United States Environmental Protection Agency

2012 GREEN INFRASTRUCTURE TECHNICAL ASSISTANCE PROGRAM
Pittsburgh UNITED
Pittsburgh, Pennsylvania

Addressing Green Infrastructure Design Challenges in the Pittsburgh Region

Space Constraints

Photo: Tree Box Facility using Silva Cell at the August Wilson Center for African American Culture

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About the Green Infrastructure Technical Assistance Program

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

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

EPA encourages the use of green infrastructure to help manage stormwater runoff. In April 2011, EPA renewed its commitment to green infrastructure with the release of the *Strategic Agenda to Protect Waters and Build More Livable Communities through Green Infrastructure*. The agenda identifies technical assistance as a key activity that EPA will pursue to accelerate the implementation of green infrastructure.

In February 2012, EPA announced the availability of $950,000 in technical assistance to communities working to overcome common barriers to green infrastructure. EPA received letters of interest from over 150 communities across the country, and selected 17 of these communities to receive technical assistance. Selected communities received assistance with a range of projects aimed at addressing common barriers to green infrastructure, including code review, green infrastructure design, and cost-benefit assessments. Pittsburgh UNITED was selected to receive assistance developing fact sheets and technical papers to provide solutions for site conditions that are perceived to limit green infrastructure applicability.

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

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Introduction

Future development in the Pittsburgh area is expected to involve significant development on space-constrained sites, including redevelopment and infill sites in dense urban environments. Integrating green infrastructure into these development sites can minimize urban stormwater impacts and provide many other environmental benefits, including improved air quality and reduced urban heat island impacts. Although the design of green infrastructure practices on space-constrained sites must be considered early in the planning and design process, many effective design practices are available for this development context.

Green infrastructure is an important design strategy for protecting water quality while also providing multiple community benefits. EPA defines green infrastructure as structural or non-structural practices that mimic or restore natural hydrologic processes within the built environment. Common green infrastructure practices include permeable pavement, bioretention facilities, and green roofs. These practices complement conventional stormwater management practices by enhancing infiltration, storage, and evapotranspiration throughout the built environment and managing runoff at its source.

This paper describes strategies to implement green infrastructure on space-constrained sites, defines the extent and nature of space-constrained sites in and around Pittsburgh, and provides examples of projects successfully implemented on space-constrained sites. The goal of this paper is to provide recommendations for design that are based on facts, research, and engineering in order to help practitioners make informed decisions regarding the use of green infrastructure on space-constrained sites.

Space Constraints and Stormwater Management Overview

Future development in the Pittsburgh area is expected to involve significant development on infill and redevelopment sites. Several characteristics of these sites may limit the space available for stormwater management. First, redevelopment and infill sites often have high percentages of impervious cover and low percentages of open space. This lack of open space may limit the ability to apply soil and vegetation-based practices. Second, redevelopment and infill sites may include many existing features that must be protected from construction or infiltration. These include buried utilities, existing structures such as basements and sewers, and mature trees. Finally, redevelopment and infill sites must accommodate multiple uses in a limited area. Care must be taken to maintain all the required uses, such as building access and required moving lane widths.

One of the challenges to the use of green infrastructure in the greater Pittsburgh area is the perception that green infrastructure is incompatible with space-constrained sites. This perception is based on the concern that green infrastructure will require significant open space that is unavailable on infill and redevelopment sites. Experience demonstrates, however, that green infrastructure can effectively be integrated into space-constrained sites. Different strategies are available for different development contexts – with some strategies more appropriate for street rights-of-way and some strategies more appropriate for larger urban development sites. The following sections provide a more detailed discussion of the extent of space-constrained sites in the Pittsburgh area, as well as methods to design green infrastructure to address space constraints.

Characterization of Development in the Greater Pittsburgh Area

The Allegheny County Comprehensive Plan contains extensive information on future planned development within the county, emphasizing redevelopment and infill development as opposed to low-density greenfield development. The plan discusses the importance of infill development and reuse of existing buildings in downtown Pittsburgh and Oakland, urban neighborhoods, community downtowns, and transit-oriented development areas. As shown in Figure 1, infill development makes up an extensive portion of the future planned development for the Pittsburgh area.

The plan also addresses the importance of 'Complete Streets' and recommends that limited-access highways be upgraded according to the concepts of 'Complete Streets.' While complete streets do not necessarily address stormwater, enhancing stormwater management is often one of the elements considered.

For additional information refer to the Allegheny Places web site and the complete comprehensive plan: http://www.alleghenyplaces.com/comprehensive_plan/comprehensive_plan.aspx.

