond to provide water quality benefits, discourage geese, and add aesthetic appeal. Although not illustrated, **the wet pond would also be utilized as a source of irrigation water**. Moreover, as water quality is already addressed prior to discharge to the wet pond, the minimum required volume is reduced.

BEFORE RULE CHANGE: COMMERCIAL PROPERTY

This comparison shows a typical commercial development consisting of a convenience store with gas and strip retail store designed. The illustration demonstrates the design under stormwater rules effective prior to March 2021, including the use of grass swales and a typical stormwater bioretention system.



While green infrastructure was used in the stormwater management design, the bioretention system is an “end-of-pipe” BMP. No decentralized BMPs were utilized. Further, infiltration is not included in the engineering calculations, resulting in the proposed bioretention BMP covering a large extent of area on the site.

AFTER RULE CHANGE: COMMERCIAL PROPERTY

The theoretical design of the same commercial site applying the amended stormwater rules adds several decentralized green infrastructure BMPs as well as **an additional quick service restaurant**. This is achieved by intercepting and infiltrating a significant portion of the overall stormwater runoff within the developed portion of the site as opposed to conveying the majority of the runoff to a single end-of-pipe bioretention basin.

Key Takeaway:






A decentralized stormwater management approach under the new rules would **increase** the developable area of the lot and provide an **additional building** to the project.

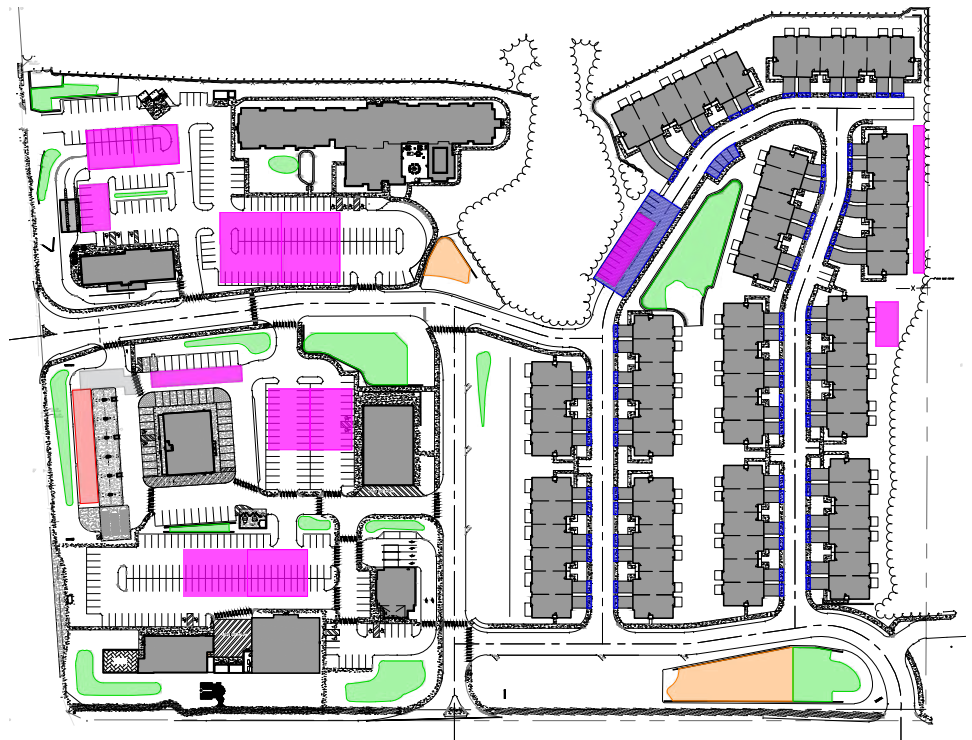


Pervious pavement treats and infiltrates both driveway and parking lot runoff; multiple rain gardens treat and infiltrate pavement runoff; a roof recharge pipe to the rear and side of the retail building infiltrates roof runoff. **These decentralized BMPs address the entirety of the required peak flow and volume mitigation for the project, allowing the end-of-pipe basin to be replaced with additional development and a shared parking concept.**

BEFORE RULE CHANGE: MIXED-USE PROPERTY

This comparison shows a complex mixed-use development project. Although a previously developed property, the site has been vacant for some time, allowing successional trees and vegetation to establish throughout the site in the pre-developed condition. The site is at the intersection of two significant roadways. The other two sides of the property include a stream corridor and a large public park with additional public amenities. The stream corridor includes freshwater wetland features adjacent to the proposed development and a floodplain with a history of flood-related impacts downstream from the site.

-  POROUS PAVEMENT
-  UNDERGROUND INFILTRATION BASIN/ RECHARGE TRENCH
-  RAIN GARDEN AND BIORETENTION AREAS
-  ABOVEGROUND DETENTION BASIN
-  UNDERGROUND DETENTION BASIN



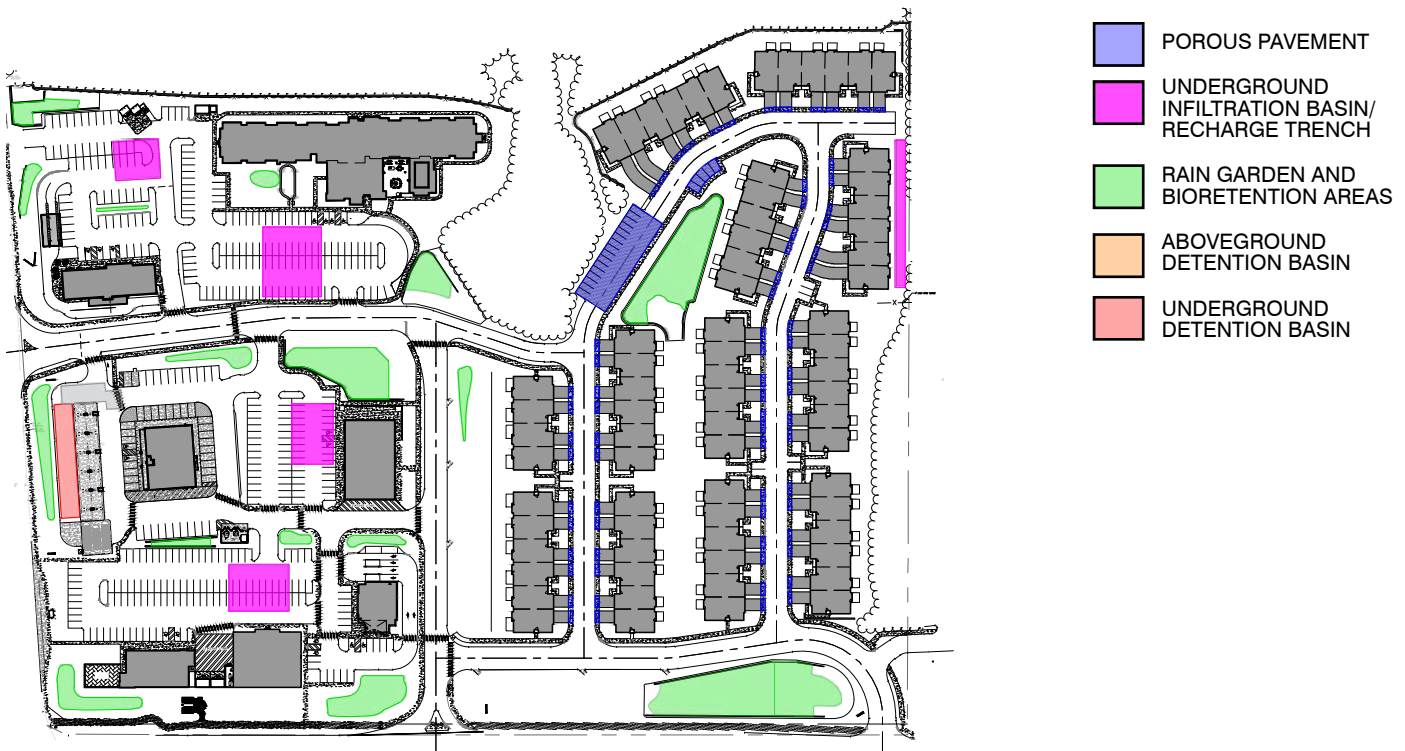
The pre-developed conditions on this long-vacant site limits the rate and volume of stormwater runoff leaving the site. The adjacent wetlands are ecologically sensitive, and the floodplain is vulnerable to additional runoff due to existing downstream flooding issues. Therefore, the applicant, design team, municipal professionals, and NJDEP all knew stormwater management would be a significant issue during the development application review process. Anticipating changes to the stormwater rule (proposed in December 2018), a state-of-the-art stormwater design based primarily on decentralized green infrastructure was prepared. This approach was not required at the time, as the rule would not be officially adopted until after the project was approved.

AFTER RULE CHANGE: MIXED-USE PROPERTY

This project presents a unique opportunity to compare a decentralized green infrastructure stormwater management design before and after the rule adoption. It demonstrates how key changes to the BMP Manual guidelines, specifically the ability to “count” infiltration in the design and routing of the stormwater management facilities, have an enormous impact on cost considerations. The updated BMP Manual requires specific geotechnical exploration, soil testing, and groundwater mounding analysis in order to verify the extent to which infiltration can be counted. In this case, the soils and depth to seasonal highwater table were very favorable. The decentralized nature of the stormwater management design acts to reduce the potential for groundwater mounding and associated adverse effects. **As a result, under the new stormwater rules and associated BMP Manual, the underground infiltration portions of the stormwater management system can be reduced in size by 30% to 40%.**

Key Takeaway:

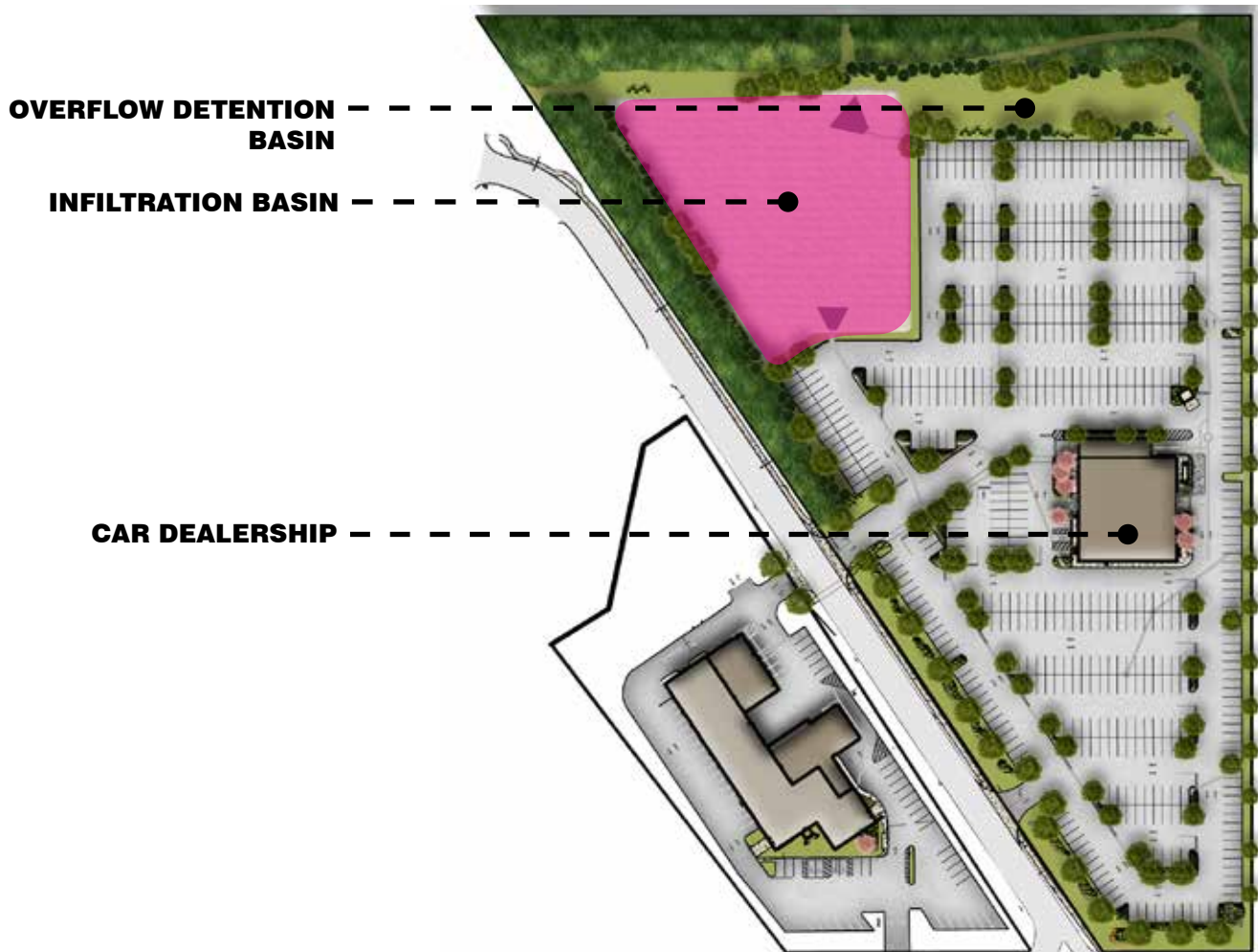
Under the new rules and BMP Manual updates, decentralized stormwater that accounts for infiltration can be used to **reduce construction costs** by minimizing the size of underground infiltration systems.



Compare the purple-shaded portions of the rendering above with the purple-shaded portions of the rendering on the left to see how much smaller and less costly the underground infiltration becomes after the rule is in place. Note also that none of the surface bioretention systems are reduced in size. Under the new rule and BMP Manual, the **decentralized BMPs are recognized and fully credited for effectively managing stormwater**. Furthermore, the site design uses green infrastructure features to enhance pedestrian mobility, access to public transit, and linkage to the adjacent public facilities, reflecting a holistic approach to land development that benefits the property owner, tenants, and community.