Development Definitions

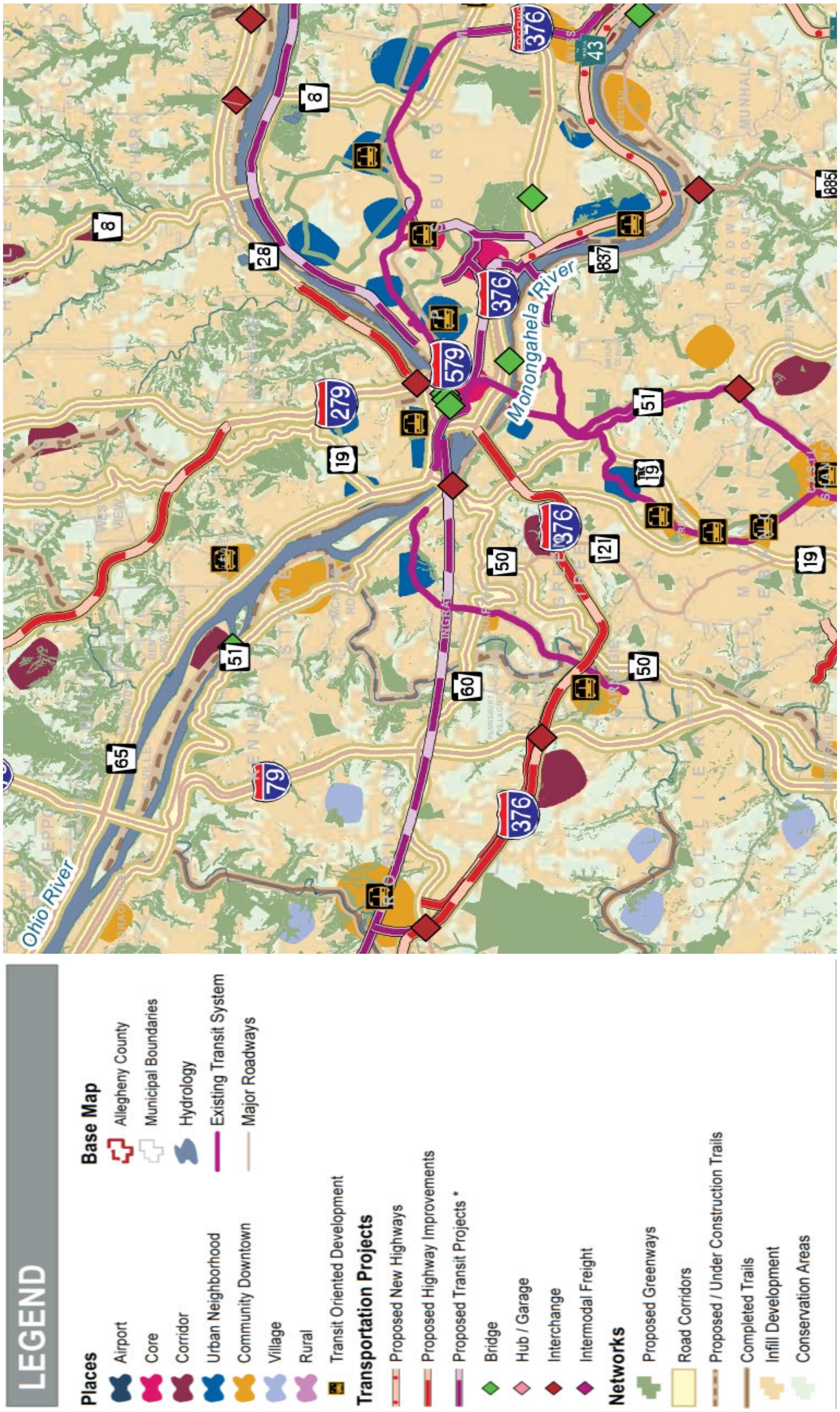
Infill – Refers to development in urban areas with existing streets, infrastructure and development. (USEPA, 1999)

Greenfield – Refers to development on previously undeveloped ("green") parcels in suburban or non-urban locations with limited existing infrastructure and development. (USEPA, 1999)

Redevelopment – Development that occurs on previously developed land. (Website: USEPA – NPDES, 2013.)

Stormwater Retrofit – Provides stormwater treatment in locations where practices did not exist or were ineffective. They are often incorporated around existing development and infrastructure. (Center for Watershed Protection, 2007).

Complete Street – The concept of making streets comfortable, safe and convenient for travel by auto, foot, bicycle and transit. (Allegheny County Comprehensive Plan)



Adapted from Map 4A.1, Allegheny County Comprehensive Plan

Figure 1. Future Land Use

Methods to Address Space Constraints

This section describes methods to safely and effectively retain runoff on sites with limited open space. The first subsection discusses general considerations for space-constrained sites. This subsection describes general planning and design approaches appropriate for dense urban environments, and reviews methods for protecting existing site features. The following subsections discuss tailored planning and design approaches for the road right-of-way and for other urban development sites.

General Considerations

1. Reducing Impervious Cover

Runoff is generated when rain falling on impervious surfaces, including streets, sidewalks, and parking areas, cannot soak into the ground. Even in dense urban environments, opportunities should be identified to reduce stormwater runoff by reducing these impervious surfaces.

One approach to reducing impervious surfaces is to remove impervious cover that is not used (Figure 2). Examples include the "no parking" zone areas 1) near fire hydrants, 2) between driveway approaches, or 3) near intersections based on intersection setback requirements. These areas could be converted to or planned as bioretention areas. Volunteers could be involved in identifying unused shopping center parking spots and driving aisles on the busiest days. Neighborhood residents could identify unused neighborhood parking spots. This knowledge can help justify incorporating green infrastructure or pervious cover in these areas. In cooperation with local or state authorities, unused sidewalk, traffic lanes, traffic islands, and curbside parking may be identified and removed.

Another approach is to reduce the demand for impervious surfaces by organizing shared parking spaces. Parking spaces could be shared between neighboring businesses or between developments that have different hours of operation. Examples include sharing parking between a bank and a bar or between a day care and a housing complex.

NE Sandy and 15th Avenue, Portland, OR

Before

After

Source: Kevin Perry,
Nevue Ngan Associates

Figure 2. Removal of Unused Impervious Cover

2. Adding Subsurface Storage

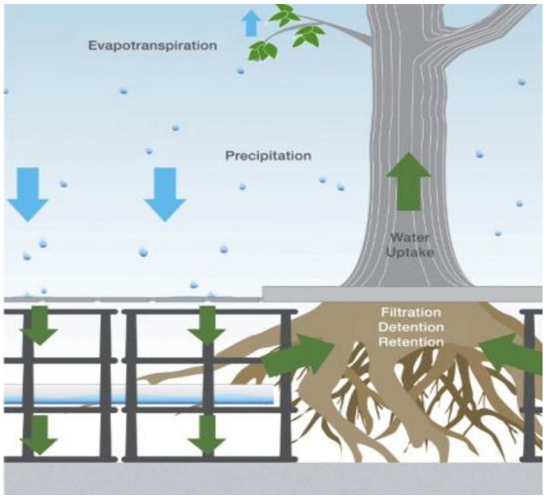
Many practices can provide subsurface detention or retention of stormwater while requiring minimal surface space. Some of these practices allow infiltration through paved surfaces, while others collect runoff from paved drainage areas and direct the runoff into a storage system.