BEFORE RULE CHANGE: CAR DEALERSHIP

This comparison shows a car dealership expansion project. The original car dealership was on the smaller parcel to the left, and the proposed expansion is located on the larger tract across the road to the right. The larger tract was an undeveloped, wooded property. The point of analysis is an existing storm sewer system in the adjacent roadway.



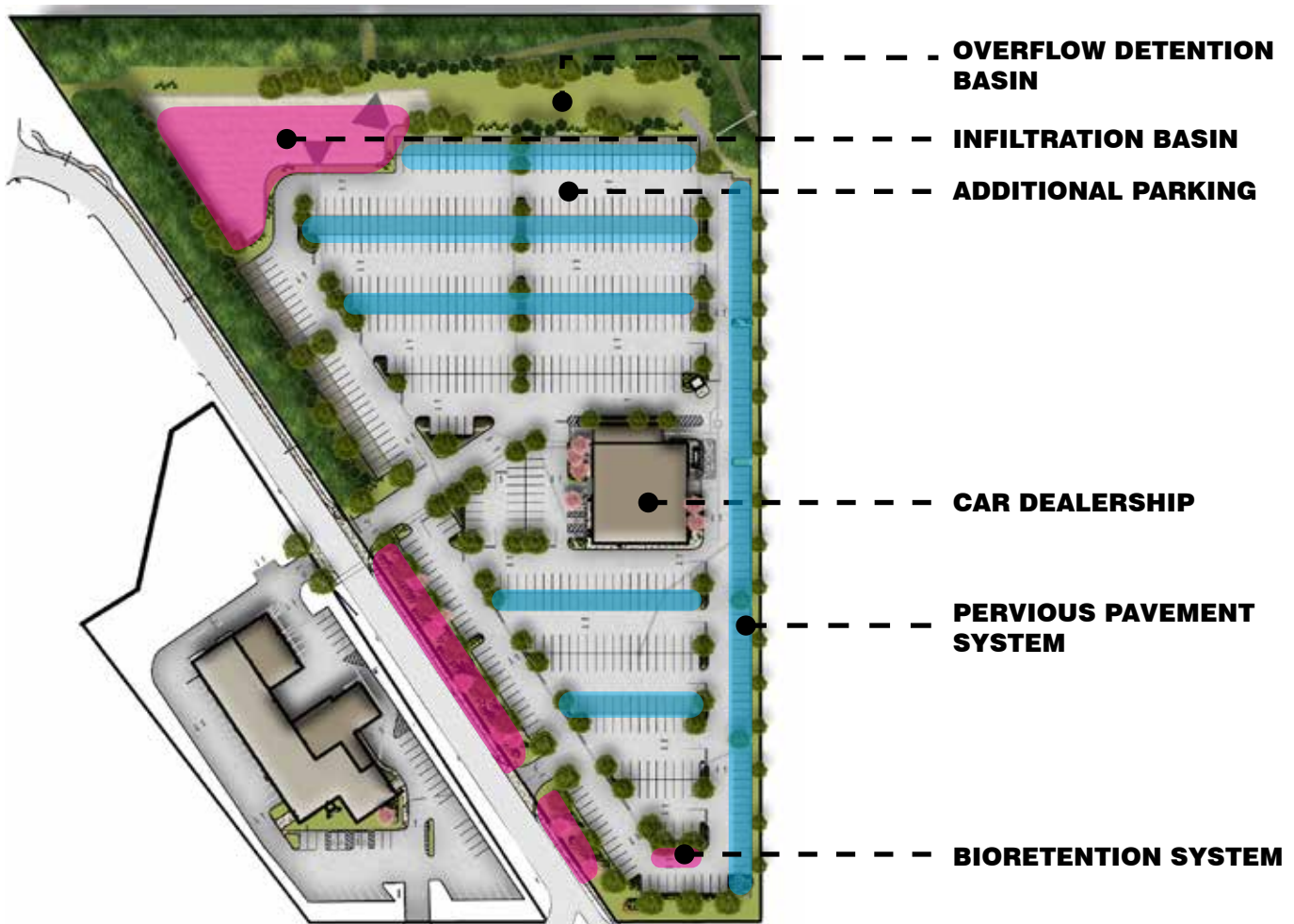
The pre-developed woodland conditions act to substantially limit the rate and volume of stormwater runoff leaving the site. Therefore, a significant stormwater management system was required to meet the recharge, water quality, and quantity requirements of the stormwater regulations effective prior to March 2021. To meet the requirements, a large, end-of-pipe infiltration basin with an attached detention basin area for quantity control during larger storm events was proposed as illustrated above.

AFTER RULE CHANGE: CAR DEALERSHIP

This project is a good example of how to approach a development with a significant amount of proposed “motor vehicle surface area” as defined in the recently adopted stormwater management rules. The updated NJ Best Management Practices (BMP) Manual guidelines include provisions and procedures to “count” infiltration in the design and routing of the stormwater management facilities. The BMP Manual requires specific geotechnical exploration, soil testing, and groundwater mounding analysis in order to verify the extent to which infiltration can be counted. In this case, the soils and depth to seasonal high water table were favorable.

Key Takeaway:

Under the new rules and BMP Manual updates, decentralized stormwater that accounts for infiltration can be used to **increase developable area**.



The rendering above shows that the land area required for the surface infiltration basin is greatly reduced. **This expands the land area available for vehicle storage or for other site amenities.** The project uses a combined approach of using decentralized green infrastructure, including porous pavement, bioretention systems, and grass swales, to meet the groundwater recharge and water quality requirements, and a smaller end-of-pipe infiltration basin to meet the remainder of the quantity control requirements. This approach shows how a decentralized green infrastructure approach can work to the property owner's benefit, even in an intense development scenario. The site design **leverages the green stormwater infrastructure to increase the project yield, which acts to offset additional costs** associated with the implemented green infrastructure approach.

A photograph of a landscaped area. In the foreground, there is a stone retaining wall made of large, grey, rectangular stones. Behind the wall, there are several clumps of tall, green, blade-like plants, possibly irises. To the left, there are some red flowers. In the background, there is a large, steel truss bridge structure. The sky is blue. A semi-transparent teal box is overlaid on the top left of the image, containing the title text.

ADDRESSING CHALLENGES, **SOLVING** **PROBLEMS**

East Park Canoe House,
Philadelphia, PA
Image Credit: E&LP, 2020



ADDRESSING CHALLENGES, SOLVING PROBLEMS

The recent amendments to NJDEP's stormwater management rule and Best Management Practices (BMP) Manual represent a paradigm shift in the approach to stormwater management. **To achieve both an effectiveness of stormwater management and efficiency of development under the new rule, the approach to site development and engineering design must shift.**

KEYS TO SUCCESS:

1. **Involve all stakeholders and professionals from the beginning. An integrative design process saves time and money and is vital to successful design.**

- Developer
- End User
- Planner
- Building Architect
- Civil Engineer
- Geotechnical Engineer
- Landscape Architect
- Contractor

With the green infrastructure requirement in place, a holistic approach to development becomes essential. Engagement with owners, municipalities, tenants, and adjacent communities, such as this public meeting in the City of Hoboken, can have a huge impact on the outcome of any given project.
Image Credit: E&LP, 2020



2. **Analyze existing site conditions.**

- Consider sun exposures in siting buildings and BMPs
- Map, explore, and test soils as part of concept planning to guide BMP selection and siting

3. Include green infrastructure design considerations and co-benefits when creating concept plans.

- Premiums on residential price points
- Added value from viewsheds, such as for outdoor restaurant seating or in/around an on-site recreation area
- Enhanced outdoor break areas for employees
- Shaded parking areas
- With pervious pavement, reduced potential for water/ice related liabilities, such as slip and fall risks
- Opportunities to highlight use of green infrastructure for site patrons
- Integration of pervious pavement systems with site amenities, such as courtyards, tot lots, playgrounds, sports courts, etc.

4. Maximize the use of small spaces.

- Locate green infrastructure in tandem with project structures
- Include more small, decentralized green infrastructure in order to best reduce the size and cost associated with end-of-pipe stormwater management systems. This will also maximize infiltration and reduce the affects of groundwater mounding.
- Use every “left over” area in the site layout to place decentralized BMPs (i.e. parking islands, around gutters, etc.)



Bioretention system located in the center of a roadway.
Avalon Somerset, Somerset, NJ
Image Credit: Maser Consulting, 2020

5. Consider permitting early in the process.

- Seek NJDEP approval of innovative green infrastructure applications where appropriate (e.g. forested retention areas)

6. Green infrastructure is the solution.

- Site constraints sometimes create a perception that green infrastructure is difficult or impossible to utilize. This chapter includes examples and guidance on common obstacles to implementing green infrastructure.

SHALLOW SEASONAL HIGH WATER TABLE

In areas with a shallow depth to the seasonal high water table elevation, select green infrastructure with shallow profiles or design green infrastructure to be submerged within the groundwater table. For example, set pervious pavement adjacent to a constructed wetland. Instead of recharging, the pervious pavement would flow horizontally into the adjacent wetland area to assist in maintaining the wetland hydrology. See the installation pictured below.

Constructed wetland.
Image Credit: Maser Consulting, 2020



Green infrastructure BMPs that have a shallow profile include the following:

- Pervious pavement such as asphalt, concrete, and pavers
- Vegetated filter strip

Green infrastructure BMPs that can be set into the water table include:

- Manufactured treatment devices
- Wet pond
- Constructed wetland
- Subsurface gravel wetland

While under construction, groundwater conditions at the East Park Canoe House in Philadelphia, PA were revealed to be more challenging than previously indicated by testing. Bioretention systems were shallowed and given greater footprints in order to maintain storage while providing adequate separation between the bottom of the system and groundwater. (LEFT) Project under construction. (RIGHT) Completed installation. Image Credit: E&LP, 2020



POOR SOILS

Poor soils are generally defined as soils that do not provide adequate infiltration. When working with these conditions, the design intent is to filter and slowly release stormwater via evapotranspiration, beneficial reuse, and/or discharge to a receiving storm sewer, waterway, or surface area over time. The following approaches are examples of how to achieve this:

- Pervious pavement with underdrain and outlet structure
- Lined/underdrained sand filter
- Lined/underdrained shallow bioretention system
- Structured bioretention manufactured treatment device (MTD)
- Grass swale
- Vegetated filter strip
- Cistern
- Wet pond
- Constructed wetland
- Subsurface gravel wetland



Pervious pavement in Princeton Bottle King parking lot.
Image Credit: Kleinfelder & D.S. Engineering, 2020

URBAN REDEVELOPMENT

In urban redevelopment areas, the design intent is to create compact BMPs to filter and slowly release stormwater via infiltration, evapotranspiration, beneficial reuse, and/or to a receiving storm sewer over time. The following are examples of green infrastructure and design solutions that can be used to achieve this:

- Bioretention systems
- Structured bioretention MTD
- Green roof
- Blue roof (stand-alone or in combination with green roof)
- Cistern
- Under-sidewalk storage adjacent to and feeding streetscape planting bed
- Sand filter
- Disconnection of stormwater from combined sewers using green infrastructure and direct connection to combined sewer outfalls

Stormwater bumpout.
Image Credit: AKRF, Inc., 2018



NO RECEIVING STORM SEWER OR WATERWAY

In situations where there is no receiving storm sewer or waterway, the design intent is to provide disconnection along the flow path of stormwater runoff to provide water quality, evapotranspiration, and/or infiltration, with any remaining water runoff continuing as surface flow.

- Infiltration-only bioretention system
- Pervious pavement
- Vegetated filter strip
- Infiltration basin
- Infiltration sand filter
- Bubbler inlet discharge from other BMPs

BROWNFIELD AREAS

Brownfield areas are similar to urban redevelopment areas except the design intent is to keep stormwater separate from impacted areas and create compact BMPs to filter and slowly release stormwater via evapotranspiration, beneficial reuse, and/or to a receiving storm sewer over time. The following approaches are examples of how to achieve this:

- Lined and underdrained bioretention system
- Structured bioretention MTD
- Pervious pavement with underdrain and outlet structure if over impermeable cap
- Sand filter with underdrain and liner
- Cistern
- Green roof
- Blue roof (stand-alone or in combination with green roof)
- Lined wet pond
- Lined subsurface gravel wetland
- For more information on brownfield areas, see the Brownfield and Contaminated Site Remediation Act, N.J.S.A. 58:10B-1. Full reference information is available in the Resources List.



Existing conditions at the Northwest Resiliency Park site in the City of Hoboken, NJ. The site is a brownfield site contaminated by former industrial uses. The temporary pop-up park shown is constructed on an asphalt cap. No stormwater management exists.

Image Credit: E&LP, 2020



Proposed Lowland Gardens at the Northwest Resiliency Park. Smaller, dispersed bioretention systems are proposed throughout the site. Green infrastructure design incorporates vegetative capping, low-profile underdrains, and liners to prevent infiltration and mobilization of contaminants.

Image Credit: OLIN, 2020

PROPER CONSTRUCTION

Incorporate construction specifications, detail, notes, and plan requirements to assist the contractor in successfully completing green infrastructure installations. For example:

- Require geotechnical engineer to observe excavation and suitability of subgrades; perform soil testing on subsurface layers to remain and on all replacement soil mixes.
- Require under-excavation of infiltration-based systems during construction, with final excavation to design subbase depth and installation of engineered soil layers to be performed only after heavy equipment is no longer traversing the area and after the entire drainage area is stable.
- Specify uniformly graded coarse sand as the surface layer of infiltration basins.
- Specify bioretention soil based on the expected silt and nutrient loading to the BMP.
- Require temporary forebays at all inlets to BMPs.
- Require silt fence to protect BMP perimeters during construction.
- Require sod to stabilize steep slopes around BMPs.
- Design wet pond depths to allow for the accumulation of silt while maintaining at least minimum design depth.
- Utilize low-ground-pressure vehicles to minimize soil compaction during construction.

Installing forebays in stormwater systems, like the ones along Tacony Creek Park in Philadelphia, can increase the longevity of the system and decrease maintenance needs.

Image Credit: E&LP, 2020



MAINTENANCE

Perhaps the most important consideration in successful green infrastructure implementation is long-term maintenance. Systems must be designed with maintenance in mind and an understanding of responsible parties. Poor maintenance for traditional gray infrastructure is easier to ignore, as it is largely below grade systems invisible to the eye. Poor maintenance of green infrastructure is much more noticeable and leads to negative perceptions of these systems when they fall into disrepair.

Maintenance is not complicated, but it does require additional knowledge and accountability. Some common maintenance concerns are listed below. Understanding these problems prior to installation and sale of a project can help contractors and clients avoid negative outcomes.



The sediment filter trap shown in the image has done its intended job and kept a large amount of sediment, trash, and debris out of the downstream system. It needs to be cleaned out in order to maintain its functionality.
Image Credit: E&LP, 2020

Standing Water

- **Problem:** Green infrastructure, like gray infrastructure, has a designed drainage time. When the system experiences a failure, water may accumulate and fail to drain at the BMP's low point. This can lead to clogging of outlet structures and mosquito breeding. While vegetation can reduce this problem from gray infrastructure conditions, failures elsewhere in the system can oversaturate soils and cause vegetation loss.
- **Solution:** Standing water can be avoided through proper construction, regular inspection, and prompt repair. Unanticipated low points in the design can be rectified through regrading of the BMP. During the design process, plans should be evaluated to ensure that slopes are sufficient to convey water. Overflow devices and outlet controls should be inspected after storms exceeding one inch in rainfall and at least four times annually for clogging that may prevent water from leaving the system. The NJDEP recommends bi-weekly inspections during vegetation establishment/restoration and a minimum of one inspection during the growing season and one during the non-growing season for established vegetation.

“More grasses, less mulch, pops of color!”
 - Tavis Dockwiler,
 Viridian Landscape Studio

GSI Partners provides maintenance training for professionals at its annual GSI Operation and Maintenance Course.
 Image Credit: Chris Kendig Photography, 2020

Dead or Missing Vegetation

- **Problem:** A common complaint with green infrastructure systems is that vegetation looks unattractive, dead, or sparse. These issues often stem from a lack of proper maintenance. Missing vegetation can not only give green infrastructure a poor reputation, but can lead to pests, ineffective water quality treatment, and increased erosion.
- **Solution:** Designs should incorporate a sufficient variety of plants to ensure biodiversity while maintaining a degree of simplicity. Biodiversity allows a system to maintain its effectiveness when certain species perform poorly. Simplicity allows maintenance crews to more easily identify intentional plantings from weeds. Additionally, soil profiles should be designed to support plant health. Regular soil testing will ensure that the system continues to thrive during establishment. Training maintenance crews on the plant maintenance is especially important for the long-term viability of a green infrastructure system. Proposed spacing of plants and seasonality must be taken into account in the BMP design. These are living systems and different plants emerge and dieback at different times of year. Over reliance on a limited variety of species spaced several feet apart will jeopardize the year-round function and aesthetics of the BMP. Planting palettes composed primarily with grasses, a variety of perennials, and tight spacing to limit mulch will have better long-term performance.



Erosion

- **Problem:** Erosion is always a concern when it comes to stormwater management. Intense rainfalls can damage stormwater infrastructure. With green infrastructure, erosion can be especially harmful to vegetative components. When erosion leads to plant loss, the system can fail to function as designed and become an eyesore. Sand infiltration layers and bioretention soil media may also become clogged as eroded sediment accumulates in these systems.
- **Solution:** Erosive damage originates from high-velocity runoff. In order to mitigate these speeds, the system should incorporate soil erosion and sediment control devices, as specified in the New Jersey Standards for Soil Erosion and Sediment Control. Riprap aprons, consisting of larger stones, are designed to dissipate speeds at the inlets and outlets of pipes and outlet controls. Appropriate planting soil depths should also be maintained in order to ensure that plants will continue to thrive when erosion strips topsoil. Erosion control matting used in areas of steep slopes and swales will protect against these issues.

Clogged Pervious Pavement

- **Problem:** While pervious pavement reduces the likelihood of potholes, black ice, and surface pooling, benefits are dependent upon maintenance of the system. The void space between pervious pavement aggregate, intentionally designed to let stormwater pass through, can become clogged with sediment and debris. This can severely impair the function of the system and lead to costly repair.
- **Solution:** Maintenance procedures for pervious pavement can vary based upon composition, manufacturer, and geographic location of the project. In addition to inspecting outlet controls and cleanouts for clogging, the system should typically be cleaned biannually with a regenerative air vacuum. The optimal times for vacuuming are in the spring after the last snow events and in autumn after leaves fall. Maintaining these schedules will facilitate drainage and increase the lifespan of the system.



Image Credit: TecEco, 2018

CASE STUDIES







Kearny Point Perspective Rendering
Image Credit: Hugo Neu, 2020

CASE STUDIES

CASE STUDY 1 KEARNY POINT

DEVELOPMENT TYPE:

Industrial to Mixed-use Redevelopment

LOCATION:

78 John Miller Way, Kearny, NJ 07032

MUNICIPALITY/NEIGHBORHOOD:

Kearny Town

DEVELOPER/DESIGN TEAM:

Hugo Neu Corporation

Michael Meyer, *Director of Development*
Dominique Lueckenhoff, *Senior Vice-President Corporate Affairs & Sustainability*

Studios Architecture

WXY Architecture

Bohler Engineering

BioHabitats

eDesign Dynamics

SEWER TYPE:

Combined Sewer Overflow

Passaic Valley Sewerage Commission

COMPLETION DATE:

Construction in Progress

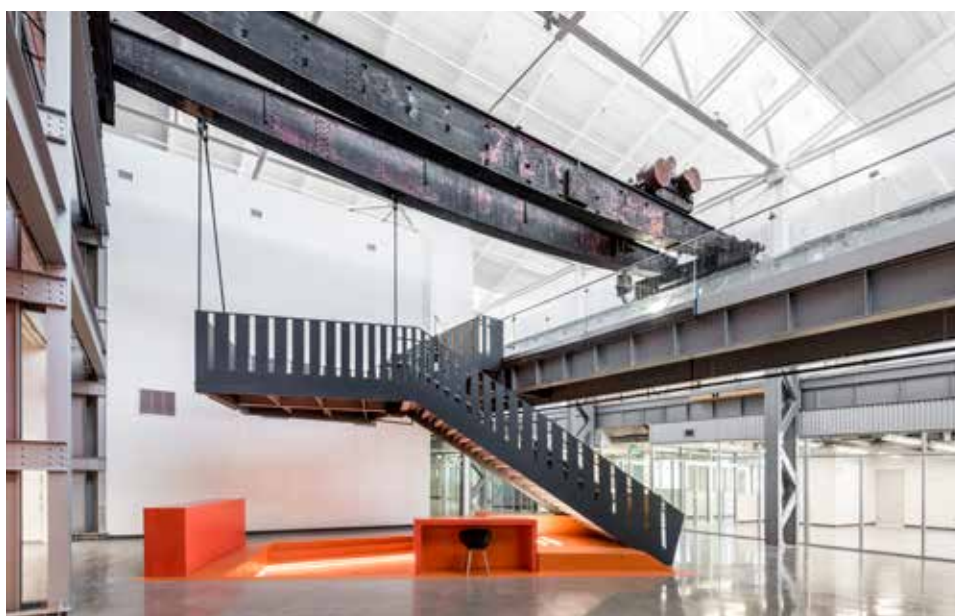
Project Overview

Kearny Point is a former shipbuilding yard located between Kearny and Jersey City on the South Kearny Peninsula. The site contains 130 acres of asphalt and industrial buildings fronting the Hackensack River. **This redevelopment project is designed to convert the space into a vibrant, riverfront complex of industrial, commercial, and office spaces. Green infrastructure Best Management Practices are proposed throughout the site in order to reduce flooding, manage stormwater, and create amenity space for tenants.** The site will be a model for developers looking to reenergize industrial complexes under the updated NJDEP stormwater rules.

When shipbuilding activities ceased in 1948, the site became a center for scrapping and recycling operations. Damage from Hurricane Sandy in 2012 spurred the initiative to redevelop the site and prepare for future hurricanes. The Master Plan for the property outlines the core design principles for the site as Authentic Identity/Adaptive Reuse, Diverse and Complementary Tenanting, Ecology and Environment, and Resiliency. From the early planning stages, green infrastructure was incorporated as a tool to achieve these aims.

The construction process will be achieved through phasing. The first phase is underway and includes the redevelopment of southern areas of the site, which will provide offices, restaurants, and indoor food markets. An outdoor amenity space incorporating habitat restoration will be constructed along the Hackensack River.

Phase 2 will include building renovations that will allow for light manufacturing, film production, and post-production work. Phase 3 includes the construction of low-density development along the Hackensack. Shoreline restoration will provide a buffer for future storm events while creating local habitat. Phase 4 will complete the project with the construction of the North Basin and the development of a flexible complex measuring one million gross square feet. Habitat restoration will surround the building.



The interior of the Historic Crane Building. This space is one of the adaptive reuse aspects of the site.
Image Credit: Hugo Neu, 2020

“It was an environmental enterprise as much as a redevelopment.”

- Michael Meyer,
Director of Development
at Hugo Neu

Design Summary

The design team knew from the inception of the project that environmental considerations were a primary driving force for the site. The goal was to incorporate resiliency in a meaningful way while providing an attractive space for tenants. The project’s phasing lends itself to the dispersed green infrastructure encouraged by NJDEP. In the first phase (underway), rain gardens manage runoff from roof and parking areas. As redevelopment continues, new green infrastructure systems will be installed.

- **Blue roofs** will collect, store, and slowly release rainwater collected from smaller storms.
- **Green roofs** will be used throughout the site to collect stormwater runoff. Green roofs provide additional water quality benefits and aesthetic value.
- **Bioretention Systems (rain gardens)** will filter pollutants and provide storage to reduce peak flows. These systems will be distributed throughout the site and will interconnect with bioswales, pervious pavement, and stormwater pipes.
- **Bioswales** will guide stormwater runoff to rain gardens while providing water quality benefits and aesthetic value.
- **Constructed wetlands** will address both water quality and water quantity. The location of the wetlands along the Hackensack River allows for storm surge buffering and flood management.
- **Pervious pavement** is proposed in select areas of pedestrian and vehicular traffic vulnerable to flooding. The system will include porous asphalt, pervious concrete, and porous pavers.
- **Manufactured Treatment Devices** will provide additional water quality treatment before stormwater discharges into the Hackensack River. The advanced filtration polymer media will remove 98-99% of remaining pollutants, including pathogens, toxics, hydrocarbons, trash, and sediment.

The revegetation of existing asphalt will play a major role in reducing stormwater runoff. In addition to groundcover change, the design team provided storage and treatment beyond the state and local requirements.
Image Credit: Hugo Neu, 2020

Key Environmental Features

- Habitat/Native Plantings**
- Water Run-off/Bioswales**
- Green Roofs**
- Farm**
- Resiliency/Flood Control/Wetlands**





Early concepts for the site heavily featured green infrastructure and usable communal green spaces.
Image Credit: Hugo Neu, 2020

Decision-Making

The selection of green infrastructure BMPs was guided based upon the needs of the development, the constraints of the site, and the environmentally conscious approach of the project:

- **Blue roofs** were selected due to their capacity to store stormwater in smaller areas. The roofs will integrate renewable energy systems generating a combined three megawatts of power. Blue roofs are ideal for the remaining roof area.
- **Green roofs** will be used where adequate space is available. Green roofs, like blue roofs, are able to collect, store, and release stormwater runoff. However, green roofs have the added benefit of filtering pollutants through plant media. They can also provide recreational and aesthetic value.
- **Bioretention Systems (rain gardens)** are important for stormwater quantity control. Rather than choosing the traditional detention basin, the design team selected bioretention systems to provide additional environmental benefits in line with the Master Plan for the project.
- **Bioswales** were selected over traditional pipe systems where possible. Bioswales provide the same conveyance function while filtering stormwater and providing aesthetic value to the site.
- **Constructed wetlands** were used to restore the site to predeveloped conditions. The previous development paved over existing vegetation and wetland habitats that served as natural buffers against storms and flooding. By revegetating the edges of the Hackensack River, the site becomes more resilient against storm events.
- **Pervious pavement** is proposed in select locations in place of traditional paved systems in order to reduce stormwater runoff. Traditional paved systems can have higher capital costs and require additional stormwater management infrastructure to mitigate the increase in runoff.
- **Manufactured Treatment Devices** were selected in order to ensure that water discharging from the site would be devoid of contaminants. The existing contaminants on the site pose a potential threat to water quality. These devices eliminate concerns by providing additional treatment beyond the green infrastructure systems.

Challenges

Kearny Point exemplifies the urban conditions that often deter developers from using green infrastructure. The design team faced contaminated soils, shallow depth to groundwater, and historic preservation. These conditions challenged the team to think critically about the implementation of green infrastructure and how best to integrate it within a complex environmental system.

The existing site presented many challenges to the design team. The industrial activities caused contamination and the nearby Hackensack River causes frequent tidal flooding.
Image Credit: Hugo Neu, 2020



Contaminated Soils:

Kearny Point is located on a brownfield site where chemical contaminants impacted soil and groundwater quality. This challenge means that the green infrastructure features on-site may not infiltrate into the subsoils.

Site remediation efforts introduced a product called Ecochar(TM), a form of biochar created from the gasification of organic feedstocks. Ecochar has the dual benefit of providing clean fill and serving as a nutrient-rich plant medium that facilitates green infrastructure.

Groundwater and Flooding:

The design team faced the challenge of anticipating rising sea levels and increasingly frequent storms. To meet flood hazard area regulations, the site was raised to an elevation of 16 feet above sea level. This fill also allowed for the use of green infrastructure practices by providing adequate separation from the seasonal high groundwater table.

BMP Construction:

The design and construction team learned a great deal through the construction process. Green infrastructure systems can be complex and difficult for contractors inexperienced in their installation. The team reflected that more detailed specifications and construction documentation would have eliminated some of the construction setbacks.



Perspective bird's-eye rendering of the completed project facing towards the Hackensack River.