Permeable Pavements: Permeable pavements can be installed in place of traditional pavements to allow infiltration through paved surfaces. These systems allow stormwater to infiltrate through the pavement into an aggregate subgrade. Depending on the system design, stormwater will then infiltrate into the soil or drain through an underdrain to an outlet. Types of permeable pavement include: interlocking concrete pavers (Figure 3), cellular reinforced paving filled with topsoil and grass or gravel, pervious concrete, or pervious asphalt. For roadway applications, interlocking concrete pavers, pervious concrete, or pervious asphalt are typically used. Cellular reinforced paving is normally used in parking lots and utility access drives.

Permeable pavement does not require additional space on a project site, but rather is an alternative to traditional pavement. Permeable pavement can be installed across the entire width of road or parking lot or just within the parking lanes or stalls. The wider the installation of permeable pavement, the less pollutant load per unit of permeable pavement from the drainage area. Permeable sidewalk and driveway approaches are others options for reducing runoff.

Concrete Pavers

Source: Clean Water Services, 2009



Suspended Pavement

Source: www.deeproot.com

Underground Pipe Storage

Source: www.cenews.com

Figure 3. Subsurface Storage

Suspended Pavement Systems: Suspended pavement systems can be combined with permeable pavement to support tree growth and provide additional storage, while also providing structural support for cars and trucks. An example of a suspended pavement system is the Silva Cell (Figure 3). The Silva Cell uses a system of crates to hold lightly compacted soil while supporting traffic loads. The lightly compacted soil will store more water than a compacted soil, allow tree roots to access a greater soil volume, and enhance evapotranspiration rates. While the rooting soil will not provide enough storage to retain large storms, it can retain the smaller storms that comprise 80 to 90 percent of the annual rainfall in Pittsburgh. A Silva Cell system is installed along Liberty Avenue at the August Wilson Center for African American Culture in Pittsburgh (see cover image).

Structural Soils: Structural soils can also be combined with permeable pavement to support tree growth while meeting load bearing requirements. Structural soil is a mixture of crushed aggregate and soil that can be compacted to bear the load of a pavement. At the same time, structural soil allows tree roots to grow freely, supporting tree growth and enhancing evapotranspiration rates.

Vault and Pipe Storage: Vault and Pipe storage systems drain runoff from a paved drainage area into a subsurface storage unit. . Curb inlets or surface drains direct stormwater into underground storage vaults or into a system of large-diameter interconnected storage pipes. The stormwater is then released directly through an outlet pipe into the stormwater drainage system, or allowed to infiltrate into the ground. Systems that allow infiltration provide some retention of stormwater, while systems that do not, provide only temporary storage. Because large storage volumes can be installed, these systems are particularly suitable if detention of large storm events is required. Note, however, that these systems should not be expected to substantially improve water quality unless preceded by a pretreatment practice such as a swale or prefabricated device.

3. Working around Buried Utilities

When installing green infrastructure on redevelopment or infill sites, care must be taken to protect existing site features, including utilities, structures, and mature trees. Many different utilities may be buried within the street right-of-way in the greater Pittsburgh area. These utilities include sewer, water, electrical, gas, fiber optic, cable, and telephone. While some rights-of-way will not include all of these utilities, others located in busier urban corridors will have multiples of these utilities. Utilities may be buried at shallow depths, within 18 inches of grade, or at greater depths, more than 5 feet below grade.

Public utilities in the Pittsburgh area are often not well marked and are sometimes unexpectedly shallow because they were installed one hundred years ago. Making conservative assumptions and building flexibility into green infrastructure designs will help alleviate problems during construction.

All work near utility lines should be coordinated with the respective utility company. When working with the utility company, collaborative decisions can be made regarding potentially moving the utility, adding waterproofing measures, and evaluating structural support requirements. Whatever the configuration of utilities, the following are a few guidelines for working around utilities:

- **Call 8-1-1** (Pennsylvania One Call) before digging to have buried utilities located on the site.
- **Combined sewer** – The combined sewer is often buried well below the bottom of a green infrastructure practice, but in Pittsburgh the older pipes are sometimes shallow. The age and condition of a nearby sewer should be considered when placing and designing a green infrastructure practice. If a green infrastructure practice is installed above an older pipe, grouting the joints of the pipe may be desired to diminish the possibility of water entering the pipe.
- **Water main** – Water main is buried approximately 4 feet from grade to the crown of the pipe, which would locate it just beneath a typical practice. As long as careful excavation of the practice is conducted, there should be no problem with a water main in the vicinity of a green infrastructure practice. In Pittsburgh, old water main may not be buried this deep. Green infrastructure practices should be located away from old water mains as much as possible.

- **Gas mains** – High pressure gas mains should definitely be avoided. Low pressure shallow mains are usually not a problem. Many times, the project is an opportunity for the gas company to update their line.
- **Single conduit utilities** – Single conduit utilities, including electrical, telephone, fiber optic, and cable, are typically buried approximately 18 inches below grade in a watertight conduit. As long as careful excavation of the practice is conducted, there should be no problem with single conduit utilities placed within the vicinity of a green infrastructure practice.
- **Concrete support structures** – Generally, utilities such as duct banks, steam, chilled water, etc., that use concrete support structures should be avoided due to the expense of moving them.