Image Credit: Hugo Neu, 2020

Maintenance Overview

Maintenance routines for the site will evolve as each construction phase progresses. The site will contain 22,000 square feet of landscaped area. While the size of this area may provoke concern over maintenance costs, the use of native plants will significantly reduce maintenance needs. Native flora and fauna require less fertilizers and pesticides and will promote a healthy ecosystem. Any increased costs due to green infrastructure maintenance is marginal compared to the site's overall operating cost.



Rendering of Phase 2, Building 54.

Image Credit: Hugo Neu, 2020



The Charlotte Rachel Wilson Student Housing with a porous paving parking lot and landscaping to minimize impervious area. Image Credit: ACT Engineering, Inc.

CASE STUDY 2 PRINCETON THEOLOGICAL SEMINARY

DEVELOPMENT TYPE:

Suburban Student/Multifamily Housing

LOCATION:

Faber Road, West Windsor Township, NJ 08540

MUNICIPALITY/NEIGHBORHOOD:

Mixed-Use Redevelopment

DEVELOPER/ DESIGN TEAM:

Princeton Theological Seminary
ACT Engineers, Inc.
Dewberry
Walter Bronson, PE, LEED AP

SEWER TYPE:

The project is served by public sewers through West Windsor Township with treatment by the Stony Brook Regional Sewerage Authority.

COMPLETION DATE:

2013

Preserving mature trees creates a sense of permanence for the development. In addition, mature trees add property value, cool the air, reduce ground-level ozone, and absorb a large volume of water.

Image Credit: Princeton Theological Seminary, 2018

Key to Success

Triple Bottom Line

The decision to incorporate green infrastructure into the project was made to expedite permitting, reduce cost, and provide an amenity to make the Charlotte Wilson Complex a highly desirable housing option.

Project Overview

Located in the West Windsor Campus of Princeton Theological Seminary (PTS), the 54-acre Charlotte Rachel Wilson Student Campus was originally made up of 25 buildings dating back to the 1950s. The surrounding area can be characterized as Mixed-Use, bounded by the Delaware and Raritan Canal State Park to the north, a condominium complex to the east, a shopping complex to the south, and Princeton Country Club to the west.

Since their original construction, buildings aged poorly and required extensive maintenance. Nevertheless, the complex provided needed housing that accommodated graduate students and their families. After extensive planning, PTS chose to redevelop a 23-acre portion of the complex as a LEED-accredited campus, with three garden-style apartment buildings containing 204 units and green infrastructure to manage stormwater. **The aesthetically pleasing new units have upgraded the school's housing stock and enhanced the living environment for prospective students.**

The project's proximity to the Delaware and Raritan Canal, as well as freshwater wetlands and flood plains associated with nearby Stony Brook, meant that special attention to stormwater management and water quality was needed. The development also had to be sensitive to aesthetic and historical concerns raised by the Delaware and Raritan Canal Commission (DRCC). **The use of green infrastructure to manage stormwater helped to meet NJDEP, local, and regional regulatory requirements. By utilizing green infrastructure and other complimentary stormwater strategies, the designers and PTS were able to provide a conservation-minded, low-impact development that preserved the wooded character of the site.**



“Wetland buffers, floodplains, and wooded areas were left largely undisturbed to provide a visual connection to the Delaware and Raritan Canal State Park and to protect valuable wildlife habitat adjacent to the nearby stream corridor.”

- Walter Bronson,
Project Engineer

Installation of subsurface
detention cells
Image Credits: ACT
Engineering, Inc., 2018

Infiltration basin immediately
after a storm event.
Image Credits: ACT
Engineering, Inc., 2018

Design Summary

The design team utilized green infrastructure to support a holistic vision of the development project, which sought to integrate naturalized stormwater management areas adjoining the existing wetland buffers. Natural areas dominated by hardwood trees around and within the project area were retained as much as possible.

- Two **infiltration basins** with extended detention were installed to provide primary water quality management and stormwater detention. The basins were designed to manage stormwater in accordance with NJDEP and local requirements. The basins were carefully sited to minimize disturbance to adjacent woodlands while their naturalized landscaping visually tied them into the surroundings. **The infiltration basins located at the perimeter of the site help to transition the carefully manicured landscape around the buildings to the more natural landscape beyond.** The decision to send overflow from the infiltration basins to the nearby canal using existing swales rather than storm drain piping was made to reduce cost and to provide additional water quality benefits through a surface vegetated conveyance system.
- Approximately 10,700 square yards of **porous bituminous pavement** were installed in parking lots and driveways where adequate separation to the seasonal high groundwater table could be achieved. The porous pavement served as water quality pretreatment for an underground extended detention system. An open bottom design provides some infiltration capacity.



Decision-Making

- The presence of sandy, highly permeable soils, coupled with relatively deep seasonal high groundwater levels, was one of the primary drivers for installing infiltration basins. One of the basins is an expansion and retrofit of an existing basin on site, which helped to minimize cost. The siting of the newly constructed basin repurposed an existing disturbed area to reduce the need for further encroachment into existing woodlands.
- The design utilized porous pavement at a cost of approximately \$550,000 for an added level of water quality protection to satisfy the concerns of the DRCC. Porous pavement also provides the 80% Total Suspended Solids (TSS) removal required by NJDEP prior to stormwater entering the underground detention system. The design team decided to use porous pavement rather than a manufactured treatment device to achieve TSS removal out of concern for cost and/or long-term maintenance requirements.
- The contractor utilized low-ground-pressure vehicles to minimize soil compaction during construction of the infiltration basins, underground detention systems, and landscape areas.

Challenges

- Permitting for the project was complicated due to multiple agencies having jurisdiction. Clear communication of the project's objective to minimize site disturbance was influential in obtaining approvals from different regulatory agencies.
- Construction challenges were overcome by paying careful attention to construction practices. For example, filter fabric was used to protect completed areas during infiltration basin and porous pavement installation. The fabric was carefully removed upon complete stabilization of the contributing drainage areas. Similarly, downstream discharge points were additionally reinforced to prevent erosion.

Maintenance Overview

The porous pavement requires periodic vacuuming instead of sweeping and is estimated to cost approximately \$3,500 per year. Salt is required for ice treatment rather than sand. The infiltration basins and subsurface-extended detention facilities require regular inspections to ensure the facilities are working properly. Repairs are made, as necessary, and typically include minor activities such as cleaning outlet control structures. There is essentially no required maintenance of the infiltration basins other than occasional cutting of vegetation on side slopes. The use of native hardy species around the infiltration basins reduces the need for pruning or regular watering.

Key to Success

Inter-agency Coordination
Close collaboration with DRCC was instrumental in obtaining approval from NJDEP regarding the siting of an infiltration basin on a pre-existing manmade wetland. While disturbance of the isolated wetlands was a cause for concern with NJDEP, the DRCC was able to make the case that clearing existing woodland was the more detrimental choice.



The Virtua Voorhees Hospital viewed across the stormwater wetland.
Image Credit: Dewberry, 2018

CASE STUDY 3 VIRTUA VOORHEES HOSPITAL

DEVELOPMENT TYPE:

Healthcare Campus

LOCATION:

100 Bowman Drive
Voorhees, Camden County, NJ 08043

MUNICIPALITY/NEIGHBORHOOD:

Major Business District

DEVELOPER/ DESIGN TEAM:

Virtua Health
Dewberry
Senior Project Manager
Christopher Cirrotti,
PE, PP, CME, LEED AP
HGA Architects & Engineers

SEWER TYPE:

Separate Sanitary and Storm Sewer

COMPLETION DATE:

May 2011

One of the three green roof gardens used as
a passive recreational element.
Image Credit: Dewberry, 2018

Project Overview

Ten years in the making, Virtua Voorhees is a 120-acre healthcare campus development constructed on a greenfield site along NJ State Highway Route 73 in Voorhees Township, Camden County, NJ. The site was assembled from a number of single-family, commercial, and vacant lots. The project consists of a 386-bed inpatient acute care hospital and 300,000-sf health and wellness center. The initial development on the campus was built by a partnership between Virtua Health and a private healthcare real estate developer. Virtua Voorhees achieved Leadership in Energy and Environmental Design (LEED) Silver certification.

The Virtua Voorhees campus was envisioned as a state-of-the-art healthcare development that promotes a sense of healing from the moment one arrives on the campus. This vision is supported by the presence of many green infrastructure practices throughout the development. From preservation of on-site freshwater wetlands, natural viewsheds, and lush native landscape treatments to site amenities such as walking trails and bike lanes, the campus allows patients, visitors, staff, and the community to experience the beauty of the setting while providing the highest level of healthcare and healing consistent with Virtua's mission to "be well, get well and stay well."

The 120-acre site lies along Route 73 is in a Major Business Zone district. As part of the project approval process, a General Development Plan defined the long-term vision for the eventual buildout of the campus and was developed and approved by Voorhees Township. The surrounding areas include residential neighborhoods, retail and commercial development along the state highway, a golf course, and a public park. NJ Transit enhances transportation opportunities with on-site bus stops.



Design Summary

The design team took on additional design and planning in order to incorporate green stormwater infrastructure and the associated water quality and aesthetic benefits. **The green infrastructure not only helped Virtua Health obtain NJDEP and local regulatory approval by delivering multiple environmental benefits, including wildlife habitat and stormwater quality treatment, but it also created a beautiful place to work and visit.**

By incorporating green stormwater infrastructure, the project also provides benefits to the local municipality by improving the water quality of stormwater leaving the site, reducing downstream flooding, and replenishing groundwater aquifers. The campus illustrates that the implementation of a sustainable approach to site development and stormwater management using green infrastructure is not only feasible, but also beneficial to the environment, the economics of a project, the property owner, and the community.

The well-integrated green infrastructure practices include a mixture of structural and nonstructural stormwater management techniques: surface and subsurface groundwater recharge basins, extended detention basins, wet ponds, constructed stormwater wetlands, vegetated swales, and rain gardens. Green roof areas are also incorporated into the building design to enhance “look down” views, provide passive cooling, and reduce roof runoff volumes. All site runoff eventually infiltrates into groundwater or discharges clean water to surface waterways at below pre-development rates.

- **Groundwater recharge basins** provide water quality treatment, runoff rate reduction, and groundwater recharge for a majority of the drainage areas at the south end of the campus. Minimal curbing on roadways and parking lots promotes sheet flow and shallow flow into linear roadside swales that convey runoff into the basins. By minimizing the amount of curbing

Green infrastructure can enhance the landscape and become an inviting space for employees and visitors.
Image Credit : Dewberry, 2018



through sheet flow and by using surface swales rather than underground piping, construction costs were reduced. Through this green infrastructure approach, the first flush of runoff has a greater opportunity to be completely retained on site and infiltrated to groundwater.

- **Subsurface infiltration** was incorporated as two large fields of HDPE arched chambers installed beneath parking areas which comprise a major subsurface infiltration system. These chambers collect rooftop runoff and directly recharge groundwater without the need for water quality treatment.
- **A constructed stormwater wetland** was an ideal green infrastructure practice for a poorly drained area with a high groundwater table located near the center of the development and flanked by two preserved wetlands. A stormwater landscape of microponds, high and low marshes, and permanent pools remove a large portion of sediment carried in runoff to achieve a TSS removal rate of 90%. The constructed stormwater wetland offered an opportunity to make the most of difficult site conditions and demonstrate compliance with regulatory requirements. A meandering walkway weaves through the complex and connects the wetland to other traditional stormwater features on site, creating a holistic and connected environment.
- **Vegetated swales** are located along the perimeter of much of the surface parking and campus loop roadway areas. By directly capturing runoff from these large impervious areas, the swales eliminate the need for traditional piped infrastructure to remove runoff, which reduced construction costs. Micro-scale design elements, such as check dams and intermittently-spaced inlets along the channels, promote infiltration, control stormwater flow, and prevent ponded water.
- Three large **rain gardens** sited at the north end of the campus collect runoff from the large employee parking lot while lush plantings of native trees, shrubs, and colorful perennials in the rain gardens serve as an attractive visual buffer along the north entry drive.
- **Green roofs** were strategically placed at lower roof levels to be visible from patient rooms, which create soothing “look down” views that would otherwise have been traditional, barren roofscapes.

“Studies show convincingly that views of trees, flowers, and water promote healing. And the ability to be outdoors, in a naturalistic landscape with trees, benefits patients and staff alike.”

(Franklin, 2012)

Decision-Making

The wide array of carefully chosen green infrastructure practices resulted in many benefits, including reduced construction costs, attractive views, and expedited compliance with regulatory requirements. The decisions that were made to incorporate green infrastructure are summarized below:

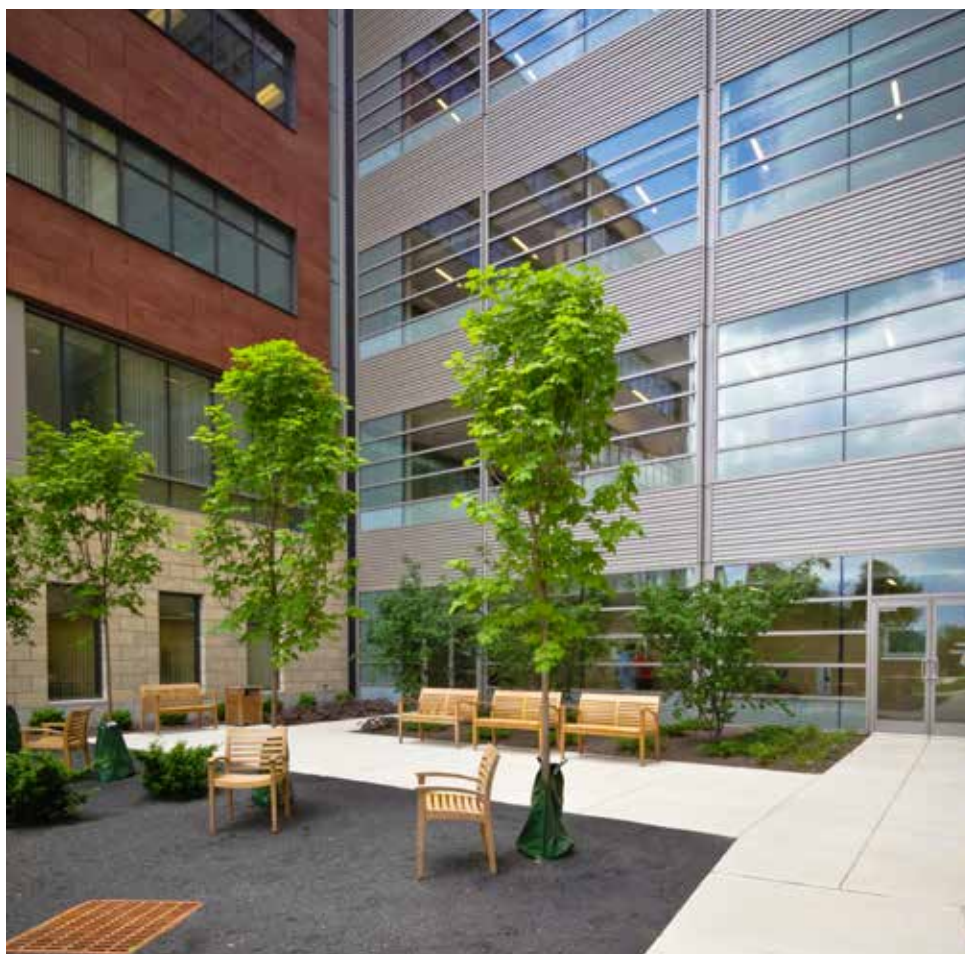
- Virtua's primary objective for this project was to create a cutting edge, high-quality environment to deliver exceptional health care services. In light of this primary objective, construction cost decisions were carefully weighed against the health system's mission statement. Accordingly, the design team elected to incorporate extensive green infrastructure practices as an opportunity to satisfy multiple needs: enhanced aesthetics, reduced construction and/or operating costs, increased natural landscape, and expedited regulatory compliance.
- The decision to eliminate curbing and traditional storm drain piping wherever possible resulted in hundreds of thousands of dollars in savings.
- The project development team decided at the beginning of the project to incorporate a site-sensitive stormwater design that responds to local soils, wetlands, woodlands, and topographic conditions. This strategy of utilizing a wide range of green stormwater practices successfully met the regulatory and functional requirements of the project.
- Green roofs were chosen as a cost-effective way to manage stormwater without the need for additional infrastructure. The minimal added weight was easily accommodated without significant change to the structural design.
- The design team's decision to incorporate green infrastructure and their close working relationship with NJDEP and New Jersey Department of Transportation (NJDOT) during the permitting process helped to meet the stormwater management goals of all parties without delay.

Green infrastructure practices were used throughout the parking lot of the hospital to handle road runoff.
Image Credit: Dewberry, 2018



Challenges

- For a project of this scale and magnitude, the design team had to negotiate a complex regulatory environment involving the requirements of multiple agencies. By incorporating green stormwater infrastructure, this process did not result in permitting and approval delays.
- Difficult site constraints and development program needs made for a challenging design effort. Green infrastructure helped to overcome this challenge. Implementing distributed green infrastructure practices to manage stormwater instead of more traditional detention storage areas in underground facilities resulted in a better design. While additional underground facilities would have increased valuable area for parking, the need for expensive pretreatment systems such as manufactured treatment devices made it more cost-effective to comply with water quality permitting requirements using green infrastructure.
- Incorporating green infrastructure into the construction sequence without negatively impacting the facilities was a challenge. Temporary stormwater controls such as rock check dams, temporary sediment basins, silt fence, haybale barriers, and temporary curbing were implemented prior to installing the permanent green infrastructure facilities in order to avoid damage during mass grading, earthwork, and paving operations. By using temporary controls, the vegetation in the swales and rain gardens was installed later in the construction process so plants were able to establish without the risk of sedimentation and damage from heavy equipment.



Areas of green infrastructure double as a space for people to gather and enjoy the outdoors.

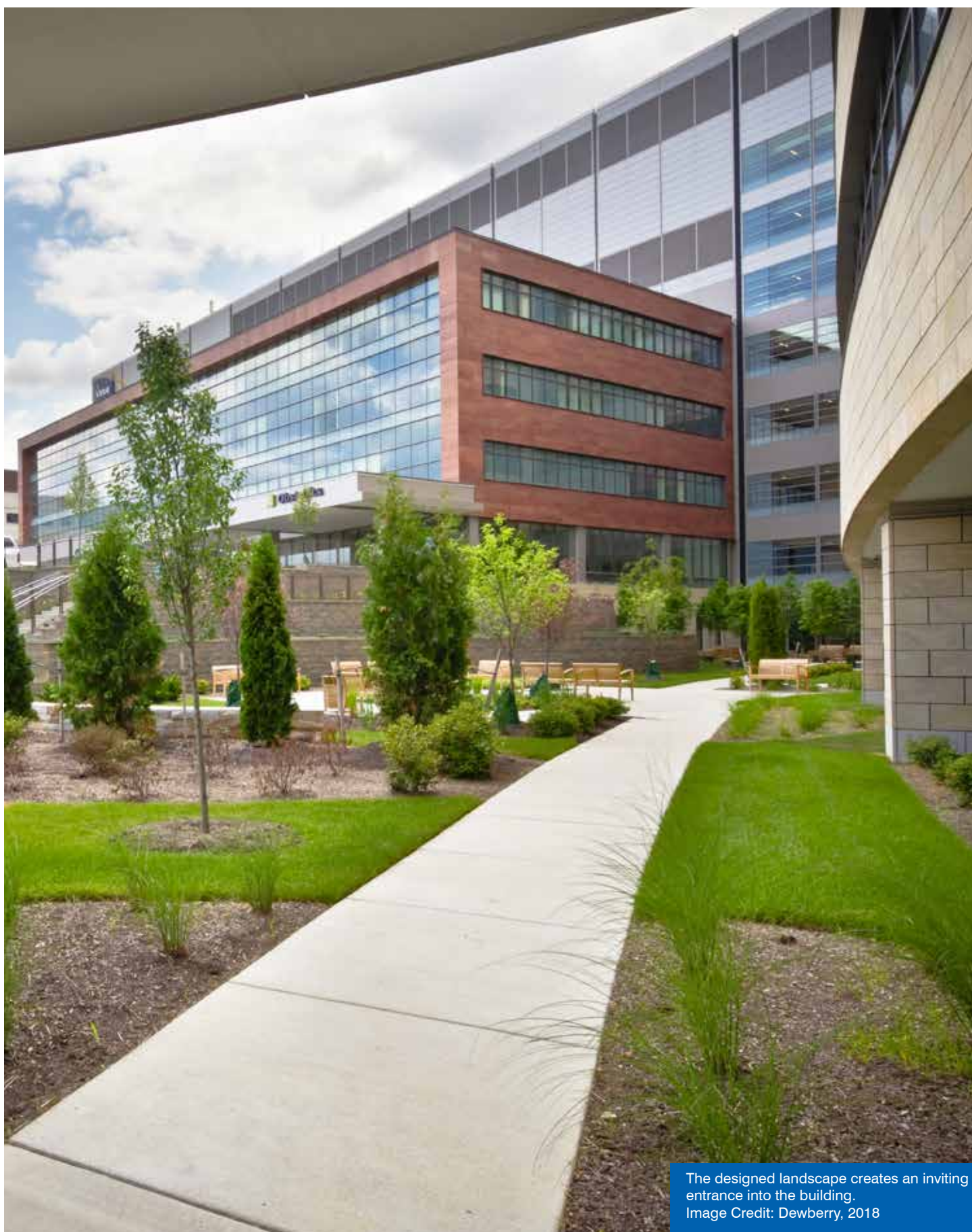
Image Credit: Dewberry, 2018

Maintenance Overview

- Maintenance of the green infrastructure and stormwater management measures is undertaken by Virtua's facility management group with the assistance of contract service providers.
- Maintenance for the green roofs is minimal and includes regular inspections to ensure that the plant material is in good condition and occasional watering is provided during extended periods of hot, dry weather.
- With extensive "no mow" meadow-type landscaped areas, mowing services are limited compared to traditional lawn areas.
- Water quality treatment is provided with nonstructural measures, so there is no need or cost for periodic removal of oils, trapped solids, and cartridge replacement as required by structural manufactured treatment devices.
- The recharge basins, constructed wetlands, wet pond, and vegetated swales all require minimal annual maintenance at a cost comparable to any typical landscaping contract.

A view of the landscaped amenities nestled within the architectural components of the campus.
Image Credit: Dewberry, 2018







Aerial rendering of 700 Jackson
Hoboken, NJ
Image Credit: Bijou Properties, 2020

CASE STUDY 4

700 JACKSON

DEVELOPMENT TYPE:

Urban Mixed-use Redevelopment

LOCATION:

700 Jackson St., Hoboken, NJ 07030

MUNICIPALITY/NEIGHBORHOOD:

City of Hoboken

Jennifer Gonzalez, AICP, PP, CFM, ENV SP, LEED GA, Director of Environmental Services/Chief Sustainability Officer

DEVELOPER/ DESIGN TEAM:

Bijou Properties

David Garber, Partner & CFO

Chris Mazzola, Development Manager

Matthew Testa, Director of Construction

Intercontinental Development, Inc.

Marchetto Higgins Stieve Architect

Langan

Leonard D. Savino, PE, Principal

Sony David, PE, Associate

Gregg Woodruff, PP, AICP, LEED-AP

BD+C, Associate/Sustainability Leader

SEWER TYPE:

Combined Sewer Overflow

North Hudson Sewerage Authority

COMPLETION DATE:

Completed

“This project will mitigate rainfall flooding in western Hoboken, which is vulnerable to flooding during intense rain storms”

- Jennifer Gonzalez,
Director of Environmental
Services/Chief
Sustainability Officer,
City of Hoboken

View of 770 House and adjacent park during construction. The park provides added value to the mixed-use building as well as stormwater storage.

Image Credit: Bijou Properties, 2020

Project Overview

700 Jackson Street Redevelopment and Resiliency Park is a mixed-use development in the City of Hoboken. The project is a public-private partnership led by local developer Bijou Properties and its partner, Intercontinental Real Estate. The redevelopment is part of a larger effort by the City to manage flooding and build resiliency through large-scale stormwater management. **The site contains a public park and plaza, a public gymnasium, 424 apartment units, a parking garage, and 30,000 square feet of retail space. Perhaps most impressive is the approximately 450,000 gallons of stormwater storage that will reduce localized flooding.**

In 2013, the City of Hoboken developed a Green Infrastructure Strategic Plan which identified this site as a potential resiliency park to retain stormwater. Concurrently, the United States Department of Housing and Urban Development (HUD) initiated the “Rebuild by Design” (RBD) competition as a tool for funding resiliency strategies in the aftermath of Hurricane Sandy. The RBD competition developed a comprehensive water management strategy for Hoboken consisting of four integrated components: resist, delay, store, and discharge. HUD awarded the State of New Jersey \$230 million to construct the resist component, which will reduce coastal flooding. The City and partners are working to implement the delay, store, discharge components which will reduce rainfall flooding. The 700 Jackson site, already identified as a potential redevelopment site by the City, became part of the City’s efforts to delay and store rainwater as a resiliency park.

As part of the development agreement, the developer designed and built a public component for the project which includes a 6,835-square-foot gymnasium, public open space, and an underground stormwater detention system. The public gymnasium, public open space, and stormwater system components of the project were completed early in the construction of the overall mixed-use development; ownership of those spaces has been turned over to the City. As part of the redevelopment design for this site, the City and developer prioritized the public space. This strategy resulted in the consolidation of development from the entire site to approximately one-third of the site through increased building height. The remaining two-thirds of the site served as area for the public space amenities.

The project exemplifies how to design a complex site within challenging urban conditions while providing stormwater management beyond previous state requirements.



Active green roof on the 770 House building. Residents can enjoy views of Hoboken while planters and lawn areas allow for added green space.
Image Credit: Bijou Properties, 2020



“Any stormwater design [...] should go through a process of identifying the most appropriate stormwater management practices to solve the specific problems of the site.”

- Gregg Woodruff,
Associate/Sustainability
Leader, Langan

Design Summary

The design of the 700 Jackson site evolved over time to maximize flood control and meet the City’s water management goals of delay, store, and discharge. The existing parcels consisted of entirely impervious surfaces. Through the creation of green space and reduction of existing impervious surface alone, the design would have been exempt from state water quality standards. However, working with the City and the North Hudson Sewerage Authority (NHSA), the design team went above and beyond requirements to provide additional treatment in the form of green roofs and an underground stormwater detention system.

- **Green roofs** will be used on areas of the proposed mixed-use complex. Both active and passive roofs are proposed. In the passive green roofs, sedum tray systems will be used to collect, store, and slowly release stormwater. The stormwater will then be directed to the underground detention system via pipes. The active roofs contain planters and usable space for tenants. The planters will reduce impervious surfaces and collect rain water.
- **Underground Detention** is the primary form of stormwater management. The system consists of High-Density Polyethylene (HDPE) pipes laid in a clean stone bed. This project includes connections from the underground detention to existing catch basins in the Right-of-Way in order to collect some stormwater from City streets immediately surrounding the site. An Opti sensor is installed as a way of controlling stormwater release from the site’s underground stormwater detention system prior to it being discharged to the City’s combined sewer overflow (CSO) system. The sensor will communicate with sensors throughout the CSO system. NHSA will remotely control the sensors via cloud to strategically release flows and reduce the impact on the CSO system.

Decision-Making

The selection of the stormwater system was primarily dictated by the realities of physical constraints on the site, specifically the shallow depth to groundwater and poor infiltration capacity associated with that condition. Stormwater design measures that were considered include a more dispersed storage approach and infiltration features. However, these alternatives were determined to be infeasible due to the shallow depth to groundwater.

Maintenance was another factor in the decision-making process. Because the stormwater detention system is located on the public parcel, there were concerns over debris and trash clogging surface systems.