4. Protecting Existing Structures

When installing green infrastructure in dense urban environments, existing structures such as basements and sewers must be protected. Because these structures are often older, they may be susceptible to leaks or damage from nearby construction. Care must therefore be taken to guard against basement flooding or infiltration into the sewer. For buildings, one waterproofing strategy is to include an impermeable barrier between the water infiltrating from the practice and the adjacent basement. Another strategy is to waterproof the outside of the adjacent basement. For sewers, engineers should determine what the impact of infiltration would be on the sewer system. Waterproofing strategies include trenchless pipe lining, as well as providing a full concrete or plastic containment system for the green infrastructure practice. Investigations into groundwater movement in the area may be warranted to determine potential impacts. If groundwater mounding is a concern, underdrains can be incorporated into the green infrastructure practice.

SW 12th Avenue, Portland ,OR

Source: Kevin Perry, Nevue Ngan Associates

Michigan Avenue, Lansing, MI

Source: Anne Thomas, Tetra Tech

Figure 4. Retaining Walls

5. Providing Support of Adjacent Structures

It may be necessary to provide structural support within green infrastructure practices that are installed near buildings and roads. Depending on the practice placement, there is often concern that nearby compacted soils will migrate into the less compacted soils used in green infrastructure practices. To guard against this, retaining walls can be constructed. Examples of green infrastructure practices with retaining walls include 1) the Lansing, MI planter boxes, which have about 5.5-foot deep reinforced masonry block retaining walls with footings, and 2) the Portland, OR planter boxes, which have about 13-inch deep poured concrete retaining walls (Figure 4). Different situations require different designs. A geotechnical engineer should be consulted.

6. Working around Healthy Trees

The sections above discussed several existing features that must be considered when developing a previously developed site, including utilities and structures. Another feature that must be considered is the presence of healthy, mature trees. While existing utilities and buildings pose obstacles to incorporating green infrastructure into a site, existing trees represent an opportunity that should be taken advantage of, particularly in the Pittsburgh area. Pittsburgh's tree canopy covers 42 percent of the city and is highly valued by city residents and leaders. The 2012 Pittsburgh Urban Forest Master Plan outlines the city's strategy for managing and growing the urban tree canopy.

> **Tree Definitions**
>
> *Mature Tree* – For purposes of stormwater management, a "mature tree" means that the tree has a well-developed canopy. This is usually a 20 to 25 year old tree. (American Public Power Association, 2013)
>
> *Interception* – The process through which plants capture and store precipitation on their leaves and branches.
>
> *Evapotranspiration* – Includes evaporation of water to the air from the tree canopy as well as transpiration of water to the air from the movement of water within a plant.

Stormwater Benefits of Trees: Mature trees provide significant stormwater quantity and rate control benefits through soil storage, interception, and evapotranspiration. A tree with a 25-foot diameter canopy can hold the 1-inch 24-hour storm event from 2,400 square feet of impervious surface. Interception and evapotranspiration also decrease runoff volume with larger trees providing exponentially more benefit than smaller trees (MacDonagh, Smiley, and Bloniarz, 2012). In addition to stormwater quantity benefits, trees provide numerous ancillary benefits including water quality treatment, a reduction in urban heat island effect, an improvement in air quality, a reduction in combined sewer treatment needs, an increase in aesthetics and recreational opportunities, a reduction in noise pollution, and a decrease in flooding (Center for Neighborhood Technology, 2010).

Because of the inherent stormwater benefits of trees, it is advantageous to plan to protect mature trees during the site planning process. Protecting trees along a right-of-way corridor or site development does not preclude the use of other green infrastructure practices along the corridor, but it will help determine placement and type of practices.

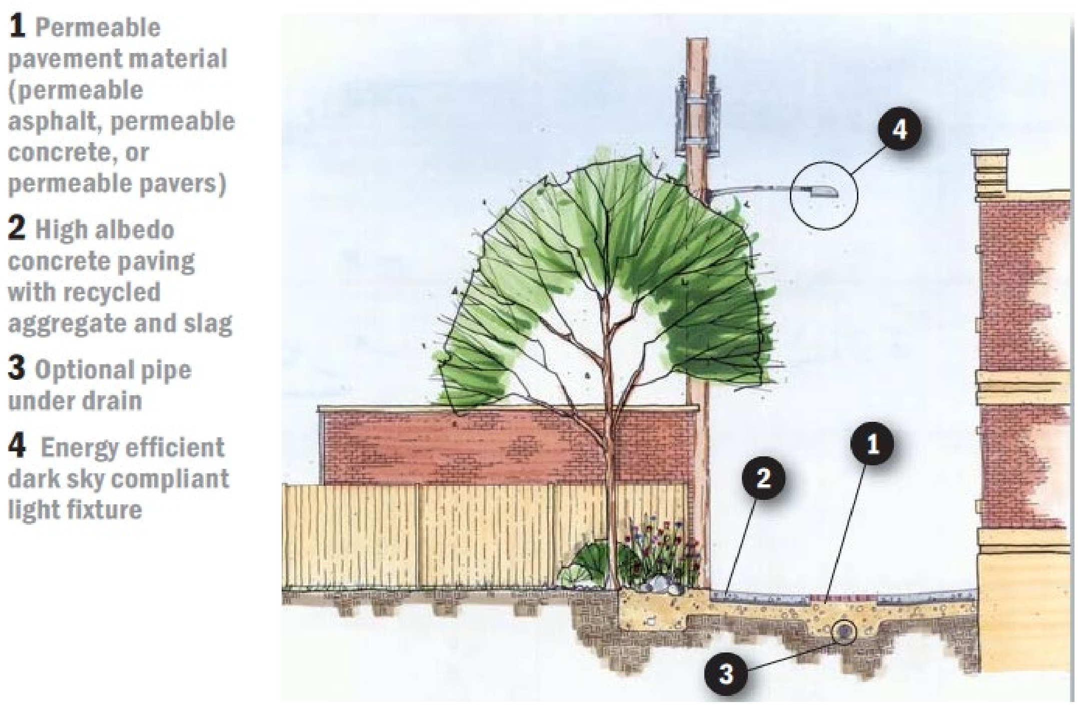
Tree Preservation and Planting: Following the identification of mature trees on a site and the decision to preserve them, it is recommended to get advice from a professional urban forester or arborist with experience in protecting trees from construction damage. Damage to the root system causes the most harm to the overall health of a tree. Different species of trees react differently to root damage, which is what a tree-care specialist can help assess during the planning phase. Most healthy trees can tolerate one-sided root cutting and recover with long-term care including watering, dead branch removal, and replacement of turf with mulch, shrubs or perennials. Construction equipment and materials should not be stored over a tree's soil to avoid compaction (Johnson, G. R., 2013).