- **Green roofs** were installed as both a stormwater management measure and an aesthetically valuable asset. These BMPs are incorporated as amenities for future tenants.
- **Underground Detention** was selected as the most effective measure for stormwater management on this particular site. The shallow depth to groundwater rendered infiltration impossible and eliminated BMPs with deeper profiles. Other forms of underground detention systems were also evaluated. Concrete chambers optimize storage but require heavy equipment for installation. The use of cranes in an urban environment can lead to road closures and complications in the construction process. The selected HDPE pipe with stone encasement is a straightforward design with relatively easy install and adequate storage for the proposed flood control.

“Any time you’re working in an urban environment, you should expect the unexpected.”

- Gregg Woodruff,
Associate/Sustainability
Leader, Langan



Interior of 770 House. The development features high-end amenities, including green roofs.
Image Credit: Bijou Properties, 2020

Challenges

The site's urban context presented a number of challenges for the design team. The majority of Hoboken has shallow depth to groundwater, numerous existing utilities, and intensive pedestrian and vehicular traffic. These constraints guided design decisions and offer learning opportunities for developers working under similar conditions.

Groundwater:

Shallow depth to groundwater can limit the types of BMPs used. The design team was not able to provide adequate separation to groundwater for infiltration BMPs while providing the required flood storage and remaining within the project's budget. Under other conditions, dispersed green infrastructure may have proved more effective. However, each case is site-specific and should be evaluated as a unique circumstance. Infiltration testing and soil borings should be conducted early in the design process. In this case, elevating the chosen BMPs off of the ground in the form of green roofs was deemed more efficient and cost effective than shallow surface features at the ground level of the site.

BMP Construction:

The design of BMPs in urban areas can be restricted based upon adjacent traffic patterns and safety concerns. Simplifying BMP design to avoid road closures proved most efficient for the design team. Detailed design plans further eased the construction process.

Maintenance Overview

The design team kept maintenance in mind throughout the design process. With the knowledge that the public portion of the project would be handed off to the City, access to the system and maintenance procedures were kept simple.

Maintenance for the underground system will be performed by the North Hudson Sewerage Authority through an interlocal agreement with the City. Hoboken's strategy for maintaining green infrastructure and flood control throughout the City is evolving with the increase in systems. Hoboken recently hired a landscape contractor to maintain all City-owned vegetated green infrastructure BMPs.

Key to Success

Design for Maintenance

Hoboken's strategy for maintaining green infrastructure BMPs involved hiring TEND, a landscape consultant, to provide detailed specifications and procedures. Private developers can make the same investment in order to ensure that green infrastructure continues to perform and function as an asset to the development.

BENEFITS OF GREEN INFRASTRUCTURE

A photograph of a modern, multi-story building with a green roof and a bioretention system in the foreground. The building features large windows and a wooden facade. The foreground is filled with lush green plants and flowers, including tall grasses and purple flowers. A concrete wall with a decorative carving is visible on the left side of the foreground. The sky is blue with some clouds.

Bioretention system at Sidwell Friends
Middle School
Image Credit: Andropogon Associates, 2020



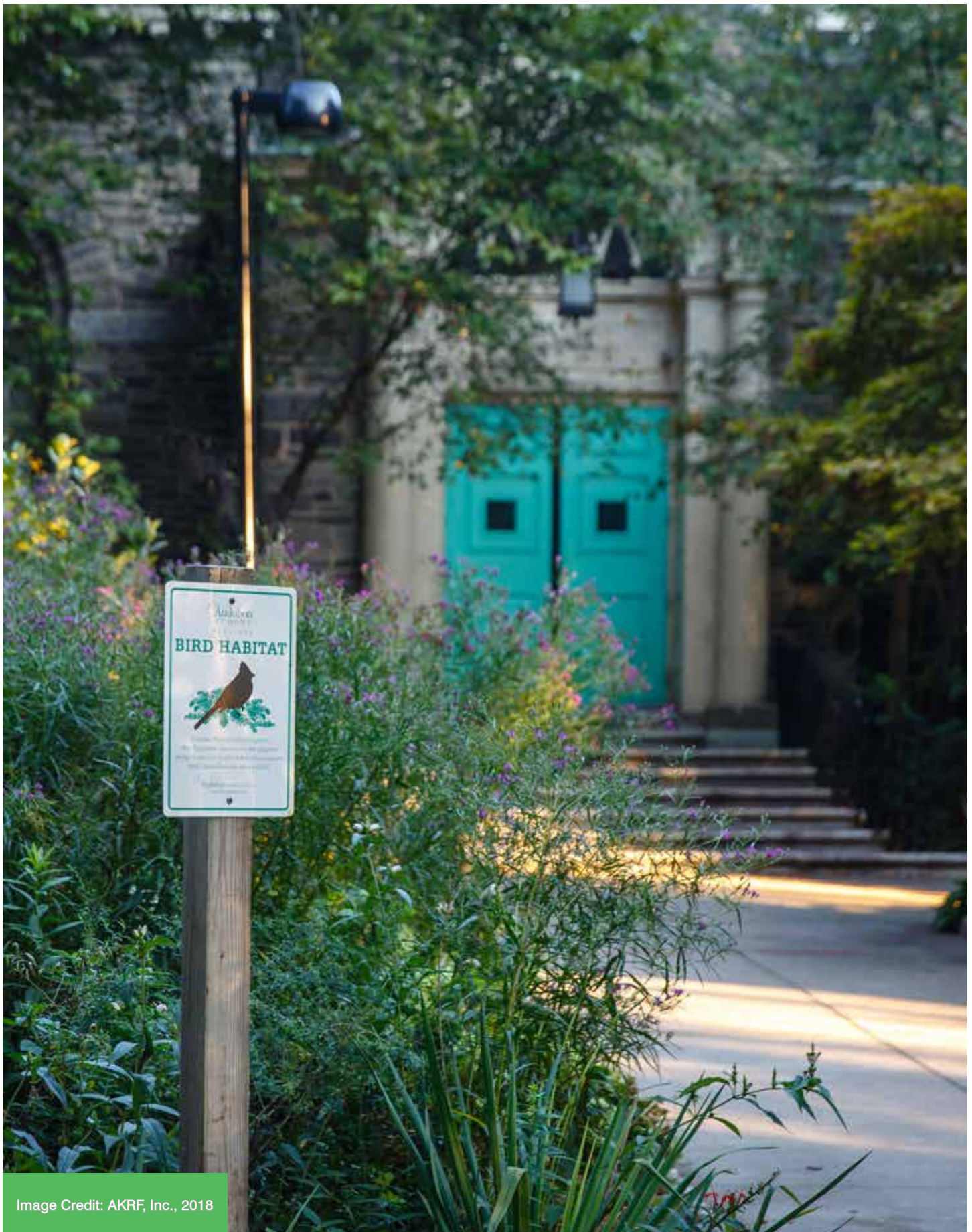


Image Credit: AKRF, Inc., 2018

BENEFITS OF GREEN INFRASTRUCTURE

Green infrastructure can offer distinct benefits over traditional gray infrastructure. Benefits fall into three categories: Financial, Community, and Environmental. These benefits, which often overlap, are referred to as the “Triple Bottom Line” of Green Infrastructure. **Using this three-lensed approach to evaluating stormwater management, green infrastructure far surpasses traditional gray infrastructure.** This chapter summarizes benefits of green infrastructure and shows developers how to realize and incorporate these benefits.

Financial benefits are often difficult to measure due to site-specific conditions. This chapter generalizes factors to consider in cost-based decision-making and provides specific maintenance cost comparisons.

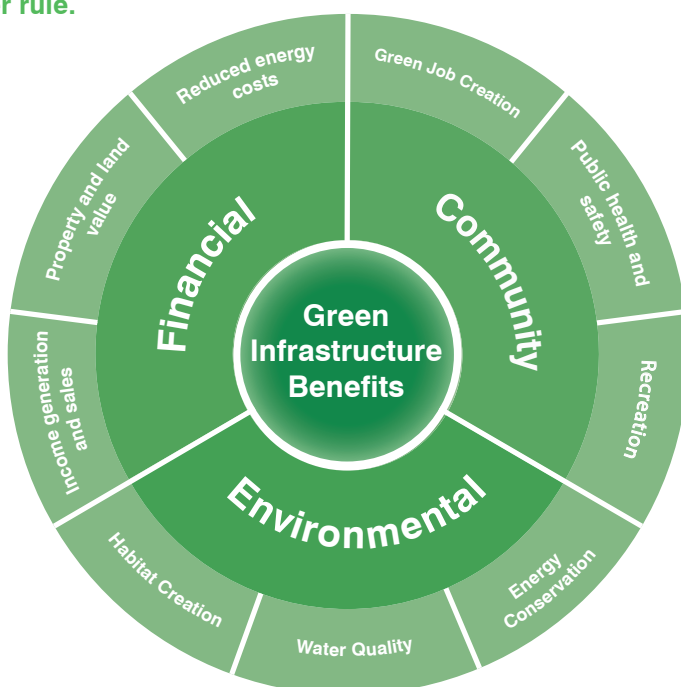
Community benefits are often discounted, but they can play a major role in garnering public support and attracting tenants. Improved exterior appearance and added amenities can only increase property values and potential rental incomes. Public-private partnerships for green infrastructure improvements as demonstrated in some of the case studies in this Guide can lead to unique funding opportunities and shared cost of long-term maintenance. Green infrastructure also provides several public health and wellness benefits including reduced heat island effect and improved air quality.

Environmental benefits are often mutually beneficial to surrounding communities and can attract environmentally-conscious clients. Additionally, use of sustainable BMPs for water re-use can save on utility costs.

Overall, having a holistic view of site development through this triple bottom line approach is integral to maximizing development benefits under the new stormwater rule.

“Green infrastructure is always introduced as a headache, not as an Advil. We need to change that.”

- Stephen Santola, General Counsel, Woodmont Properties



FINANCIAL BENEFITS

Green infrastructure can offer numerous financial benefits that are real and quantifiable. Depending on the type of practice used, financial benefits may include:

- Operational cost savings associated with lower building heating and cooling costs.
- Increased property values associated with more appealing landscape elements and improved opportunities for recreation.
- Higher market appeal for more socially conscious demographics, such as Millennials and Generation Z, leads to faster absorption.
- Marketing stories related to landscape and recreational appeal, better social and environmental conditions, climate resilience, and meeting LEED standards and other sustainability metrics build community support and shorten the public review phases.
- Decentralized systems designed to quantify the benefits of infiltration can result in additional buildable area.

Signs like these can be used to attract positive attention and add value to a project.

(LEFT) Image Credit: Maser Consulting, 2020

(RIGHT) Image Credit: E&LP, 2020



Operational Cost Savings

Many studies have shown that green infrastructure can help you save on long-term operations costs through savings in building energy use, specifically for green roofs, landscape maintenance, and potable water use.

- **Energy cost savings.** For buildings with a green roof installation, there are cost savings associated with reductions in heating and cooling needs due to better insulation (*General Services Administration*, 2011). When estimating the exact value of energy savings for a specific green roof, it is helpful to think of the roof's layer of plants and soil as insulation. Opportunities vary based on the size and type of your building, the overall site design, and the intended use.
- **Potable water cost savings.** Green infrastructure that incorporates rainwater harvesting for irrigation, toilet flushing, or industrial processes can significantly reduce costs associated with potable water service fees (*CNT*, 2010).

Increased Property Values

Green infrastructure can improve the appearance of the landscape and increase property value. Both home prices and commercial spending have been linked to the presence of green amenities, which can improve the character, visual quality, and overall “feel” of your development. This has tremendous implications if you are weighing the costs of green stormwater management versus the costs of a subsurface system.

Multiple studies have linked public green space and street trees with increased property value and spending:

- **An analysis of residential property in Philadelphia found a ten percent increase in the value of residences that were located near green infrastructure practices** (*Sustainable Business Network, The Economic Impact of Green Cities, Clean Waters*, 2016).
- On commercial property, the presence of green infrastructure-related plantings is associated with 5-7 percent higher rents (*Wolf, City Trees and Property Values*, 2007).
- Research on consumer behavior in shopping districts has found that customers are willing to pay significantly more for goods—up to 8-12 percent—to shop in landscaped areas with mature tree canopy (*NRDC, The Green Edge*, 2013).
- A study of apartment building rental rates in New York City found that buildings with a green roof can charge 16 percent higher rents after other factors have been controlled (*Ichihara & Cohen, New York City Property Values: What Is the Impact of Green Roofs on Rental Pricing?* 2011).

Simply put, green infrastructure can help make your site a place where people want to spend time—to live, shop, relax outdoors, or take a morning walk. This increased foot traffic and curb appeal can lead to direct financial benefit.

“In Philadelphia, green infrastructure is associated with a 10% increase in property values, a 7% increase in commercial office rents and a 5% increase in apartment rents.”
(GSI Partners / Econsult Solutions, 2016)



Allowing access to a green roof is a way to increase customer demand and add value to the property.
Image Credit: Live Roof, 2018

Marketing Opportunities

There are several ways in which developers can use green infrastructure to add value to projects and differentiate their brand in the marketplace. **Financial benefits can be marketed as value-added amenities that create a competitive advantage.** Indirect benefits can be leveraged to align the project with a social and environmental purpose that can resonate with like-minded customers. In some cases, customers may even be willing to pay a premium for these types of services, as evidenced by the ongoing popularity of green building products and LEED developments.

Another way of marketing green infrastructure is through the use of landscape photography to document the visual aesthetic of the site, such as the aerial photo below used to represent the appearance and character of a cutting-edge park designed for the Philadelphia Navy Yard.

Image Credit: Halkin Mason
Photography, 2018



Increased Yield

Under the new stormwater rules, developers can realize increases in lot yields. Decentralizing stormwater management and incorporating green infrastructure into parking lots, site amenities, and unused spaces, decreases areas dominated by large end-of-pipe basins. As a result, developers may be able to incorporate additional residential units, commercial spaces, and other features that add value to the development. This may also decrease construction costs by eliminating expensive underground detention systems in favor of small, surface BMPs.