In addition, it is helpful to incorporate trees as much as possible into a development site or right-of-way for the many long-term benefits they provide. A helpful guide for preserving and planting urban trees is the Urban Watershed Forestry Manual, Part 2: Conserving and Planting Trees at Development Sites (Center for Watershed Protection, 2006).

Green Infrastructure Placement: Bioretention and permeable pavement are common candidates for green infrastructure proposed to be installed around or in conjunction with mature trees. Depending on the results of a tree-care specialist's assessment and the density of the trees, it is likely either one of these practices can be retrofitted into a right-of-way or development site including mature trees.

Many times, curb extension bioretention can be located in open spaces away from trees or near smaller trees. The depth of these practices is usually 3 to 4 feet below grade, which would impact adjacent tree roots, but perhaps not detrimentally.

Similarly, permeable pavement within a parking lane or a parking row as opposed to across the entire road or parking lot may be a possibility depending on the tree assessment. A permeable pavement system including a storage layer typically extends an additional one to two feet below the existing pavement. If extensive tree damage seems likely with permeable pavement installation, consider 1) crowning the road along the curb line and including permeable pavement within the depressed centerline (Figure 5) or 2) eliminating just the storage layer along the curb line.



Source: Chicago Department of Transportation, 2010

Figure 5. Permeable Pavement within a Depressed Centerline

Right-of-Way Projects

Challenges to incorporating green infrastructure within the right-of-way often include maintaining essential moving lane and pedestrian pathway widths, keeping necessary roadside parking spots, and providing access to businesses or residences. The use of permeable pavement is often a practical option within the right-of-way, but more thought must be given to incorporating bioretention practices. This section offers guidance on retrofitting bioretention within the right-of-way.

1. Right-of-Way Widths and Roadside Parking

Right-of-way widths and the location of roadside parking will vary from street to street throughout the Pittsburgh area. There are different concerns regarding space availability for different green infrastructure practices. This section will discuss curb extension bioretention and "behind-the-curb" bioretention/bioswales as related to right-of-way width and roadside parking. Specific design guidance on these practices can be found in the Pennsylvania Stormwater Best Management Practices Manual.

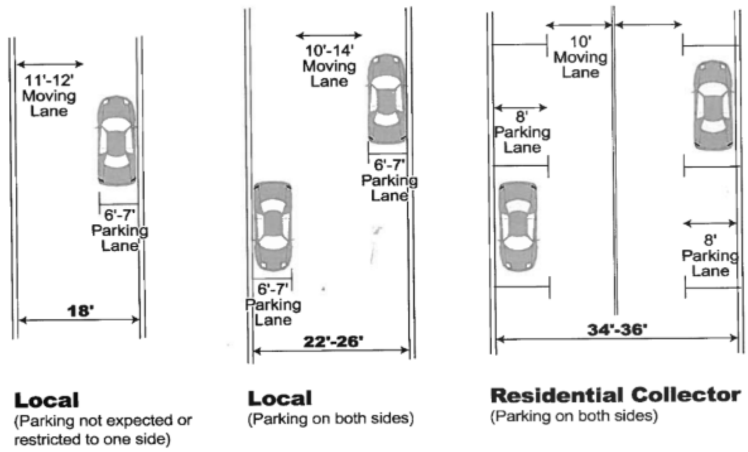
Curb Extension Bioretention: Curb extension bioretention is the practice of capturing road runoff within a vegetated shallow depressed area which extends out from the curb into the street, typically into a parking lane (Figure 6). Curb extension bioretention also results in traffic calming and can be used to shorten pedestrian crossing distances. An important concern when evaluating for retrofit of curb extension bioretention within the right-of-way is maintaining the appropriate moving lane widths, pedestrian pathway widths, and parking spots.

Source: Washington Square, Lansing, Michigan

Figure 6. Curb Extension Bioretention

Maintaining a 10- to 14-foot moving lane is recommended in most situations, which should also allow access by emergency vehicles. Refer to Figure 7 for recommendations on moving lane widths for three variations of residential streets. According to Americans with Disabilities Act (ADA) regulations, pedestrian pathways should be at least 48 inches in width.

The location and utilization of roadside parking (one side or both sides) must also be considered. If there is a high demand for roadside parking, loss of parking spots due to curb extension bioretention may not be a good option. In such situations, permeable pavement or bioretention/bioswale located behind the curb may be considered as they do not result in changes to moving lane widths.



Source: Kulash, 2001

Figure 7. Street and Lane Widths

Behind-the-Curb Bioretention: Behind-the-curb bioretention provides the same function as a curb extension bioretention but is located behind the curb and is sometimes installed along a lengthy portion of the road (Figure 8). It is not dependent on the road width but is dependent on the available right-of-way area behind the curb. At a minimum, a 5-foot width is needed without subtracting from the minimum ADA sidewalk width of 48 inches.

To accommodate roadside parking, a minimum 18-inch wide flat surface (e.g. grass, concrete, mulch) should be provided directly behind the curb at the level of the curb to allow people to safely step out of a car (Figure 8).

With both curb extension bioretention and behind-the-curb bioretention, it is possible to increase storage in the system by utilizing one of the subgrade storage options discussed in Section 'Adding Subsurface Storage.' The subgrade storage can be provided beneath the area behind the curb or even the road. Refer to Figure 9 for a design detail of subgrade storage.

Behind-the-Curb Bioretention

Source: SvR Design Company Green Factor Workshop

Roadside Parking Safety Bench

Source: Maywood Avenue, Toledo, Ohio

Figure 8. Behind-the-Curb Bioretention Practices

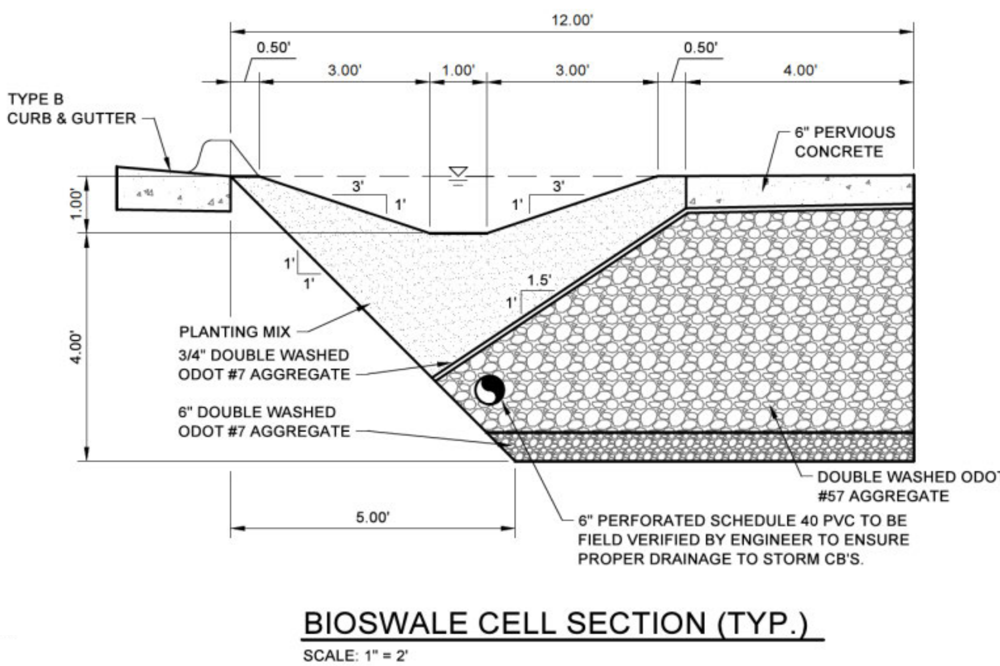


Figure 9. Behind-the-Curb Bioretention with Subgrade Aggregate Storage – Toledo, OH

2. Building Access

When installing green infrastructure practices within the right-of-way, it is essential to consider access to businesses and residences. This can be done by incorporating pedestrian "bridges" across practices or placing the practices so that access is not inhibited. For example, movable metal plates placed over behind-the-curb bioretention in Lansing, MI serve to provide pedestrian access to businesses as well as outdoor seating (Figure 10).

Moveable metal plates over bioretention providing for outdoor seating.

Source: Michigan Avenue, Lansing, Michigan

Metal plates allowing pedestrian access from roadside parking.

Source: Market Street, Lemoyne, Pennsylvania

Figure 10. Bioretention Practices within Pedestrian Corridors

Urban Site Development

While bioretention and permeable pavement are the most appropriate practices for urban right-of-way projects, many different green infrastructure practices can be integrated into other urban development sites. The suite of green infrastructure practices appropriate for larger infill or redevelopment sites includes permeable pavement, bioretention, vegetated roofs, dry wells, and rainwater harvesting. Table 1 describes the practices not discussed in previous sections.

All of these practices share one feature in common – they can be integrated into existing or planned land uses while requiring minimal additional surface space. For example, vegetated roofs can be integrated into the building design, providing storage and evapotranspiration on the roof surface. Similarly, bioretention can be integrated into planned landscaped areas, while permeable pavement can be integrated into planned paved areas. Instead of requiring additional space, these green infrastructure practices enhance the hydrologic function of planned land uses. Figure 11 through Figure 15 below illustrate how many of these green infrastructure practices can be integrated into the building or landscape design.