Municipal Incentives

Some municipalities may occasionally offer incentives for development projects that incorporate a significant amount of green infrastructure. **These kinds of incentives are not common practices and do not relieve the developer from NJDEP requirements. Possible incentives vary by municipality, but they could include the following:**

- **Density bonuses.** In some cases, development projects may be allowed to exceed municipal density limits if green infrastructure is incorporated in a certain quantity or configuration.
- **Tax abatements.** Municipalities may offer multi-year tax abatements for projects that incorporate green infrastructure, especially if the benefit to the community and/or municipality can be demonstrated.
- **Municipal connection fee credits.** It may be possible to cost share the price of the project's sewer connection with the municipality if the proposed development can support municipal stormwater management goals.
- **Redevelopment area bonuses.** Municipalities may offer a one-time tax credit for development projects that incorporate green infrastructure in a way that benefits the local community.

COMMUNITY BENEFITS

In addition to the direct benefits green infrastructure can offer to developers and property owners, there are numerous benefits to communities associated with public greening, better air, and green jobs opportunities. **The benefits that green infrastructure offers to a community can help build stakeholder support for the development project and increase community interaction with a project.**

Beautification of Public Spaces

Generally, a green infrastructure approach is associated with more green space as well as better landscape design. Public spaces will look and feel more “green,” a quality that studies have found can drive positive feelings about a place. This is evidenced by people’s willingness to pay more for properties with increased greenery, as noted earlier (“Increased Property Values” section on page 93).



The Schuylkill River Trail in Philadelphia highlights the aesthetic value that bioretention basins and other green infrastructure can add to public spaces. Image Credit: E&LP, 2020

Opportunities for Recreation

Greening public spaces creates more opportunities for outdoor activities like walking, jogging, biking, and bird watching. Trails, courtyards, roof decks, flexible lawns, athletic fields, sports courts, tot lots, and playgrounds are all typical development amenities that can easily integrate with green infrastructure BMPs. Developers should view their amenity spaces as prime opportunities to co-locate green infrastructure systems. This will not only improve the aesthetic and functional value of the space but will also avoid the loss of developable area caused by locating the green infrastructure in isolated spots where it does not serve any other use beyond stormwater management. Incorporating these elements within a design can make a development desirable for future tenants and increase local support for a project.

Green Job Creation

Green infrastructure creates additional job opportunities in design and construction. In Philadelphia, the green infrastructure sector provides approximately 1,160 jobs per year. Green infrastructure development requires specialized skills in design, construction, and maintenance, creating opportunities for jobs in the region. In New York and Philadelphia, specialized training programs have been developed to transition service providers from the landscaping and construction industries into green infrastructure construction and maintenance.

Green infrastructure workers installing geotextile matting to control erosion in a bioretention system.
Image Credit: AKRF, Inc.



“Improvements like this create a derived benefit for the residents of a community.”

- Kevin Kernahan, Sr.
Vice President - Land
Development, Toll
Brothers, Inc.

Public Health and Wellness

- **Air Quality** - Green infrastructure systems that increase the number of plants, especially trees, in a development will help to keep the air clean by absorbing air pollution. Improved air quality reduces the rate of respiratory illnesses like asthma. In addition to direct pollution removal, green infrastructure can help reduce energy costs as noted earlier, which can help reduce fossil fuel needs and the carbon footprint of a site.
- **Heat Mitigation** - Plants and trees can decrease temperatures in the immediate vicinity, which in summer can have a measurable effect on heat-related illnesses. Even porous pavement can reduce heat stress in summer by allowing water to evaporate. Heat reduction is especially important in urban areas where mean temperatures can be much greater than surrounding suburbs.

Public Safety

Studies have shown that where there is green infrastructure in public spaces, there is often a reduction in crime. In Philadelphia, a study concluded that areas within one quarter mile of vegetated green infrastructure projects experienced a significant reduction in burglaries and narcotic possessions (*Kondo et. al*, 2016). Green infrastructure may also help to slow traffic when used in certain configurations in the right-of-way (*EPA*, 2015).

ENVIRONMENTAL BENEFITS

In addition to the direct benefits green infrastructure can offer to developers and property owners, there are numerous benefits to the environment. These include improved water quality, energy conservation, habitat creation, and flood prevention, which are mutually beneficial to surrounding communities. Development is trending towards more resilient designs that allow for long-term planning in changing environments. **Developers can not only garner public support through environmentally conscious designs, but they can also ensure the long-term viability and resilience of a project.**



Green infrastructure can provide benefits to pollinators, such as butterflies and bees. These pollinators are essential components of our ecosystems.

Image Credit: E&LP, 2020

Water Quality

Stormwater quality can be significantly improved by green infrastructure. Green infrastructure vegetation filters pollutants and reduces impacts to groundwater. Improved water quality helps reduce human impacts to local wildlife, which supports the natural systems surrounding built infrastructure.

Green infrastructure removes sediment, nutrients, and other pollution from runoff and can help increase groundwater reserves through infiltration. Certain types of green infrastructure can also reduce flooding damage to property and to streams. It can also be a cost-effective alternative to traditional water treatment infrastructure.

Flooding

Green infrastructure can reduce the effects of flooding in an area. Providing natural stormwater systems restores naturalistic buffers to coastal areas and manages runoff in developed areas. Flood control protects local ecosystems and mitigates impact from proposed impervious surfaces.

Recent catastrophic storm events have illustrated the value of resilient infrastructure planning and flood mitigation and prevention. State entities like the I-Bank offer revenue bonds to make loans to finance the construction of eligible environmental and transportation infrastructure projects for municipalities. The development community has felt the ripple effect of this rapidly changing landscape. Public-private partnerships to integrate flood prevention into redevelopment projects are becoming more regular. Green infrastructure is one of the key components in this aspect of effective resiliency planning.

Habitat Creation

If designed using native plant species, green infrastructure can provide habitat for a variety of beneficial animals such as birds and pollinators. Although developers may not immediately recognize the value of habitat creation, pollinators provide various “ecosystem services” essential for humans. Approximately one third of food production relies on animal pollination (EHP, 2015). Consequently, the agricultural economy relies heavily on pollinators. A study (Gallai et. al, 2009) approximated the economic value of pollinators to be \$167 billion.

Mercer Meadows Environmental
Education Basin in Mercer County,
New Jersey.
Image Credit: E&LP, 2020

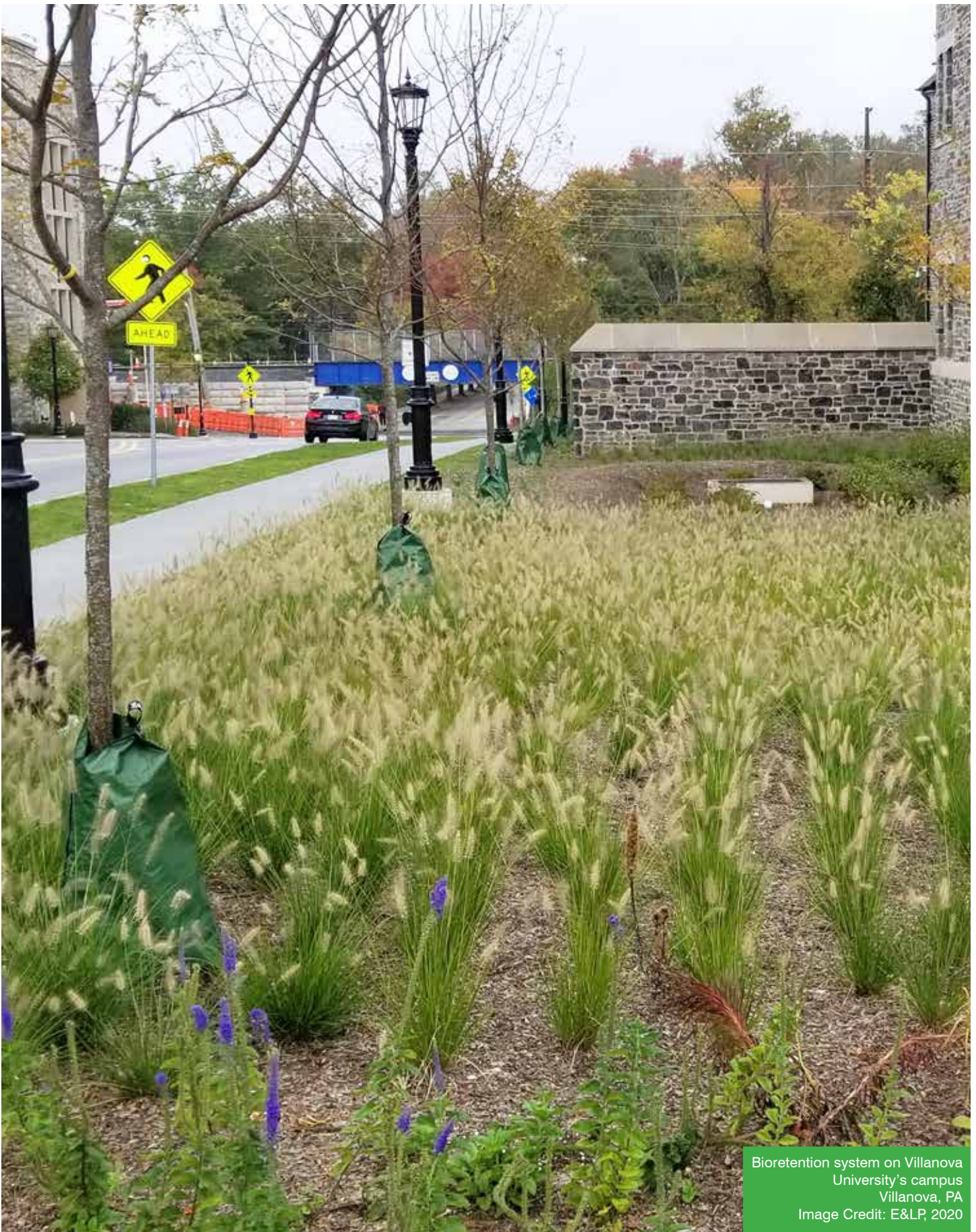


Energy Conservation

Shade trees located around buildings help regulate outside temperature, slow wind, and reduce temperatures in warm weather. Likewise, green roofs help reduce the amount of solar heat that enters a building in summer and provide year-round insulation. These benefits have the effect of reducing overall energy usage, and consequently, the carbon footprint of the development. As noted earlier, energy conservation also makes these buildings more cost-effective to operate in the long term.

Green roofs, like the one on University
of Pennsylvania’s Nursing School, can
reduce heating and cooling needs
by naturally regulating changes in
temperature. Image Credit: Viridian
Landscape Studio, 2020

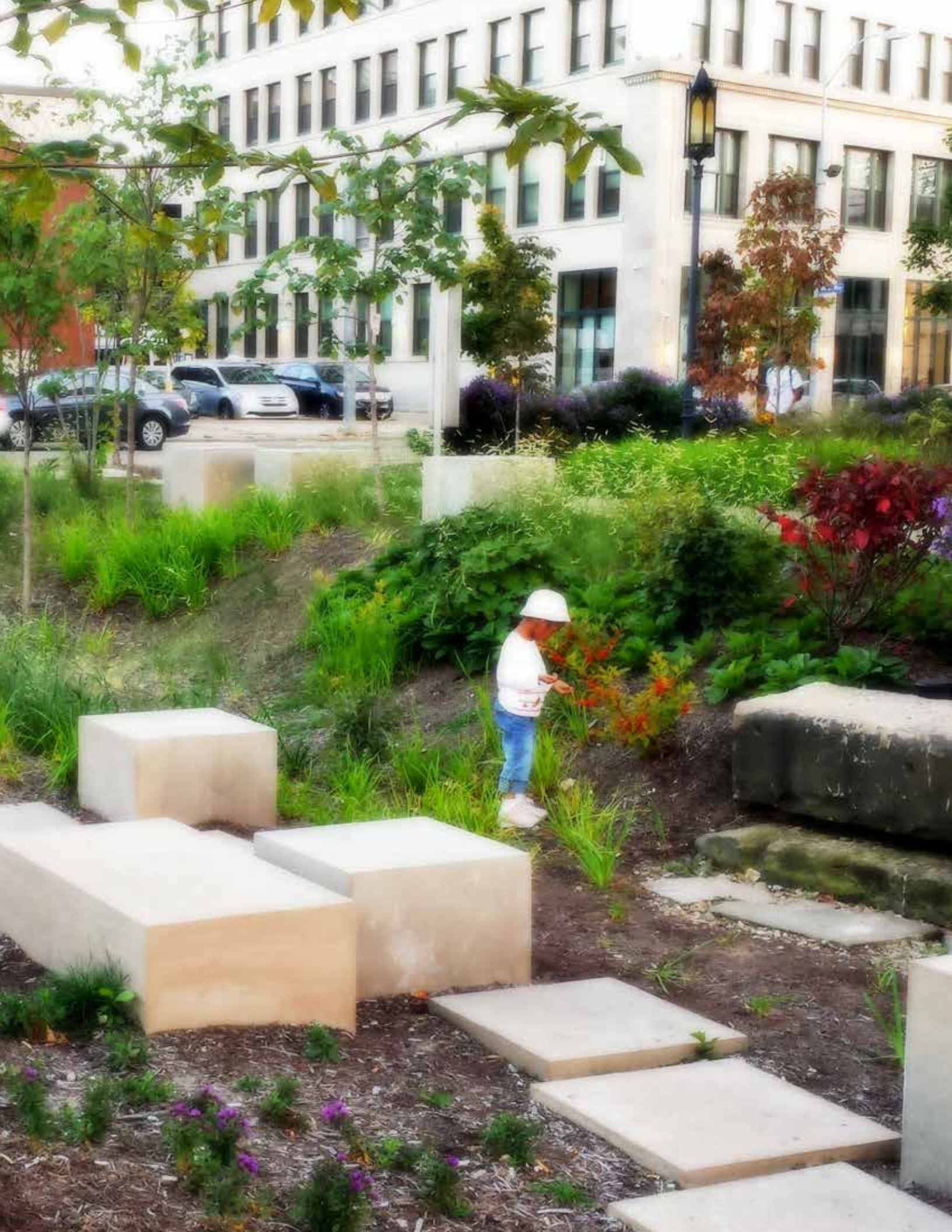




Bioretention system on Villanova University's campus
Villanova, PA
Image Credit: E&LP, 2020

FREQUENTLY ASKED QUESTIONS

Cathedral of Hope Rain Garden,
East Liberty Pittsburgh, PA
Image Credit: Viridian Landscape
Studio, 2020



FREQUENTLY ASKED QUESTIONS

GENERAL QUESTIONS

What is green infrastructure?