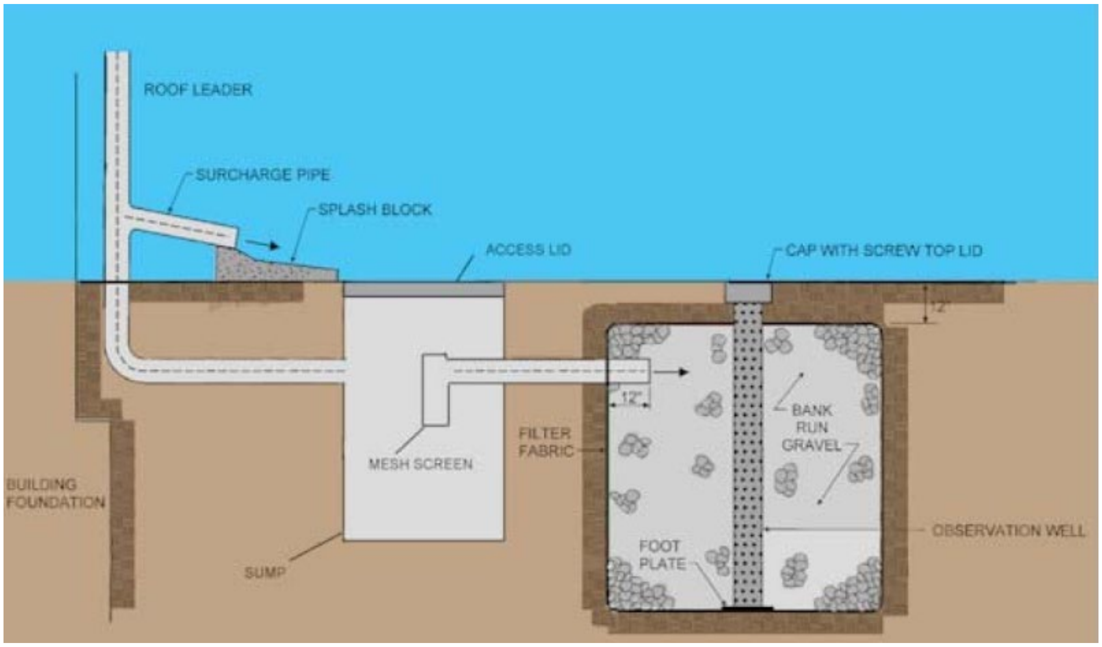
Table 1. Green Infrastructure Practices for Urban Site Development

Green Infrastructure Practice	Description
Vegetated Roof	Captures the rain that falls directly onto the roof. Soil storage and evapotranspiration help reduce peak flow and volume. Stormwater is treated by the many processes within the soil layer. It is often the first step of a treatment train. Refer to BMP 6.5.1 from the PA Stormwater BMP Manual for design guidance.
Dry Well or Seepage Pit	Captures roof drainage. Infiltration reduces peak flow and volume. Can be useful on sites where no surface storage is available. Refer to BMP 6.4.6 from the PA Stormwater BMP Manual for design guidance. This is regulated as a Class V well and is overseen by EPA Region 3.
Rain barrels and Cisterns	Captures roof drainage. Storage reduces peak flow and volume. Can be used as part of a gray water reuse system or for irrigation. Refer to BMP 6.5.2 from the PA Stormwater BMP Manual for design guidance.

Source: PA Stormwater BMP Manual

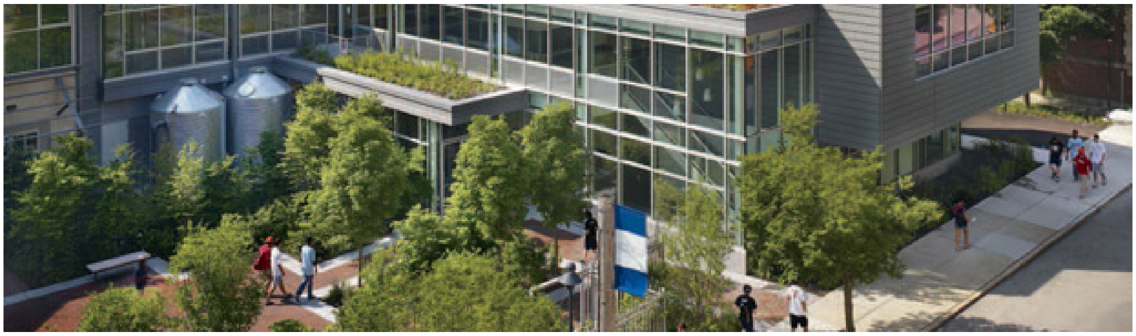
Source: Friends Center, Philadelphia, PA

Figure 11. Vegetated Roofs



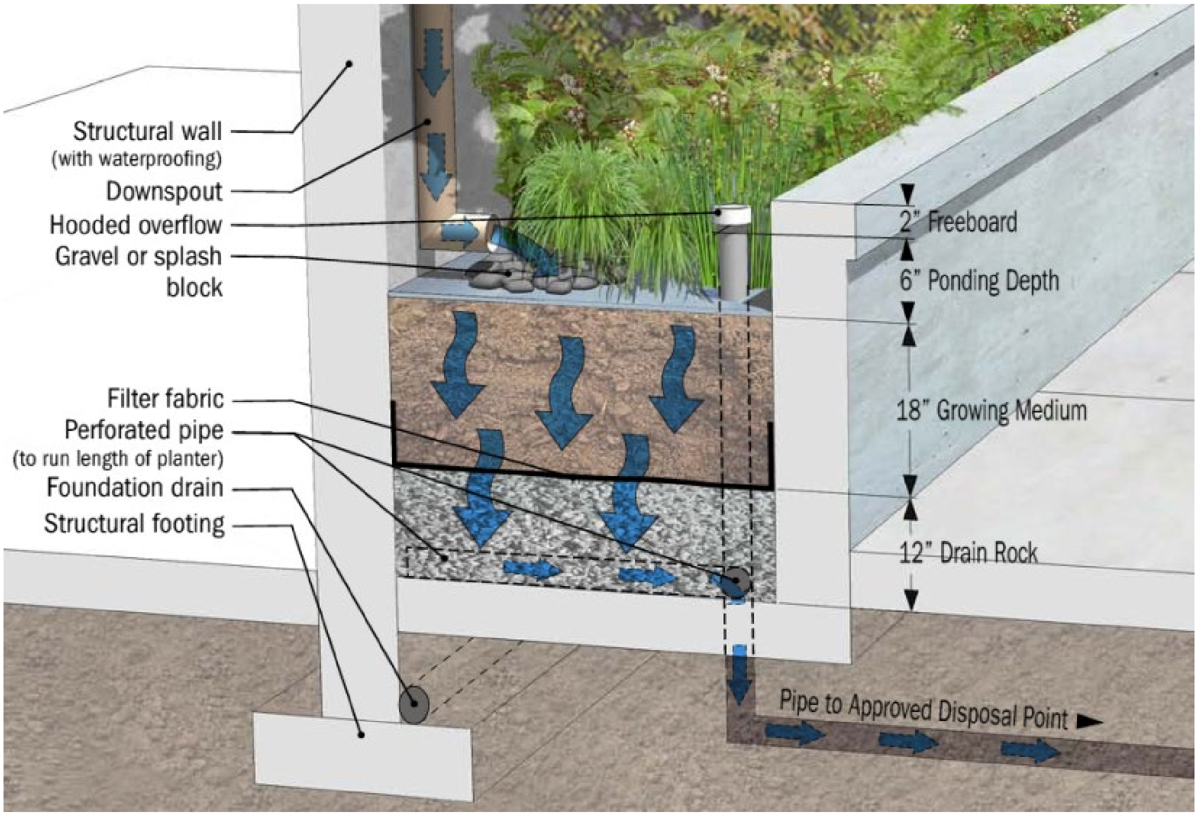
Source: PA Stormwater BMP Manual

Figure 12. Dry Well or Seepage Pit



Source: Sustainable Urban Science Center, Philadelphia, PA

Figure 13. Cisterns



Source: Clean Water Services, 2009

Source: Clean Water Services, 2009

Source: SvR Green Factor Workshop

Figure 14. Planter Boxes

Source: Clean Water Services, 2009

Source: SvR Green Factor Workshop

Source: SvR Green Factor Workshop

Source: SvR Green Factor Workshop

Figure 15. Bioretention

Examples of Implemented Projects

Market Street Rain Gardens, Lemoyne, Pennsylvania

Source: Kairos Design Group, LLC

The Lemoyne Borough in Cumberland County, PA completed Phase I of their downtown revitalization project in 2010. The revitalization project calls for several phases of streetscape improvements within the Market Street corridor based on a "Complete Street" design. A Complete Street is designed to create a comfortable, safe, attractive, and easily accessible travel route for pedestrians, bicyclists, motorists, and public transport. The Market Street Complete Street also includes bioretention to provide stormwater management (Figure 16). This project is an example of a right-of-way project with space constraints typical of an urban area. Available space in the Market Street corridor is constrained by underground utilities, the need to provide pedestrian access to businesses, and the need to provide roadside parking.

Figure 16. Lemoyne, PA Market Street Rain Gardens

Design Summary

The Market Street design uses a combination of green infrastructure practices along the corridor including bioretention planter boxes, bioretention curb extensions, and interlocking concrete pavers to capture and infiltrate the "first flush" of rainfall. An underdrain was not utilized in the designs. Within the bioretention areas, a variety of salt/drought tolerant native plant species were used with an engineered soil mix to support the plants and promote infiltration into the in situ soils. Not only do the green infrastructure practices provide stormwater treatment, but also green space. The overall design accommodates buried utilities, roadside parking, pedestrian traffic, and gutter flow for the larger storm events. Utilities located beneath the green infrastructure practices include the water, telephone, gas, and sanitary sewer lines.

Albert M. Greenfield Elementary School, Philadelphia, PA

Source: Michele Adams, President, Meliora Design, LLC; American Society of Landscape Architects; Schuylkill Action Network

As part of the Philadelphia Water Department's "Green City, Clean Waters" plan, the Albert M. Greenfield Elementary School became a pilot site for using green infrastructure to reduce the volume and rate of stormwater discharges into the combined sewer system within Philadelphia. The school is located in center city Philadelphia, which is a highly urbanized area. The project was a collaborative effort between the Philadelphia Water Department, PA Dept. of Environmental Protection, the Albert M. Greenfield Foundation, the Philadelphia School District, and many others. This project serves as an example of an urban site development which transformed impervious surfaces into a green drainage network while maintaining the intended school playground use.

Source: http://phillywatersheds.org/category/blog-tags/stream-restoration

Figure 17. Albert M. Greenfield Elementary School "Green" Playground

1. Design Summary

In 2009 and 2010, the first two phases of this retrofit project were completed installing an indigenous Pennsylvania woodland forest garden and agricultural zone, removing impervious cover, adding a permeable play surface, and installing two rain gardens (Figure 17 through Figure 19). The improvements capture and treat 97 percent of the rainfall from the school yard or 1 inch of rainfall depth as required by the water department. The existing soil was a compacted urban fill not conducive to supporting plant growth or storing water, so up to three feet of engineered soil was brought in to support the system. A perforated underdrain was used beneath the rain gardens and permeable play surface, not as an outlet to the combined sewer system, but only as a means to distribute the water to promote infiltration. An overflow system was installed to drain runoff from events larger than the 1-inch event. Future phases include adding a vegetated roof to the building.

2. Lessons Learned

Located in a constrained urban setting in center city Philadelphia, the Albert M. Greenfield Elementary School did not have additional open space in which to install green infrastructure. The pilot project therefore focused on creating shared usage of the playground area. Significant concerns and ideas were identified in design charrettes and included the importance of maintaining the system integrity while understanding that this is a functioning school playground. Rather than fencing off the rain gardens, these areas were incorporated into the curriculum of the school such that the students understand their significance and are engaged in the plant and animal life of the gardens. Innovative design features were also used to protect the gardens such as installing strategically placed nets/climbing structures near the basketball courts (Figure 17); an idea courtesy of a student involved in the charrettes.

From a stormwater design perspective, this project shows the ability of an urban site to infiltrate a significant amount of water. From a comprehensive design perspective, the overall lesson learned is the importance of involving all stakeholders in the design process to successfully share space in a constrained urban setting.

Source: www.viridianls.com

Figure 18. Permeable Play Surface (left) and Rain Garden (right)

Photo Credit: Paul Rider

Figure 19. Pennsylvania Woodland Forest Garden and Agricultural Zone

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