Green infrastructure is an approach to managing stormwater that is modeled on natural processes and systems. The NJDEP defines green infrastructure as stormwater management measure that manages stormwater close to its source by: 1) Treating stormwater runoff through infiltration into subsoil; 2) Treating stormwater runoff through filtration by vegetation or soil; or 3) Storing stormwater runoff for reuse. Unlike conventional gray infrastructure, which carries rainwater away from where it falls through gutters, drains, and pipes, green infrastructure keeps most stormwater on site through infiltration and beneficial reuse. In urban and suburban areas, this helps restore the natural water cycle and provides many environmental benefits. Rain gardens, green roofs, pervious pavements, and other types of green infrastructure practices can save money, satisfy permitting requirements, and increase public acceptance of your development project.

Green infrastructure practices have been installed successfully throughout New Jersey and they have proven to be as effective as gray infrastructure at managing stormwater in many settings. They offer a cost-effective way for developers to meet regulatory requirements, provide aesthetic enhancements for communities, attract customers to retail centers, and reduce long-term building energy costs.

Where can I learn more about green infrastructure options to consider for my next project?

NJDEP's Stormwater Best Management Practices (BMP) Manual offers thorough guidance on all facets of stormwater management planning, design, and compliance. In addition, Rutgers Cooperative Extension (RCE) has created the *Rutgers Green Infrastructure Guidance Manual for New Jersey* in which the different types and benefits of green infrastructure practices are described. Other useful resources are available through the Georgetown Climate Center, the University of New Hampshire, the Center for Watershed Protection, Philadelphia Water Department, Villanova University, the New York State Sustainable Design Manual, and the EPA.

How do I know if my team has the right skills?

While general knowledge of grading and landscapes is important for all contractors, many construction teams lack the knowledge and experience to successfully build green infrastructure. Stormwater management designs are site specific. Green infrastructure design can have even more specificity due to soil media and plants associated with the system. Not all contractors are prepared to construct such systems. Be sure to require a demonstration of existing green infrastructure work as well as references for those projects during the bid process. Mandatory Pre-Bid meetings can help the design team convey the complexity of the systems to contractors. A contractor associated with subconsultants specializing in green infrastructure should be seriously considered. For certain systems, such as green roofs, familiarity with construction processes may determine the success or failure of a project.

In addition to a contractor with experience, it is also important to select design professionals with green infrastructure portfolios and a high degree of detail in their work. Engineers and landscape architects may be hired as a team to ensure that green infrastructure functions on a vegetative and hydrologic level in addition to an aesthetic and programmatic one. The transition from the design phase to the construction phase of a project is key as the owner, design professionals, and contractors need to be coordinated and aligned on the project goals and expectations. Throughout the entire process, communication between the client, developer, engineer, landscape architect, architect, contractor, and owner is vital.

Are there special requirements for the soil used in green infrastructure systems, or can I use topsoil?

There are specific requirements for “engineered soil” used in all types of bioretention systems, including rain gardens. Engineered soil is not topsoil. For specific guidance about soil mix, soil bed requirements, and best practices for soil amendments such as compost, consult Chapter 9.1 “Bioretention Systems” of the NJDEP Stormwater BMP Manual.

REGULATORY

When do these regulations come into effect?

The NJDEP released the rule change into the state register on March 2, 2020. A one-year implementation period allows municipalities, developers, engineers, contractors, and other affected parties to adopt these rules into their policies, practices, and in the case of municipalities, their ordinances. On March 2, 2021, the rules will be in full effect, and all new development will be required to meet the new stormwater standards.

Does my town have the same requirements as the new NJDEP rules?

In addition to incorporating NJDEP stormwater rule standards and requirements into local ordinances, municipalities have the option to impose higher standards on non-residential projects than those set forth in N.J.A.C. 7:8. For instance, some municipalities define a “major development” with a smaller area of disturbance than the NJDEP’s one-acre standard. Thus, a project that is exempt from NJDEP major development regulations may still be required to provide stormwater management. Check your local ordinances early in the design process in order to ensure compliance.

Will green infrastructure help me qualify for LEED certification?

Yes. The LEED rating system offers up to four points toward certification for managing rainwater on site. Points are awarded based on the percentile of regional or local rainfall events that are managed using green infrastructure. For example, managing rainfall in the 80th percentile is worth one point, while the 95th percentile is worth four points. It is calculated using a comparative analysis of daily rainfall data.

Where do I find more specific information about meeting the new requirements?

The full text of the rules as adopted on March 2, 2020, along with a set of Frequently Asked Questions can be found on NJDEP’s website (njstormwater.org). The website also includes revised or new chapters of the BMP Manual (Chapters 5, 12 and 13) and a revised model ordinance (Appendix D) to provide detailed information about complying with the new green infrastructure requirement. All of these resources can be accessed through the online version of this Guide.

MAINTENANCE

Do all rain gardens look weedy and overgrown?

Rain gardens can be planted to look naturalistic, like a meadow, or they can be maintained with a more formal garden appearance. The plants and landscape design that are chosen will determine the appearance. If you think your customers would prefer a garden-like aesthetic over a meadow, simply communicate this need to the landscape architect or engineer. Like any garden, regular maintenance will ensure that it does not become weedy and overgrown. Unlike gray infrastructure, these are living systems and failure to provide regular maintenance to the vegetation will have a noticeable aesthetic impact.

Does green infrastructure require more maintenance?

No. A common misconception about green infrastructure is that it requires significantly more maintenance than traditional gray infrastructure or traditional landscape maintenance. This is not the case. Maintenance tasks are usually routine and can be done by the property owner or traditional landscape maintenance crew. Additional education may be needed for landscape crews unfamiliar with green infrastructure systems. However, the tools, practices, and manpower required are unaffected.

All stormwater management systems, whether gray or green, are recommended to have regular maintenance after storm events to inspect for clogs, debris, sediment accumulation, etc. The main difference is that failure to keep up with regular maintenance of a vegetated green infrastructure system will have a more noticeable aesthetic impact than an underground gray system.

Maintenance varies depending on the type of green infrastructure practice. For example, recommended maintenance for pervious asphalt pavement involves biannual vacuuming to remove fine sediments. Less overall maintenance is required compared to regular asphalt due to superior snow melting characteristics.

Landscape practices need regular maintenance to remove debris, replace mulch, and maintain vegetation (weed removal, cutback of dead vegetation, etc.). Inspections for erosion and sediment accumulation, pH testing, and other specified maintenance tasks can be performed occasionally as needed.

Since it collects water, does green infrastructure also breed mosquitoes?

Mosquitoes are one of the most common concerns that citizens tend to raise about green infrastructure, but this concern is addressed by standard design requirements. Green infrastructure practices are designed to drain within 72 hours or less, which will prevent colonization of mosquitoes that take about 72 hours to develop into their adult stage. Rain barrels, which may contain standing water for longer, should be covered with a mosquito net or screen to prevent mosquitoes from laying their eggs. Owners of rain barrels may also use microbial insecticide (BTI) granules or “dunks,” an organic and highly effective way to prevent mosquitoes from multiplying.

Will road salt kill the plants in green infrastructure practices?

Green infrastructure practices, especially those located next to streets or sidewalks, should be designed with plants that are salt tolerant. They are also designed with well-drained soil that helps flush salt through the soil more rapidly and reduce high concentrations that negatively affect plants. Thus, road salt rarely kills the plants, although it can cause stress and damage if used in large quantities. To reduce the potential for any damage, you can choose eco-friendly salt alternatives such as calcium chloride, which is safe for plants and pets, or you can reduce the amount of salt spread.

How well does pervious pavement work? Is it durable?

The key difference between conventional concrete and asphalt pavements compared to pervious pavements is that the smallest stone particles, or fines, are left out of the pervious pavement mixture. This leaves small voids that allow water to infiltrate through the pavement. However, these pore spaces do slightly reduce the durability of the pavement in comparison with conventional pavements. Therefore, pervious pavements should be used strategically in areas with low vehicular traffic like parking stalls in parking lots or pedestrian and bicycle pathways. With proper design, construction, and maintenance, pervious pavement works well for many years, including in winter weather. Black ice does not form on pervious asphalt, as any thawed water infiltrates; thus, pervious asphalt can help prevent slip and fall accidents. The admixtures and binders selected will have significant impact on the pavement's effectiveness. Refer to the NJDOT specifications and National Ready Mixed Concrete Association for design guidance. Durability varies based upon the type of pervious pavement system selected. For grass pavers, gravel systems, resin-bonded aggregates and various other products, consult manufacturer guidelines for construction and maintenance procedures.

Will a green roof work in winter?

Green roofs are still able to perform in cold weather, although not necessarily at the same level of effectiveness as during warm seasons. The soil in green roofs is porous and remains pervious when frozen. Consequently, rainfall as well as snow that melts during freeze-thaw cycles can still be stored, although the water will not be used by dormant plants.

Where do I find more information on maintenance for green infrastructure?

Various resources exist to guide contractors, developers, and maintenance crews in maintaining green infrastructure. The New Jersey Department of Environmental Protection provides sample maintenance plans for Best Management Practices outlined in this guide. Additional online resources include the Philadelphia Water Department's "Green Stormwater Infrastructure Maintenance Manual, Version 2.0." The manual provides descriptions of routine maintenance procedures, frequency of maintenance, and preventative maintenance.

The Environmental Protection Agency (EPA) provides maintenance guidance in a "Green Stormwater Operations and Maintenance Manual." The guide demonstrates levels of maintenance service from "Excellent" to "Poor." This system is useful for evaluating the performance of your maintenance team.

How do I discourage geese from populating the green infrastructure on my site?

Geese can be both a nuisance and a destructive force on green infrastructure. Young vegetation is particularly attractive to geese. There are several methods for repelling geese that should be considered in the design process. The most natural and effective is the use of vegetative buffers. Buffers should include tall grasses around the perimeter of the green infrastructure feature.

COST

Does green infrastructure cost more?

Green infrastructure practices often are more cost-effective than traditional gray infrastructure. Integrating green infrastructure into development projects can reduce costs by decreasing the amount of underground drainage piping and structures needed to manage stormwater, which reduces construction costs. Green infrastructure can also reduce operations and maintenance costs associated with development properties. For example, a green roof can reduce heating and cooling costs for a building. Green roofs also last longer than conventional roofs, which reduces replacement costs. In some cities and municipalities, there are incentives for use of green infrastructure, such as expedited reviews, density bonuses, connection fee credits, and redevelopment area bonuses. Consult the jurisdiction where the development is located for options.

Will a green roof cost more because of its structural requirements?

Green roof cost will depend on the type of roof and the amount of weight associated with the type of system designed. A new building can be designed to support this additional weight. For existing buildings, a structural engineer should be consulted to ensure the rooftop is able to support the additional load. In many cases, the lightweight materials used for green roof construction allow for a retrofit on an existing building.

Will using green infrastructure on my projects increase my costs to meet building codes?

If designed thoughtfully, green infrastructure should not affect your ability to meet building codes. In most cases, green infrastructure can be sited far enough away from the building to avoid any potential concerns about infiltrating near foundations, etc. In the case of green roofs, these are most commonly integrated as part of the overall building design, and any potential increase in structural loads is addressed through the normal design process. Before installing green infrastructure, it is always advisable to check municipal codes, design standards, and planning to determine potential impacts on the development process. There are different steps that can be taken to address issues that might arise as a result of regulations and codes. For more information, visit the US Environmental Protection Agency website.

Does green infrastructure qualify me for any tax abatements or tax savings?

Currently, green infrastructure practices do not usually qualify for abatements or tax savings. Tax abatements or tax savings vary from municipality to municipality as each city or town decides what will or will not qualify for tax abatement or tax savings. Contact your local municipality for information about abatements or other incentives.

RESOURCES LIST



Resources List

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3. Rutgers Cooperative Extension Water Resources Program. Retrieved from <http://water.rutgers.edu/index.html>
4. *Brownfield and Contaminated Site Remediation Act, N.J.S.A. 58:10B-1*. Retrieved from <https://www.nj.gov/dep/srp/regs/statutes/bcsra.pdf>
5. *Chesapeake Bay Landscape Professionals Program*. Retrieved from <https://cblpro.org/>
6. Center for Neighborhood Technology (2010). *The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits*. Chicago, Illinois.
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17. Sustainable Business Network of Greater Philadelphia. (June 2019). *The Economic, Social, and Environmental Case for Green City, Clean Waters: An Updated*. Philadelphia, Pennsylvania.
18. United States General Services Administration (2011). *The Benefits and Challenges of Green Roofs on Public and Commercial Buildings*. Retrieved from GSA Website: <https://www.gsa.gov/portal/content/166443>
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20. United States Environmental Protection Agency. (January 2015). *Green Infrastructure Opportunities that Arise During Municipal Operations*.
21. University of New Hampshire Stormwater Center. *Maintenance Guidelines and Checklists for Pervious Pavements and Infiltration Beds*. Retrieved from <https://www.unh.edu/unhsc/>
22. *Urban Land Institute (ULI) Case Studies*. Retrieved from <https://casestudies.uli.org/>
23. Villanova University. Retrieved from <https://www1.villanova.edu/villanova/sustainability/>
24. I tree. Retrieved from <https://www.itreetools.org>

All permit applicants are encouraged to consult directly with NJDEP staff and/or NJDEP regulations and guidance documents regarding compliance issues.



**New Jersey
Builders Association**

THANKS TO OUR CONSULTANT TEAM:

