12. STREETSCAPE ECOSYSTEM

(Credit: Kimley-Horn and Associates, Inc.)

INTRODUCTION

The street is a system: a transportation system, an ecosystem, and a system of social and economic interactions. The idea of a streetscape ecosystem is to mimic nature, building reciprocal relationships within an interconnected system to sustainably enhance the local environment, its resources, the community, and the local economy. To do this, the tools addressed in this chapter should be integrated with those of the other chapters in this manual.

Broward Street Tree Canopy
(Credit: Alena Alberani)

This chapter is organized into sections based on a natural hierarchy. The first section focuses on streetwater management because water is the fundamental ingredient for other components of a streetscape ecosystem. The streetwater management section provides guidance on how to work with and maximize the beneficial aspects of rain, its byproduct, stormwater, and other sources of water. The second section addresses street trees and landscaping, providing guidance on how to design streets to include site-appropriate vegetation that maximizes environmental and social benefits. Canopy trees provide summer shade that cools the streets and the hardscapes from which the streetwater is harvested. These sheltered micro-climates create ideal locations for people to gather, walk, and bike.

To help local jurisdictions achieve street designs that create great places fostering community, the final sections of this chapter address street furnishings, utilities, and lighting. The sections recommend that these elements (e.g., sheltered benches, bike racks, and bus shelters) should be placed where people can utilize them well. These sections also provide guidance as to the placement of utilities and how placement coordinates with other components of the streetscape. The elements described can help attract pedestrians to a street and thereby make the street safer, more dynamic, and more vibrant economically.

PRINCIPLES OF STREETSCAPE ECOSYSTEM DESIGN

Each section in this chapter includes design principles followed by tools to achieve these principles. These streetscape element-specific principles collectively support both the overarching principles of this chapter and the broader goals of this manual. The collective use of the tools in this chapter can provide numerous aesthetic and functional elements in the public rights-of-way, including the entire space between buildings, traveled way, and sidewalks. The following overarching principles should be applied:

> *"Too far, too hot, too rainy, too lazy"*
> *-- (Broward Complete Street survey response to why you are unable to get out of your car)*

- Coordinate all streetscape elements with traveled way design to maximize ecological, economic, and social benefits. No individual street project should be pursued in a vacuum, but rather planned as part of a comprehensive strategy. Use street medians, roundabouts, chicanes, curb extensions, and other road configurations as space for people and nature. They provide opportunities for spaces with vegetation, streetwater management tools, and other streetscape elements like benches and bike racks.
- Create a contextualized sense of place. Using the large menu provided in this chapter, select streetscape elements that reflect the context and unique character of the location as well as support connections to adjacent land uses. The street

Broward Street Tree Canopy
(Credit: Alena Alberani)

can then function as a shared living room for the community and a welcoming front door for the buildings along the street. Native plantings can be used to root the context in the surrounding natural landscape while acknowledging the local ecosystem and climate.

STREETWATER MANAGEMENT

The street is a constructed waterway, often differing from the natural path of water and ignoring the hydrologic cycle. Traditional design has focused on speedy removal of water from the street and disposal of it as waste in storm drains and sewers. This section provides tools to reclaim streetwater as a resource and allow it to nourish trees and soils on its path to ground or surface waters. These tools help local jurisdictions design streets to sustainably work with both dry and wet weather sources of water. During the wet season (summer in Southeast Florida), rain and its byproduct, stormwater, are the primary sources of streetwater. During the dry season (winter in Southeast Florida), man-made sources of water include urban runoff from irrigation, car washing, and other residential, commercial, and industrial activities.

Both dry and wet weather streetwater can contain bacteria and other pollutants, and are thereby regulated at the state and local level. Streets represent a large percentage of the impervious area within Broward County and therefore generate substantial amounts of runoff from storm events. Many of the sources of pollutants to waterways come from streets directly either from motorized vehicles, such as oils, rubber, metals, and galvanized materials, or litter, chemicals, and vegetation debris from adjacent properties.

While conventional stormwater controls aim to move water off-site and into storm drains as quickly as possible, streetwater management seeks to use and store water on-site for absorption and infiltration in order to clean it naturally and use it as a resource. The storm drain system, therefore, is an overflow support system rather than a primary conveyance system. Streetwater management deals with water as an amenity rather than a liability.

Many of the streetwater management options discussed in this section can and should integrate easily with traffic calming measures installed along streets, such as boulevard islands, rotary islands, traffic circles, street ends, chicanes, and curb extensions. These elements can easily incorporate streetwater treatment into the landscape and streetwater tools can be made more cost-effective if integrated early in the design process.

Streetwater management also provides opportunities to leverage other streetscape elements and components of living streets. A strategic plan linking streetscape elements and street design can maximize benefits.

This section provides guidance to comply with Broward County's Municipal Separate Storm Sewer System (MS4) Permit. The MS4 Permit requires that jurisdictions in Broward County reduce contaminants in runoff to improve water quality in waterways. These requirements stem from National Pollutant Discharge Elimination System (NPDES) requirements of the Clean Water Act, as promulgated by the U.S. Environmental Protection Agency and delegated to Broward County via the Florida Department of Environmental Protection (FDEP).

Parkway incorporating streetwater tools: Bicknell Avenue, Santa Monica, CA (Credit: Neil Shapiro)

GOALS AND BENEFITS OF STREETWATER MANAGEMENT

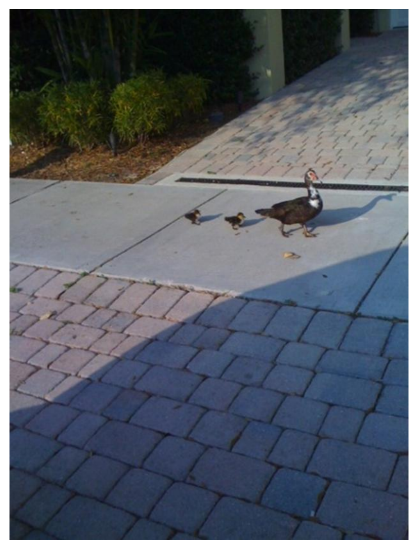
The primary goals of streetwater management are as follows.

- Reduce—limit the amount of impervious surfaces that generate additional runoff
- Slow—friction slows flow
- Spread—allow water to be slowed enough to infiltrate
- Sink—keep water on site
- Store—contain water for direct non-potable/potable indoor/outdoor purposes
- Use—to irrigate and replace imported potable water

These goals can be expressed succinctly: slow it, spread it, store it, and sink it, but use it.

The tools provided in this section enable local jurisdictions to attain regulatory compliance and provide the following ecological, economic, and aesthetic benefits.

- Reduced use of potable water for irrigation
- Reduced surface water pollution
- Support for the urban ecosystem and wildlife habitat
- Enhanced flood control
- Biological filtration and bioremediation
- Groundwater recharge
- Reduced heat island effect
- Education through best management practices (BMP) visibility
- Aeration of root zone
- Potential reductions in stormwater infrastructure and treatment costs
- Improved aesthetics and public space within neighborhoods



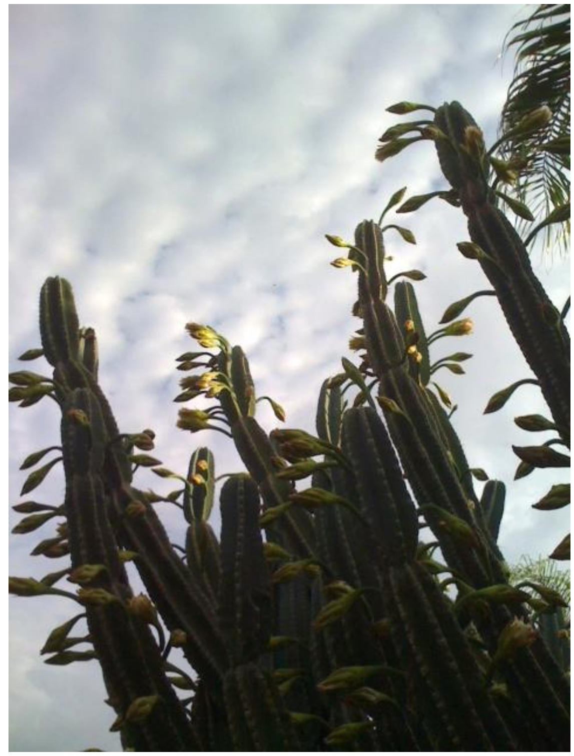
Design for all users
(Credit: Alena Alberani)

PRINCIPLES OF STREETWATER MANAGEMENT

- Use the conventional storm drain system as the overflow approach, not the primary system to manage streetwater. Wherever possible, natural drainages should be the primary overflow.
- Harvest, use, and/or store stormwater as close to its source as possible. Wet weather rainfall and its byproduct, stormwater, can offset or eliminate imported potable irrigation water needs when harvested and used on-site. Harvesting and storing stormwater transforms a flooding liability into an on-site irrigation resource. This ensures natural waterways and their plant communities have local sources of water, thereby reducing the need for imported water. Harvesting and

storing rainwater also reduces the need for costly drainage conveyance infrastructure for stormwater management.

- Use on-site non-potable water sources for irrigation before any imported water source. In dry weather, irrigation overspray can be reduced by enforcing existing laws/ordinances banning these practices. This leads to more efficient water use, reducing costly imported potable water consumption.
- Select tools that mimic natural processes. Minimize the cost of the installation and maintenance by using gravity flow rather than pumped flow, living filtration over synthetic/mechanical filtration, and living surface infiltration instead of piped drainage. Priority should also be given to pervious versus impervious surfaces. The primary purpose is to harvest and utilize rain as part of a healthy vegetated watershed. For example, vegetation can reduce runoff water volume and pollutant load, provide summer shade and cooling, and enhance wildlife habitat and sense of place with native vegetation rooted to the local ecosystem.



Native adaptable vegetation
(Credit: Alena Alberani)

- Maximize streetwater management by integrating it into the myriad design elements in the public right-of-way. The water system is part of a larger, interconnected system. Maximize the benefits of stormwater strategies. For example, traffic calming and road diets can double as streetwater harvesting strategies. In addition, use vegetation to make streets better places and use streetwater management as an integral element of the urban forest.
- Show the water flow. The benefits of streetwater management are ecological, economic, and social. Make the functions described in this section visible for street users to see, understand, appreciate, and replicate. Public right-of-way streetwater installations can inspire private property installations and serve as model installations for neighborhoods. Visible water flow systems are also easier to maintain. Blockages are easier to notice and easier to access for regular maintenance.

DEFINITIONS

The terms below describe the elements and techniques of sustainable streetwater management.

Best Management Practice (BMP). Operating methods and/or structural devices used to reduce stormwater volume, peak flows, and/or pollutant concentrations of stormwater runoff through one or more of the following processes: evapotranspiration, infiltration, detention, filtration, and biological and chemical treatment.

Bioretention. A soil and plant-based retention practice that captures and biologically degrades pollutants as water infiltrates through sub-surface layers containing microbes that treat pollutants. Treated runoff is then slowly infiltrated and recharges the groundwater. These biological processes operate in all infiltration-based strategies, including various retention systems.

Conveyance. The process of water moving from one place to another.

Daylight. To bring stormwater or streetwater flow to the surface, exposed to open air and visible to the public.

Design Storm. A storm whose magnitude, rate, and intensity do not exceed the design load for a storm drainage system or flood protection project

Detention. Stormwater runoff that is collected at one rate and then released at a controlled rate. The difference is held in temporary storage.

Dry weather runoff. Human activity-related sources of water, such as irrigation overspray, car wash runoff, leaking plumbing, fire hydrant and well flushing, and runoff from mechanical processes such as air conditioning.

Filtration. A treatment process that allows for removal of solid (particulate) matter from water by means of porous media such as sand, soil, vegetation, or a man-made filter. Filtration is used to remove contaminants.

Hardscape. Impermeable surfaces, such as concrete or stone, used in the landscape environment along sidewalks or in other areas used as public space.

Infiltration. The process by which water penetrates into soil from the ground surface.

Permeability/Impermeability. The quality of a soil or material that enables water or air to move through it, and thereby determines its suitability for infiltration-based stormwater strategies.

Retention. The reduction in total runoff that results when stormwater is diverted and allowed to infiltrate into the ground through existing or engineered soil systems.

Runnel. Narrow, shallow drainage channel designed to carry small amounts of runoff

Runoff. Water from rainfall that flows over the land surface that is not absorbed into the ground.

Sedimentation. The deposition and/or settling of particles suspended in water as a result of the slowing of the water.

Softscape. Natural, permeable, landscape surfaces such as vegetation, mulch, and loose rock.

Stormwater. Rainwater that flows and collects in the street.

Streetwater. All waters flowing in the street or other hardscapes in the right-of-way, whether from dry weather runoff or rainwater sources.

Tools for Streetwater Management

There are many tools and best management practices (BMPs) for managing streetwater sustainably. Most popular are devices and practices that encourage water percolation on-site to the maximum degree practicable (given soil conditions, pollutant levels, etc.). The most important devices and practices are bioretention BMPs consisting of swales, planters, and vegetated buffer strips, as well as detention BMPs consisting of rain gardens and infiltration trenches. While permeable paving also slows and retains streetwater, it is listed separately because its primary function is to serve as a surfacing material that reduces runoff. Additional tools include delivery and conveyance tools and inlet protections.

The streetwater management tools mentioned in this manual are highly customizable and can be integrated into a variety of different types of spaces in any of the street types. They can be implemented alone or in concert with one another to achieve cumulative benefits. Opportunity sites include medians, corner and midblock curb extensions, roadway and park edges, front building edges, and surrounding street trees. Selecting the appropriate BMP is very dependent on street type and site conditions. High traffic commercial streets have different parameters than smaller residential streets.

The following sections describe techniques to site and construct systems to integrate streetwater management tools into both new and existing streets. Table 12.1 below describes typical applicability of specific streetwater tools to individual street types.

Table 12.1 Best Fit for Streetwater Tools by Street Context

		BIORETENTION			DETENTION		PAVING	DELIVERY AND CONVEYANCE	INLET PROTECTIONS			
	STREET CONTEXT	Swales	Planters	Vegetated Buffer Strips and Retention Ponds	Rain Gardens	Infiltration Trenches and Detention Ponds	Permeable Paving	Channels and Runnels	Screens	Inlet Inserts	Pollution Control Boxes	Pipe Filters
Commercial	Downtown Commercial		o		o	o	o	o	o	o	o	o
	Commercial Throughway		o	o	o	o	o	o	o	o	o	o
	Neighborhood Commercial		o	o	o	o	o	o	o	o	o	o
Residential	Downtown Residential	o	o		o	o	o	o	o	o	o	o
	Residential Throughway	o	o		o	o	o	o	o	o	o	o
	Neighborhood Residential	o	o		o	o	o	o	o	o	o	o
Industrial And Mixed-Use	Industrial	o	o		o	o	o	o	o	o	o	o
	Mixed-Use		o	o	o	o	o	o	o	o	o	o
Special	Sidewalk Furniture Zone	o	o		o	o	o	o	o	o	o	o
	Park Edge	o	o		o	o	o	o	o	o	o	o
	Boulevard	o	o		o	o	o	o	o	o	o	o
	Ceremonial (Civic)						o	o	o	o	o	o
Small	Alley		o			o	o	o	o	o	o	o
	Shared Public Way		o			o	o	o	o	o	o	o

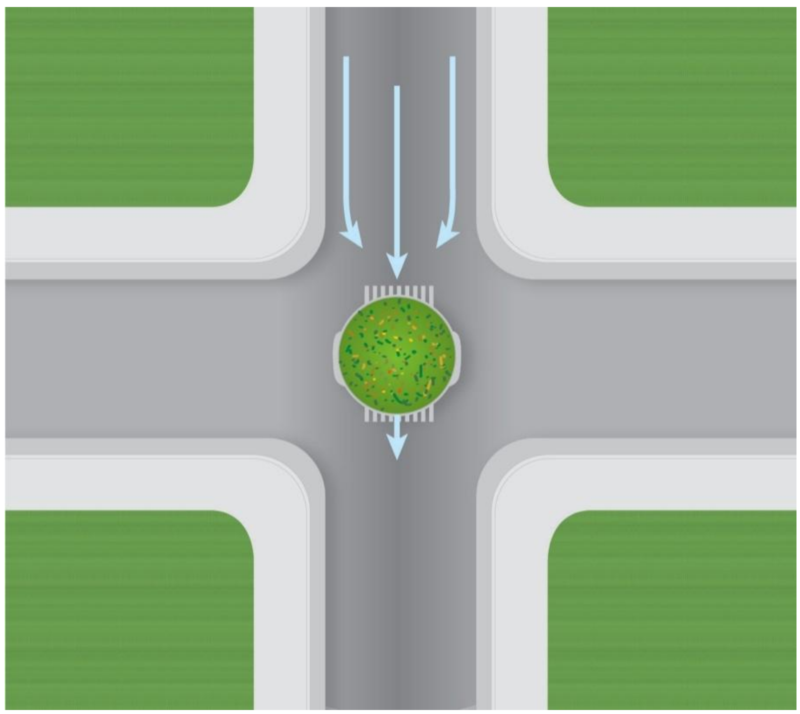
General Guidelines

Site Considerations

Streetscape geometry, topography, and climate determine the types of controls that can be implemented. The initial step in selecting a streetwater tool is determining the available open space and constraints. Although the maximum size of a selected streetwater facility may be determined by available area, the standard design storm should be used to determine the appropriate size, slope, and materials of each facility.

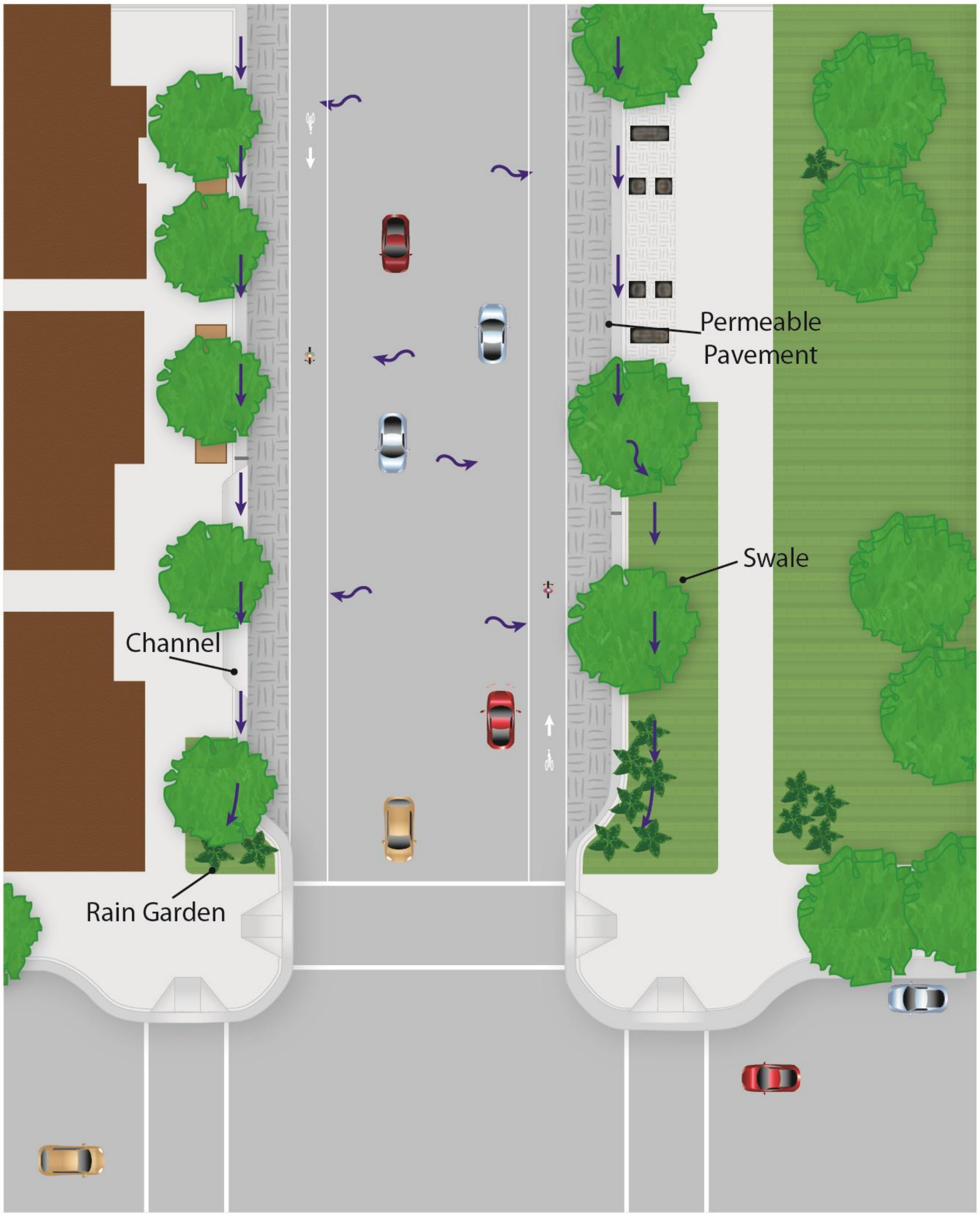
After identifying the appropriate streetwater facilities for a site, an integrated approach using several tools is encouraged. To increase water quality and functional hydrologic benefits, several streetwater management tools can be used in succession. This is called a treatment train approach. The control measures should be designed using available topography to take advantage of gravity for conveyance to and through each facility.

Traffic calming measures, such as medians, circles, chicanes, and curb extensions, should integrate streetwater management options discussed in this section. The first image to the right illustrates a center-draining street utilizing a rain garden integrated into a circle. These areas offer ideal opportunities for treating runoff as they typically intercept the flow path of water along a street and provide additional surface and subsurface space for treating and infiltrating streetwater. By integrating streetwater management tools at an early design stage, new facilities can be added with only marginal cost when paired with other streetscape construction projects. However, this idea should also be incorporated into street repaving projects.



Rain garden in rotary island
(Credit: Michele Weisbart)

The image below illustrates a possible treatment on a traditional crowned street with traffic calming measures.



Crowned complete street
(Credit: Michele Weisbart)

Infiltration Considerations
Appropriate soils, infiltration media, and infiltration rates should be used for infiltration BMPs. Ideally, a complete geotechnical or soils report should be undertaken to determine infiltration rates, soil toxicity and stability, and other factors that will affect the ability and the desirability of infiltration. At a minimum, the infiltration capacity of the underlying soils

should be deemed suitable for infiltration and appropriate media should be used in the BMP itself.

Using certain techniques, streetwater tools can still be incorporated into areas of low permeability or where infiltration of stormwater is not desirable. Underdrains should be used in areas of low soil permeability. The location of the underdrain is an important consideration: if placed higher in a facility, the stored water below the perforated pipe will be infiltrated. If placed at the bottom of a sealed system, the perforated pipe will release the stored water slowly over time. These infiltration BMPs may overflow to appropriate locations such as catch basins and outfalls.

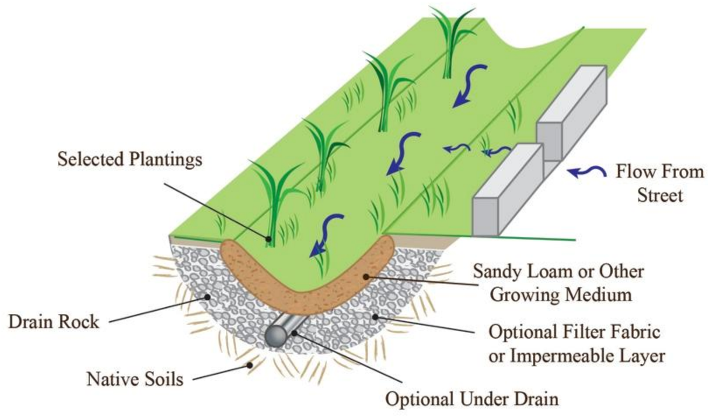
Details are important to the ultimate success or failure of an infiltration system. Poor soil conditions may cause stormwater to infiltrate either too fast or too slow. Over-compaction of subsurface soil during construction can lead to reduced infiltration capacity, flooding, and ponding. The bottom surface of infiltration areas should be level to allow even distribution. Soils and gravels in an infiltration installation should be meticulously specified and verified in the field during construction. Proper maintenance is crucial to the success of an infiltration BMP. To ensure proper caretaking, a maintenance plan or contract with a local agency is necessary.

<u>Bioretention</u>

Swale as Planter: Broward County
(Credit: Pattie Gertenbach)

Bioretention is a stormwater management process that cleans stormwater by mimicking natural soil filtration processes as water flows through a bioretention BMP. It incorporates mulch, soil pores, microbes, and vegetation to reduce and remove sediment and pollutants from stormwater. Bioretention is designed to slow, spread, and, to some extent, infiltrate water. Each component of the bioretention BMP is designed to assist in retaining water, evapotranspiration, and adsorption of pollutants into the soil matrix. As runoff passes through the vegetation and soil, the combined effects of filtration, absorption, adsorption, and biological uptake of plants remove pollutants.

For areas with low permeability or other soil constraints, bioretention can be designed as a flow-through system with a barrier protecting streetwater from native soils. Bioretention areas can be designed with an underdrain system that directs the treated runoff to infiltration areas, cisterns, or the storm drain system, or may treat the water exclusively through surface flow.



Established swale in the landscape
(Credit: Julia Campbell and Michele Weisbart)

Included in this section are discussions of swales, planters, and vegetated buffer strips.

Location and Placement

Bioretention facilities can be included in the design of all street components: adjacent to the traveled way and in the frontage or furniture sidewalk zones. They can be designed into curb extensions, medians, traffic circles, roundabouts, and any other landscaped area. Depending on the feature, maintenance and access should always be considered in locating the device. Bioretention systems are also appropriate in constrained locations where other stormwater facilities requiring more extensive subsurface materials are not feasible.

Guidelines

A sponge-like surface application of organic mulch can quicken the rate of absorption into the soil, slow soil moisture loss to evaporation, and reduce the solid waste stream if the mulch is generated from local organic matter. This strategy can also intercept and reduce sediment and nutrient concentrations in runoff via bioremediation.

Plants should be microclimate-appropriate and must be able to tolerate occasional saturation as well as dry periods (see the Urban Forestry section of this chapter for planting recommendations).

The use of multiple small devices is often more feasible in tight urban environments than the use of one large device. Small systems can be linked together to achieve the desired cumulative capacity.

Swales

Swales are linear, vegetated depressions that capture rainfall and runoff from adjacent surfaces. The swale bottom should have a gradual slope to convey water along its length. Swales can reduce off-site streetwater discharge and remove pollutants along the way. In a swale, water is slowed by traveling through vegetation on a relatively flat grade. This gives particulates time to settle out of the water while contaminants are removed by the vegetation. Because the vegetation receives much of its needed moisture through streetwater, the need for irrigation is greatly reduced.

Sidewalk-adjacent swale during storm event

(Credit: Edward Belden, Los Angeles and San Gabriel Rivers Watershed Council)

Location and placement. Swales can easily be located adjacent to roadways, sidewalks, or parking areas. Roadway runoff can be directed into swales via flush curbs or small evenly-spaced curb cuts into a raised curb. Swale systems can be integrated into traffic calming devices such as chicanes and curb extensions.

Swales can be placed in medians where the street drains to the median. Placed alongside streets and pathways, vegetated swales can be landscaped with native plants which filter sediment and pollutants and provide habitat for wildlife. Swales should be designed to work in conjunction with the street slope to maximize filtration and slowing of streetwater.

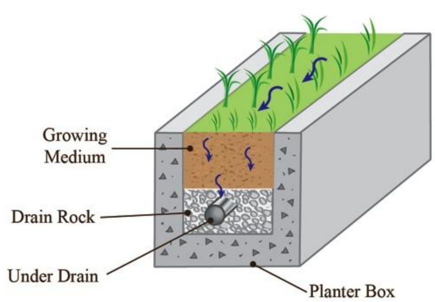
Guidelines. Soils that promote absorption and support vegetation, such as sandy loams, should be specified on a case-by-case basis. Base layers of rock and stabilizing filter fabric may also be specified. Swale length, width, depth, and slope should be determined by capacity needed for treatment of the design storm.

Swales are designed to allow water to slowly flow through. Depending on the landscape and design storm, an overflow or bypass for larger storm events may be needed. Curb openings should be designed to direct flow into the swale. Following the inlet, a sump may be built to capture sediment and debris. Mulch can be used in systems where it will not escape the swale system, such as in flatter, deeper swales. Check dams should be used to slow the velocity of water and catch sediment when the slope along the length of the swale exceeds 4 percent.

Swales should be landscaped with deep-rooted grasses and vegetation that tolerate short periods of inundation, deposits of sediment, and periods of drought. Vegetation will filter sediment and slow erosion, protecting the swale from failure. The sides of swales should be minimally sloped to protect the swale from erosion and slope failure.

Swale with curb cut opening and decorative grate outlet
(Credit: AHBE Landscape Architects)

Planters



Planter detail
(Credit: Julia Campbell and Michele Weisbart)

Planters are typically above-grade or at-grade with solid walls and a flow-through bottom. They are contained within an impermeable liner and use an underdrain to direct treated runoff back to the collection system. Where space permits, buildings can direct roof drains first to building-adjacent planters. Both underdrains and surface overflow drains are typically installed with building-adjacent planters.

At-grade street-adjacent planter boxes are systems designed to take street runoff and/or runoff from sidewalks and incorporate bioretention processes to treat stormwater. These systems may or may not include underdrains.

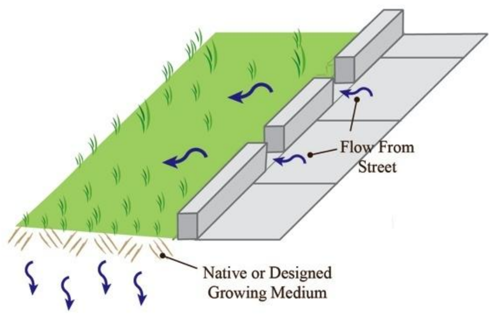
Location and placement. Above-grade planters should be structurally separate from adjacent sidewalks to allow for future maintenance and structural stability per local department of public works' standards. At-grade planter systems can be installed adjacent to curbs within the frontage and/or furniture zones.

Guidelines. All planters should be designed to pond water for less than 48 hours after each storm. Flow-through planters designed to detain roof runoff can be integrated into a building's foundation walls, and may be either raised or at grade.

For at-grade planters, small localized depressions may be included in the curb opening to encourage flow into the planter. Following the inlet, a sump (depression) to capture sediment and debris may be integrated into the design to reduce sediment loadings.

Planter along a downtown street
(Credit: Kevin Robert Perry)

Vegetated Buffer Strips



Vegetated buffer strip detail (Credit: Julia Campbell and Michele Weisbart)

Vegetated buffer strips are sloping planted areas designed to treat and absorb sheet flow from adjacent impervious surfaces. These strips are not intended to detain or retain water, only to treat it as a flow-through feature. They should not receive concentrated flow from swales or other surface features, or concentrated flow from pipes.

Location and placement. Vegetated buffer strips are well-suited to treating runoff from roads and highways, small parking lots, and pervious surfaces. They may be commonly used on multi-way boulevards, park edge streets, or sidewalk furniture zones with sufficient space. Vegetated buffers can be situated so they serve as pre-treatment for another streetwater management feature, such as an infiltration BMP.

Guidelines. Buffer strips cannot treat large amounts of runoff; therefore, the maximum drainage width (with the direction of flow being towards the buffer) of the contributing drainage area should be 60 square feet. In general, a buffer strip should be at least 15 feet wide in the direction of flow to provide the highest water quality treatment.

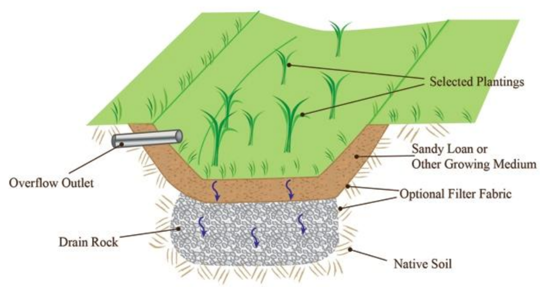
The top of the strip should be set 2 to 5 inches below the adjacent pavement or contributing drainage area, so that vegetation and sediment accumulation at the edge of the strip does not prevent runoff from entering.

Buffer strips should be sited on gentle slopes. Steep slopes in excess of 15 percent may trigger erosion during heavy rain events, thus eliminating water quality benefits.

Detention

Detention devices differ from retention in that they are designed and sized to hold a specific volume of water and then slowly release it over time. On the other hand, the bioretention BMPs described in the previous section are designed and sized based on flow—the rate of water passing through them. The objective of bioretention is to improve the quality of streetwater by promoting filtration and adsorption as water flows through vegetation and soil. Detention devices do not function as flow-through features, but rather the objective is to collect and contain water until it is removed by controlled release or infiltrated into the soil. Overflow outlets may be included to manage large storm events. Pollutants may be removed by vegetation and the topsoil layer as in bioretention BMPs so that streetwater is treated before it is infiltrated. Detention devices can greatly reduce the volume of runoff from streetscapes and for small storm events may completely eliminate runoff.

Rain Gardens



Rain garden detail
(Credit: Julia Campbell and Michele Weisbart)

Rain gardens are shallow, vegetated depressions in the landscape that are planted with deep-rooted plants and grasses. Rain gardens can also be planted with native trees as space allows. This is especially desirable because one tree can reduce stormwater runoff by 4,000 gallons per year. Rain gardens have flat bottoms and gently sloping sides. Rain gardens can be similar in appearance to swales, but their footprints may be any shape. Rain gardens hold water on the surface, like a pond, and have overflow outlets. The detained water is infiltrated through the topsoil and subsurface drain rock unless the volume of water is so large that some must overflow. Rain gardens can reduce or eliminate off-site streetwater discharge while increasing on-site recharge.

Rain garden in an urban landscape
(Credit: Kevin Robert Perry)

Location and placement. Rain gardens may be placed where there is sufficient area in the landscape and where soils are suitable for infiltration. Rain gardens can be integrated with traffic calming measures installed along streets, such as medians, islands, circles, street ends, chicanes, and curb extensions (pedestrian bulb-outs). Rain gardens are often used at the terminus of swales in the landscape.

Rain garden: Portland, OR
(Credit: Brad Lancaster, www.HarvestingRainwater.com)

Guidelines. Native soils should have a minimum permeability rate of 0.5 inches per hour. Sites that have more than a 5 percent slope may require other stormwater management approaches or special engineering. The topsoil layer should be designed on a case-by-case basis and may often be a type of sandy loam. Subsurface drain rock will promote infiltration and should also be designed for each installation. Local public works departments may have additional guidelines for rain garden design.

The size and shape of rain gardens will vary in each case and the available area in the landscape may determine the maximum footprint. Because rain gardens are volume-based BMPs, their surface area and depth will be designed to achieve the desired detention volume. Overflow outlets should be below the lip of the rain garden and at a height consistent with the desired detention volume. Sides should be gently sloping to prevent erosion.

Rain gardens should be landscaped with deep-rooted grasses and other vegetation that can tolerate short periods of inundation, deposits of sediment, and periods of drought. According to the University of Florida IFAS Extension, suggested Florida rain garden plantings include Loblolly Bay, Sweetbay Magnolia, Wax Myrtle, Cabbage Palm, Saw Palmetto, and Dahoon Holly.

Infiltration Trenches

Infiltration trenches are linear, rock-filled features that promote infiltration by providing a high ratio of sub-surface void space in permeable soils. They provide on-site stormwater retention and may contribute to groundwater recharge. Infiltration trenches may accept streetwater from sheet flow, concentrated flow from a swale or other surface feature, or piped flow from a catch basin. Because they are not flow-through BMPs, infiltration trenches do not have outlets but may have overflow outlets for large storm events.

Infiltration trenches are typically designed to infiltrate all flow they receive. In large storm events, partial infiltration of runoff can be achieved by providing an overflow outlet. In these systems, significant or even complete volume reduction is possible in smaller storm events. During large storm events, these systems may function as detention facilities and provide a limited amount of retention and infiltration.

Location and placement guidelines. Infiltration trenches typically have small surface footprints so they are potentially some of the most flexible elements of landscape design. However, because they involve sub-surface excavation, these features may interfere with surrounding structures. Care needs to be taken to ensure that surrounding building foundations, pavement bases, and utilities are not damaged by infiltration features. Once structural soundness is ensured, infiltration features may be located under sidewalks and in sidewalk planting strips, curb extensions, roundabouts, and medians. When located in medians, they are most effective when the street is graded to drain to the median.

Infiltration features should be sited on uncompacted soils with acceptable infiltration capacity. They are best used where soil and topography allow for moderate to good infiltration rates (0.5 inches per hour) and the depth to groundwater is at least 10 feet. Prior to design of any retention or infiltration system, proper soil investigation and percolation testing should be conducted to determine appropriate infiltration design rates. Any site with potential for previous underground contamination should be investigated. Infiltration trenches and can be designed as stand-alone systems when water quality is not a concern or may be combined in series with other streetwater tools.

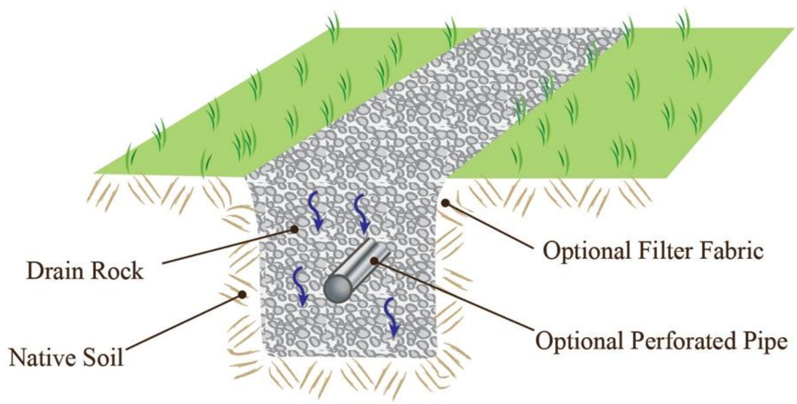
Pre-treatment, design, and installation guidelines. Infiltration features do not treat streetwater and may become damaged by streetwater carrying high levels of sediment. In general, infiltration features should be designed in series with bioretention tools unless the infiltration features receive water from well-vegetated areas where sediment is not expected. Pre-treatment features should be designed to treat street runoff prior to discharging to infiltration features. Bioretention devices, sumps, and sedimentation basins are several pre-treatment tools effective at removing sediment.

Trenches are typically backfilled with coarse drain rock (coarse gravel) and may or may not be lined with filter fabric. Additional void space can be achieved by including materials such as perforated pipes, half pipes, or open blocks within the drain rock. The trench surface can be planted, covered with grating, covered with boardwalks, or simply remain as exposed drain rock. Local public works departments should be contacted for any local guidance on infiltration feature design.

The slope of the infiltration trench bottom should be designed to be level or with a maximum slope of 1 percent. Infiltration BMPs should be installed parallel to contours with maximum ground slopes of 20 percent and be located no closer than 5 feet to any building structure. Sub-soils should not be compacted. Drain rock and, if needed, filter fabric with an overflow drain should be designed for each installation.

Perforated pipes and piped inlets and outlets may be included in the design of infiltration trenches. Cleanouts should be installed at both ends of any piping, and at regular intervals in long sections of piping, to allow access to the system. Monitoring wells are recommended for both trenches and wells and can be combined with clean-outs. If included, the overflow inlet from the infiltration trench should be properly designed for anticipated flows.

Infiltration trench with perforated pipe during installation (Credit: Neil Shapiro)



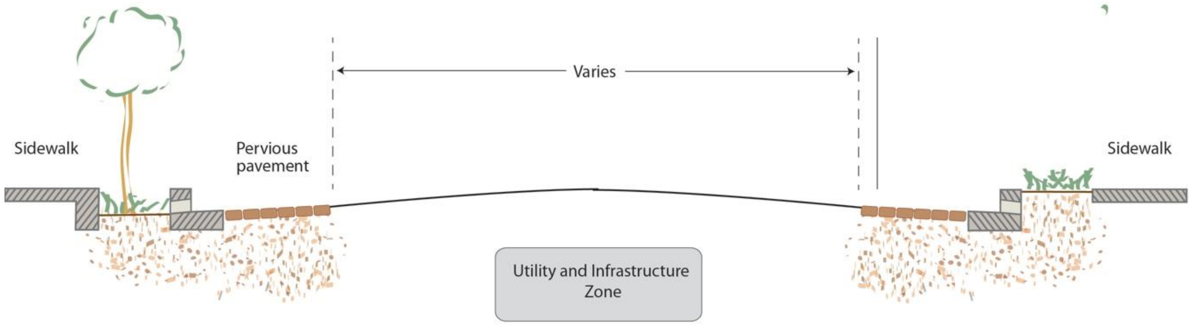
Infiltration trench
(Credit: Julia Campbell and Michele Weisbart)

Paving

Permeable Paving
Permeable paving is a system with the primary purpose of slowing or eliminating direct runoff by absorbing rainfall and allowing it to infiltrate into the soil. This BMP is impaired by sediment-laden run-on which diminishes its porosity. Care should be taken to avoid flows from landscaped areas reaching permeable paving. In those cases, bioretention is a better choice for BMPs. Permeable paving is, in certain situations, an alternative to standard paving. Conventional paving is designed to move streetwater off-site quickly. Permeable paving, alternatively, accepts the water where it falls, minimizing the need for management facilities downstream.

Permeable paving

- Filters and cleans pollutants such as petroleum deposits on streets
- Reduces water volumes for existing overtaxed pipe systems
- Decreases the cost of offsite or onsite downstream infrastructure



Street section elevation illustrating placement of pervious pavement
(Credit: Marty Bruinsma)

Permeable pavement after a rain event
(Credit: Neil Shapiro)

Location and placement guidelines. Conditions where permeable paving should be encouraged include:

- Sites where there is limited space in the right-of-way for other BMPs
- Parking or emergency access lanes
- Furniture zones of sidewalks especially adjacent to tree wells

Conditions where permeable paving should be avoided include:

- Where runoff is already being harvested from an impervious surface for direct use, such as irrigation of bioretention landscape areas
- Steep streets
- Large traffic volume or heavy load lanes
- Gas stations, car washes, auto repair, and other sites/sources of possible chemical contamination
- Areas with shallow groundwater
- Within 20 feet of sub-sidewalk basements
- Within 50 feet of domestic water wells

Material guidelines. When used as a road paving, pervious pavement that carries light traffic loads typically has a thick drain rock base material. Pavers should be concrete as opposed to brick or other light-duty materials. Other possible permeable paving materials include porous concrete and porous asphalt. These surfaces also have specific base materials that detain infiltrated water and provide structure for the road surface. Base material depths should be specified based on design load and the soils report.

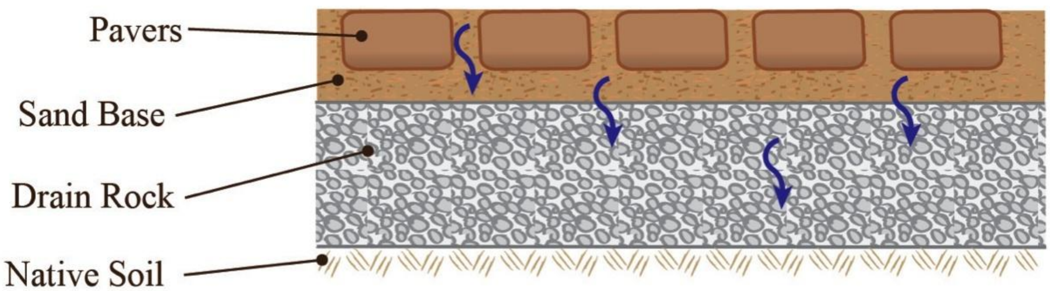
Plazas, emergency roads, and other areas of limited vehicular access can also be paved with permeable pavement. Paving materials for these areas may include open cell paver blocks filled with stones or grass and plastic cell systems. Base material specifications may vary depending on the product used, design load, and underlying soils.

When used for pedestrian paths, sidewalks, and shared-use paths, appropriate materials include those listed above as well as rubber pavers and decomposed granite or something similar (washed of pore-clogging fine material). Pedestrian paths may also use broken concrete pavers provided ADA requirements are met. Paths should drain into adjoining landscapes and should be higher than adjoining landscapes to prevent run-on. Soil paths are not successful on slopes in excess of 4 percent. Any pervious materials used for sidewalks or paths should be very smooth for wheelchairs and bicyclists.


Permeable paving and a trench drain in a parking area
(Credit: Stephanie Landregan)

Design guidelines. Design considerations for permeable paving include:

- The location, slope and load-bearing capacity of the street.
- The infiltration rate of the soil.
- The amount of storage capacity of the base course.
- The traffic volume and load from heavy vehicles.
- The design storm volume calculations and the quality of water.
- Drain rock, filter fabrics, and other subsurface materials.
- Installation procedures including excavation.



Pervious pavement detail
(Credit: Julia Campbell and Michele Weisbart)

A soil or geotechnical report should be conducted to provide information about the permeability and load-bearing capacity of the soil. Infiltration rate and load capacity are key factors in the functionality of this BMP. Permeable paving generally does not have the same load-bearing capacity as conventional paving, so this BMP may have limited applications depending on the underlying soil strength and paving use. Permeable paving should not be used in general traffic lanes due to the possible variety of vehicles weights and heavy volumes of traffic.

The soil report should also provide the depth of the water table to determine if permeable pavers are an appropriate application for the site. Pervious pavement typically requires a 4-foot or more separation from the water table or bedrock to properly infiltrate streetwater. Pervious pavement is not recommended over new or compacted fill.

Because permeable pavement is damaged by sediment deposits, it should be carefully placed in the landscape so as to avoid run-on, especially from sediment-laden sources such as landscaped areas.

Pavement used for sidewalks and pedestrian paths should be ADA compliant, especially smooth, and not exceed a 2 percent slope or have gaps wider than 0.25 inches. In general, tripping hazards should be avoided.

Maintenance and installation guidelines. Proper construction and installation of permeable pavement is vital to its success. To ensure that the paving system functions properly, sub-base preparation and stormwater pollution prevention measures should be performed appropriately during installation.

Construction considerations include:

- Scarifying soils so that they remain porous.
- Avoiding compaction of soils.
- Preventing run-on and sedimentation during construction.

Maintenance of permeable pavement systems is essential to their continued functionality. Regular vacuuming and street sweeping should be performed to remove sediment from the pavement surface. The bedding and base material should be tested to ensure continued sufficient infiltration rates on a regular basis. Additionally, base material may need to be removed and replaced every several years based upon the material manufacturer's specifications.

<u>Delivery and Conveyance</u>

Water conveyance measures in the hardscape may support the treatment BMPs outlined above. By daylighting streetwater flow, these measures draw attention to water movement and can in turn highlight bioretention and detention BMPs. Delivery and conveyance measures do not treat streetwater for quality and do not reduce water volume. They are therefore only recommended as supporting infrastructure, a preferable alternative to traditional piped flow.

Channels, Runnels, Trench Drains, and Constructed Swales

Channels, runnels, trench drains, and constructed swales are conventional methods of conveying moderate amounts of streetwater from buildings and impervious surfaces to other drainage collection systems, streets, or planters. They are hardscape features constructed from impermeable materials.

Typically, these structures work well where there is a need for water redirection and space is limited. These hardscape methods may serve to move streetwater from the street to landscaped areas. Channels and constructed swales are not used for stormwater treatment but serve as daylighted, visible conveyance features in lieu of closed pipe systems. They provide opportunities to acknowledge natural drainage processes with artistic design features along the drainage path.

A variety of materials can be used for channels, runnels, and constructed swales: stone, brick, pebbles, pavers, and concrete. Rock swales can be created by arranging stones loosely and mortaring them in place. When a closed top is required, grates can be constructed; proprietary products in standard sizes are readily available. Decorative grates are aesthetic and help illustrate water flow processes.

Because these structures are gravity fed, they require slopes to function properly. On slopes greater than 6 percent, check dams or other velocity reduction devices should be provided.

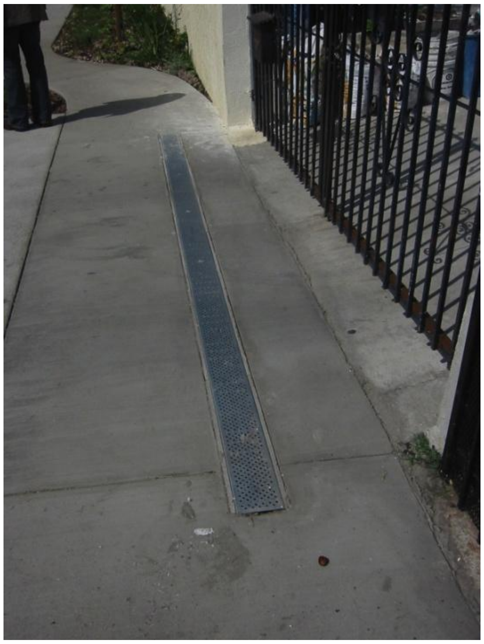
These conveyance features may direct sheet flow to bioretention or infiltration features or simply serve as an alternative to piped flow in conventional drainage systems. Dimensions should be determined based on the design storm.

Channels have vertical sides and provide a drainage path to a downstream streetwater management feature. Channels vary in depth depending on the amount of flow they are designed to carry, have a sloped bottom, and can be covered or open. In some cases, channels can be constructed with pervious bottoms. Channels can be placed in plazas, driveways, and other hardscapes where conveyance is needed. Channels may be used in some situations where swales or pipes would be too costly or impossible due to site constraints. In broad landscape contexts, channels can be large and constructed to carry large volumes of water.

Runnels are shallower than channels, typically only a couple of inches deep, and are designed to carry small flows of streetwater. Runnels may have an open top but must be covered if they cross pedestrian walkways. Most often runnels are used to convey runoff from hardscapes to adjacent streetwater treatment landscapes. Runnels may be very useful in pedestrian hardscape areas where artistic construction is highly visible. The location and design of runnels should be carefully selected so that they do not pose tripping hazards.

Decorative runnel and fountain
(Credit: Stephanie Landregan)

Trench drains are a type of conveyance system similar to runnels. Trench drains differ from runnels in that they are usually smaller and have a grated top. They also have solid sides and bottoms. Trench drains are available in standard sizes and dimensions from a variety of manufacturers.



Trench drain in hardscape
(Credit: Stephanie Landregan)

Constructed swales are similar to the swales discussed earlier but are constructed from impervious materials. They typically are long narrow depressions used to convey water. The size of a swale should be determined by the design storm and landscape features.

Constructed swale with drain
(Credit: Stephanie Landregan)

Access, design, and maintenance guidelines. All conveyance structures, both open and covered, need to meet accessibility guidelines when in the path of travel. Boardwalks can cover large swales, or decorative grates can be used over smaller widths.

Channels, runnels, and constructed swales should be designed to meet the local agency design storm requirements. Overflow features may be required in some areas and should drain to the nearest gutter or other drainage feature, always draining away from adjacent properties. These features should be designed to allow debris to move through them and account for stoppages that could limit the drainage capacity.

Maintaining a clear conduit is essential for the proper functioning of conveyance structures. These features should be cleaned before the rainy season and checked before and after storm events. Trash, cigarette butts, soil sediment, and leaf litter all can contribute to failure and decrease the function of these features.

Storm Drain Inlet Protections: Retrofitting Existing Storm Drains

Existing storm drain systems may be retrofitted to improve streetwater quality without costly capital improvements. The BMPs described below can be used with existing conventional piped storm drain systems to address water quality but not water volume concerns. The measures described below are designed to prevent particulates, debris, metals, and petroleum-based materials conveyed by streetwater from entering the storm drain system. All storm drain protection units should have an overflow system that allows the storm drain to remain functional if the filtration system becomes clogged during rainstorms.

Typical maintenance of catch basins includes scheduled trash removal if a screen or other debris capturing device is used. Street sweeping should be performed by vacuum sweepers with occasional weed and large debris removal. Maintenance should include keeping a log of the amount of sediment collected and the data of removal. Some local jurisdictions have incorporated the use of GIS systems to track sediment collection and to optimize future catch basin cleaning efforts. Bulb-outs should be designed with two return curves with a radius of over 10 feet to allow street sweepers to clean the corners.

All inlet tools located in the pedestrian access route should conform to ADA requirements.

Curb inlet grate catching debris
(Credit: Andre Haghverdian)

Storm Drain Inlet Screens: Placement and Guidelines
Inlet screens are designed to prevent large litter and trash from entering the storm drain system while allowing smaller particles to pass through. The screens function as the first preventive measure in removing pollutants from the storm water system. Storm drain inlet

screens can be designed and fabricated on an as-needed basis; proprietary screens are readily available for standard size inlets.

Inlet screens are external units mounted on existing curb side storm drain catch basins. The unit captures bigger particles and allows the storm water and small particles to pass through. The screen can be mounted on hinges to create a bypass if the screen is clogged during a storm.

A wide range of storm drain inlet screens is available. The city's street sweeping department should be consulted to ensure compliance with local specifications and to schedule regular maintenance. Annual inspection of the screen is recommended to ensure functionality.

Storm Drain Inlet Protection: Placement and Guidelines

The inlet protection should be designed to protect curbside catch basins or inlets within the traveled way. Inlet inserts contain filter cartridges that can be easily replaced.

The inlet protection can be installed on the existing wall of the catch basin. It can be placed on the curb side wall of catch basins so that during storm events water can overflow around the unit.

Inlet inserts should be sized to capture all debris and should therefore be selected to match the specific size and shape of each catch basin and inlet. Maintenance should be taken into account—systems with lower maintenance requirements are preferred.

Storm Drain Pipe Filter: Placement and Guidelines

The storm drain outlet pipe protection or filter is designed to be installed on an existing outlet pipe or at the bottom of an existing catch basin with an overflow. This filter removes debris, particulates, and other pollutants from streetwater as it leaves the storm drain system. This BMP is less desirable than a protection system that prevents debris from entering the storm drain system because the system may become clogged with debris.

Outlet pipe filters can be placed on existing curbside catch basins and flush grate openings. Regular maintenance is required and inspection should be performed rigorously. Because this filter is located at the outlet of a storm drain system, clogging with debris is not as apparent as with filters at street level. This BMP may be used as a supplemental filter with an inlet screen or inlet insert unit.

URBAN FORESTRY

The urban forest includes all trees, shrubs, and other understory plantings on both public and private lands. Street trees and landscaping are essential parts of the urban forest, as they contribute positively to the urban environment—to climate control, stormwater collection, and the comfort and safety of people who live or travel along the street. A street lined with trees and other plantings looks and feels narrower and more enclosed, which encourages drivers to slow down and to pay more attention to their surroundings. Trees provide a physical and a psychological barrier between pedestrians and motorized traffic, increasing safety as well as making walking more enjoyable.

A healthy urban forest is also a powerful streetwater management tool. Leaves and branches catch and slow rain as it falls, helping it to soak into the ground. The plants themselves take up and store large quantities of water that would otherwise contribute to surface runoff. Part of this moisture is then returned to the air through evaporation to further cool the city.

As an important element along sidewalks, street trees must be provided with conditions that allow them to thrive, including adequate uncompacted soil, water, and air. This section provides guidance for appropriate conditions and selecting, planting, and caring for street trees, as well as for other landscaping along streets.

Urban forest of street trees on a residential street in Fort Lauderdale (Credit: Kimley-Horn and Associates, Inc.)

Street Trees

Goals and Benefits of Street Trees

The goal of adding street trees is to increase the canopy cover of the street, the percentage of the streets surface either covered by or shaded by vegetation, not simply to increase the overall number of trees. The selection, placement, and management of all elements in the street should enhance the longevity of a city's street trees and healthy, mature plantings should be retained and protected whenever possible.

Street trees purify and cool the air, reduce stormwater runoff, and conserve energy. Additional related benefits of street trees include increased property values, neighborhood beautification, and enhanced human health and well-being. According to www.rootfortrees.org, street tree benefits are directly related to tree size. The environmental benefits of trees arise from respiration and transpiration, which are the biological processes by which trees breathe and absorb water from the environment. Because these processes involve interactions between a tree's leaves, the environment, and the atmosphere, the benefits increase as trees grow in size.

A large tree will yield $48 to $62 in average annual net benefits over 40 years with costs factored in (McPherson, G. et al, *"Tree Guidelines for San Joaquin Valley Communities*," Western Center for Urban Forest Research and Education, USDA Forest Service, 1999). Adding street trees provides the following benefits.

Appropriate local street trees
(Credit: Kimley-Horn and Associates, Inc.)

- Creates shade to lower temperatures in a city, reduces energy use, and makes the street a more pleasant place in which to walk and spend time
- Slows and captures rainwater, helping it soak into the ground to restore local hydrologic functions and aquifers
- Improves air quality by cooling air, producing oxygen, and absorbing and storing carbon in woody plant tissues
- Increases property values and sales revenues for existing businesses
- Enhances local neighborhood and cultural identity through specific plant forms and materials, the act of planting and sharing food crops, or by creating sheltering spaces for social interaction
- Enhances safety and personal security on a street by calming traffic and by fostering a denser and more consistent human presence, also referred to as eyes on the street
- Provides cover, food, and nesting sites for indigenous wildlife as well as facilitates habitat connectivity

Principles for Street Trees

The following principles influence the selection of street trees and landscaping design:

- Seek out and reclaim space for trees. Streets have a surprising number of residual or left-over spaces between areas required for travel lanes and parking, once they are examined from this perspective. Traffic circles, medians, channelization islands, and curb extensions can provide space for trees and landscaping.
- Create optimum conditions for growth. Space for roots and above ground growth is the main constraint to the urban forest achieving its highest potential. Typically a 6 to 8-foot wide, continuous sidewalk furniture zone must be provided, with uncompacted soil to a minimum of a 3-foot depth. If space for trees is constrained, provisions should be made to connect these smaller areas below the surface to form larger effective areas for the movement of air, root systems, and water through the soil.
- Select the right tree for the space. In choosing a street tree, consider what canopy, form, and height will maximize benefits over the course of its life. Provide necessary clearances below overhead high-intensity electrical transmission lines and prevent limbs from overhanging potentially sensitive structures such as flat roofs. In commercial areas where the visibility of façade-mounted signs is a concern, choose species whose mature canopy allows for visibility, with the lowest branches at a height of 12 to 14 feet or more above the ground. Select trees with non-aggressive root systems to avoid damaging paving and sidewalks.
- Start with good nursery stock and train it well. When installing plant material, choose plants that have complete single leaders and are in good "form," and check that boxed trees are not root bound. Proper watering and pruning every three to four years will allow trees to mature and thrive for many years of service.
- Do not subject plants to concentrated levels of pollutants. Trees and other plants should be integrated within streetwater management practices whenever possible, but filtering of pollutants from “first flush” rain falls and street runoff will extend the life of trees and prevent toxic buildup of street pollutants in tree wells.

Guidelines

Climate and Soil

Selecting trees that are adapted to a site's climate and local rain cycles can create a more sustainable urban forest. The urban environment is harsh for many plants. Often plants native to an area are best adapted to that area’s climate. Select plants that can tolerate the environmental elements, such as radiant heat from the sidewalk or street surface or 50 to 60 mph winds from passing traffic.

Urban soils have become highly compacted through construction activities and the passage of vehicle and even foot traffic. Compaction reduces the soil's capacity to hold and absorb water. Plants need healthy soil, air, and water to thrive.

Using planters in the urban forest can increase the biomass and canopy cover, but these plants and trees are still compromised and confined. At its bottom and sides a barrier will exist as the prepared area meets the surrounding compacted soils. Covering the soil surface with some form of mulch can help as the shade, cooling, and retained moisture that mulch provides help support the biological activities close to the soil's surface. These activities open the pore structure of the soil over time, help keep it open, and cushion the impact of foot traffic. This process works better if the mulch material is organic, as opposed to stones. If planters have limited resources for soil preparation they should have an extensive covering of mulch.

The generalized soil types map for a city can be used as a starting point when planning projects, but then the basic soil classifications should be identified on-site, especially when confronted by planting sites at the extreme ends of the spectrum: very fast-draining, nutrient-poor sands and dense, often nutrient-rich but oxygen-starved poorly drained clays.

Street trees (Credit: Kimley-Horn and Associates, Inc.)

Planting Sites

Traditionally, trees have been squeezed into whatever limited space is easily found, but this does not work well for either the tree or the street. The following guidelines provide recommended planting areas:

- Establish and maintain 6 to 8-foot wide sidewalk furniture zones where possible. Many large trees need up to 12 feet in width, and are not suitable for placement in narrower furniture zones. In residential areas, sidewalk furniture zones within the root zone should be unpaved and planted/surfaced with low groundcover, mulch, or stabilized decomposed granite where these can be maintained. Where maintenance of such extensive sidewalk furniture zones is not feasible, provide 12-foot long tree wells with true permeable pavers (standard interlocking pavers are not permeable).

- If the above conditions are not feasible, provide for the tree's root system an adequate volume of uncompacted soil or structural or gap-graded soil (angular rock with soil-filled gaps) to a depth of 3 feet under the entire sidewalk (in the furniture, frontage, and pedestrian sidewalk zones).
- Spacing between trees will vary with species and site conditions. The spacing should be 10 percent less than the mature canopy spread. Closer spacing of large canopy trees is encouraged to create a lacing of canopy, as trees in groups or groves can create a more favorable microclimate for tree growth than is experienced by isolated trees exposed to heat and desiccation from all sides. On residential streets where lots are 40 or 50 feet wide, plant one tree minimum per lot between driveways. Where constraints prevent an even spacing of trees, it is preferable to place a tree slightly off the desired rhythm than to leave a gap in the pattern.
- Planting sites should be graded, but not overly compacted, so that the soil surface slopes downward toward the center, forming a shallow swale to collect water. The crown of the tree should remain 2 inches above finished grade and not be in the center of a swale, but off to the side. The finished soil elevation after planting is held below that of the surrounding paving so 2 to 3 inches of mulch can be added. The mulch layer must be replenished as needed to maintain a nearly continuous level surface adjacent to paving.
- Generally tree grates and guards are best used along streets with heavy pedestrian traffic. Along streets without heavy foot traffic and in less urban environments, use mulch in lieu of tree grates.

Species Selection

- Select trees with non-aggressive root systems to avoid damaging pavement and sidewalks.
- In general, street trees should be species that will achieve a height and spread of 50 feet on residential streets and 40 feet on commercial streets within 10 years of planting to provide reasonable benefits. Typically, trees on commercial streets will not achieve the same scale as they will on residential streets where greater effective root zone volumes may be achieved. On commercial streets with existing multi-story buildings and narrow sidewalks, select trees with a narrower canopy than can be accommodated on the limited sidewalk width.
- Local jurisdictions should establish a list of recommended tree species for use in the public street rights-of-way. In Broward County, drought-tolerant native trees with large canopies should be utilized where possible. Coordination with the

University of Florida Institute of Food and Agricultural Sciences (IFAS) Extension Service (UF-IFAS Broward County Extension Office) should be conducted. For example, large trees may include palms, live oaks, gumbo limbo, mahogany, and paradise tree. Medium trees may include satin leaf, pigeon plum, bay cedar, Geiger, and red maple. (Note that dry weather runoff should not be directed to oaks and other trees that are not tolerant of dry season irrigation.) On commercial streets with ground-floor retail, deciduous trees with a strong central leader, such as Ginkos and London Planes, are desirable as they grow rapidly above the ground floor business signs. A city's list of recommended tree species should specify minimum planting site widths for each and which trees may be planted below overhead utility lines. Where there are overhead power lines that are less than 50 feet above grade, braided insulated electrical wire should be used so that trees do not have to be pruned to avoid the electrical lines. If braided insulated electrical wire cannot be provided, appropriate trees that will not grow tall enough to reach the power lines should be specified and planted.

- Trees that are part of streetwater management practices must be species that respond well to the extremes of periodic inundation and dry conditions found in water catchment areas. Design of all planting areas should include provisions for improved streetwater detention and infiltration.
- Consistent use of a single species helps reinforce the character of a street or district, but a diversity of species may help the urban canopy resist disease or insect infestations. New plantings added to streets with existing trees should be selected with the aim of meeting the same watering requirements and creating visual harmony with existing trees and plantings. Native species should be considered for inclusion whenever possible, but consideration should be first given to a species' adaptability to urban conditions.
- Consider deciduous species where their ability to allow sunlight to penetrate into otherwise shaded areas (such as south facing windows of adjoining buildings) during the winter months will be a plus.

NatureScape Broward provides information on selecting plants species for Florida-friendly landscapes that preserve water, protect water quality, and create wildlife habitat (Credit: Broward County, NatureScape Broward http://www.broward.org/NaturalResources/NatureScape/Pages/Default.aspx)

Tree Spacing and Other Considerations

- See Chapter 5, "Traveled Way Design," for an understanding of how to take intersection sight distance into account when designing intersections. Many jurisdictions have tree spacing requirements at intersections, which typically vary from 30 to 45 feet, to provide visibility at corners. But as discussed in Chapter 5, this distance can often be reduced with no compromise in safety in slow speed environments.
- Most jurisdictions have spacing requirements between trees and street lights (typically about 30 feet high), which typically vary from 10 to 20 feet. The smaller setback provides greater flexibility in tree spacing and allows for a more complete tree canopy.
- Pedestrian lights, which are about 12 feet tall, generally do not conflict with the tree canopy, so spacing is less rigid. Some jurisdictions still require wide clearance for their convenience in maintaining the lights, but this wide spacing greatly reduces tree canopy and is therefore discouraged. Spacing of 10 feet away from trees is generally adequate.
- An 8-foot minimum clearance must be maintained between accessible parking spaces and trees.
- Trees may be planted as close as 6 feet from bus shelters, where they provide welcoming shade at transit stops.
- Adequate clear space should be provided between trees and awnings, canopies, balconies, and signs so they will not come into conflict through normal growth or require excessive pruning to remediate such conflicts.
- Trees may be planted in medians that are 4 feet or wider, but must have an adequate clear height between the surface of the median and the lowest branches so that pedestrians can be seen. Where trees hang over the street, the clear height should be 14 feet.

Understory Landscaping

Understory landscaping refers to landscape elements beneath the tree canopy in areas within the public right-of-way not required for vehicular or pedestrian movement, including

- Medians
- Curb extensions
- Furniture and frontage zones

Benefits of Understory Landscaping

- Complements and supports street trees, in particular by providing uncompacted, permeable areas that accommodate roots and provide air, water, and nutrients.

- Reduces impervious area and surface runoff.
- Treats stormwater, improving water quality .
- Provides infiltration and groundwater recharge.
- Provides habitat.
- Reduces the perceived width of the street by breaking up wide expanses of paving, particularly when the understory is in medians and sidewalk furniture zones.
- Contributes to traffic calming.
- Provides a buffer between the walkway zone and the street, contributing to pedestrian comfort.
- Improves the curb appeal of properties along the street, potentially increasing their value.
- Enhances the visual quality of the community.

Principles

- Trees take precedence: the understory landscape should support them. It should not compete with them.
- Only pave where necessary: keep as much of the right-of-way unpaved and planted as possible to maximize benefits
- Design understory areas to infiltrate water
- The entire understory area does not have to be covered with plants—composted mulch is a good groundcover (top of mulch should be below adjoining hardscape so that runoff will flow into planning areas).
- Make the understory sustainable: use drought-tolerant plants
- Replenish the soil with compost
- Design the understory to contribute to the sense of place

Guidelines

Soil

Provide good quality, uncompacted, permeable soil. Soil analyses should address the concentration of elements that may affect plant growth, such as pH, salinity, infiltration rate, etc. Remove and replace or amend soil as needed. Good preparation saves money in the long run because it reduces the need to replace plants, lowers water consumption, and reduces fertilizer applications.

Landscaped shared-use path in Coconut Creek
(Credit: Kimley-Horn and Associates, Inc.)

Design

Generally, understory landscaped areas should be as wide as possible where there are trees: when feasible, at least 6 to 9 feet wide for parkways and 8 to 12 feet wide for medians. However, many existing parkways and medians are less wide. Narrower parkways can support understory plants and some tree species. A path or multiple paths should be added as needed across a parkway as a means of access from the curb to the sidewalk. For example, where there are striped curbside parking spaces, a path across the parkway should be provided at every one or two parking spaces.

Walking path across understory landscaping provides access from parked cars to sidewalk (Credit: Patricia Smith)

Plant with species that

- Do not require mowing more frequently than once every few months
- Are drought tolerant and can survive with minimal irrigation upon establishment
- Do not exceed a height of 2 feet within 5 feet of a driveway/curb cut and within 20 feet of a crosswalk, and, excluding trees, 3 feet elsewhere
- Do not have thorns or sharp edges adjacent to any walkway or curb
- Are located at least 4 feet from any tree trunk

STREET FURNITURE

Street furnishings in the street environment add vitality to the pedestrian experience and recognize the importance of the pedestrian to the fabric of a vibrant urban environment. Street furnishings encourage use of the street by pedestrians and provide a more comfortable environment for non-motorized travel. They provide a functional service to the user and provide uniformity to the urban design. Street furnishings include benches and seating, bollards, flower stands, kiosks, news racks, public art, sidewalk restrooms, signs, refuse receptacles, parking meters, and other elements.

Street furnishings achieve improved vitality in many ways:

- They make walking, bicycling, and public transit more inviting.
- They improve the street economy and common city prosperity.
- They enhance public space and create a place for social interaction.

Placement of street furnishings should be provided:

- At concentrations of pedestrian activity (nodes, gathering areas).
- On streets with pedestrian-oriented destinations. Pedestrians may gather or linger and enjoy the public space.
- Site furnishing placement should follow these criteria :
  - Street furnishings are secondary to the layout of street trees and light standards as street trees and light standards develop a street rhythm and pattern. Site furnishing should be placed in relation to these elements sensitive to the vehicular flow and pedestrian use of these elements. Careful consideration to the placement provides ease of recognition and use.
  - In addition to the guidelines provided for each element, placement should adhere to the minimum spacing. Site furnishing installed within the appropriate zone will be spaced not less than as shown in Table 12.2.

Table 12.2 Site Furnishing Minimum Setbacks

Location	Setback
Face of Curb	18”
Driveway	2’
Wheelchair Ramp	2’
Ramp Landing	4’
Fire Hydrant	5’
Stand Pipe	2’
Transit Shelter	4’

- All site furnishing must be accessible per Public Rights-of-Way Accessibility Guidelines (PROWAG) and other city regulations.
- Local jurisdictions should strive to include sustainable materials for street furnishings.

Benches and Seating

Public seating provides a comfortable, utilitarian, and active environment where people can rest, socialize, or read in a public space. The proper placement of a bench is a simple gesture creating a sense of place for the immediate area.

Street Furniture on a wide sidewalk
(Credit: Kimley-Horn and Associates, Inc.)

Location

Seating arrangements should be located and configured according to the following guidelines:

- Seating should be located in a shaded area under trees.
- Seating should be oriented toward points of interest; this can be the adjacent building, an open space, or the street itself if it's lively. Where sidewalk width permits, seating can also be oriented perpendicular to the curb.
- Informal seating opportunities, incorporated into the adjacent building architecture, may be used as an alternative to free-standing benches. Low planter walls can be used as informal seating areas.

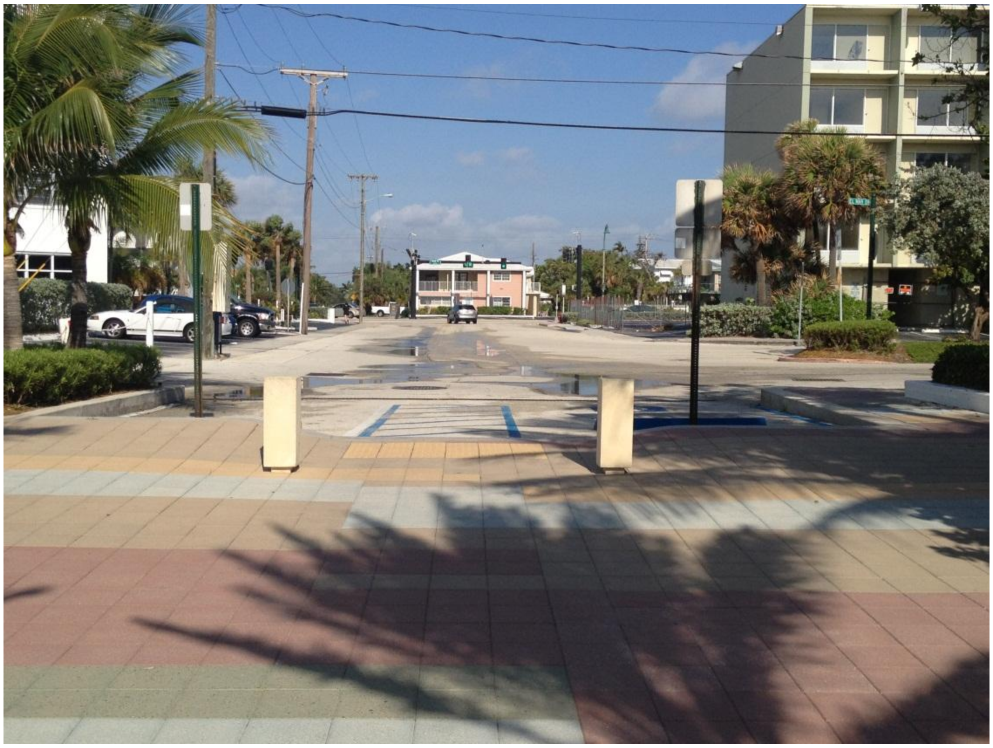
Design

Benches and seating should be made of durable high-quality materials. The seating design should complement and visually reinforce the design of the streetscape.

Seating opportunities should be integrated with other streetscape elements.

BOLLARDS

Bollards are primarily safety elements to separate pedestrians or other non-motorized traffic from vehicles. Thoughtful design and/or location of bollards can add interest, visually strengthen street character, and define pedestrian spaces.



Bollards separate a street-end from the sidewalk
(Credit: Kimley-Horn and Associates, Inc.)

Location

Bollards are used to prevent vehicle access on sidewalks, or on other areas closed to motor vehicles. Removable bollards should be placed at entrances to permanent or temporary street closures.

Design

Bollards range in size from 4 to 10 inches in diameter. Bollards should have articulated sides and tops to provide distinct design details. The details should be coordinated with other street elements of similar architectural character.

Removable bollards should be designed with a sturdy pipe projecting from the bottom of the exposed bollard. Removable bollards should appear permanent. Electrically controlled mechanisms retract the bollard into a void below the surrounding finish surface. This allows emergency vehicle access to closed streets.

Street Vendor Stands

Street vendor stand
(Credit: Sky Yim)

Street vendor stands, such as flower, magazine, and food vendor stands, rely on regular pedestrian traffic to sustain their business. To maximize efficiency, the stands operate during daytime work hours and cater to those commuting to/from employment areas. In areas with a vibrant evening environment, stands may have evening hours to benefit from the extended period of exposure to pedestrian traffic.

Location

Generally, street vendor stands should either be located outside the street right-of-way or in the sidewalk, furniture, or frontage zones.

Design

The design of the street vendor stands should have details and features coordinated with other street elements. These details should be of a similar architectural character. The stands should allow a minimum of 6 feet of clear pedestrian passage between the edge of the display area and other elements.

Kiosks

Kiosks in public areas provide valuable information, such as maps, bulletin boards, and community announcements. Kiosks can often be combined with gateway signs and are an attractive and useful street feature. In Broward County, the B-Cycle automated bicycle rental system has kiosk locations within the streetscape in several areas. More information is available on the B-Cycle website (http://broward.bcycle.com/).

Location

Kiosks should not block scenic views. Kiosks may be located in any of the following areas:

- The sidewalk, in furniture or frontage zones (kiosks should not block the pedestrian zone)
- Curb extensions
- Where parking is not allowed
- Close to, but not within transit stops

Informational kiosk
(Credit: Paul Zykofsky)

B-Cycle Station located outside of the pedestrian zone of the sidewalk
(Credit: Kimley-Horn and Associates, Inc.)

<u>Design</u>

Kiosks should be designed to the following guidelines:

- Kiosks should include bulletin boards or an enclosed case for display of information.
- As a gateway element, the kiosk should include the neighborhood, commercial district, street, or park name; a map; or other information.
- Kiosks should have details and features coordinated with other street elements and should have a similar architectural character.

News rack
(Credit: Ryan Snyder)

NEWS RACKS

<u>Location</u>

News rack placement is subject to municipal guidelines. In addition, the following guidelines should be considered:

- News racks located within the furniture or frontage zones should not reduce the minimum width of the sidewalk pedestrian zone with news rack doors open.
- News racks should be placed no closer than 2 feet from adjacent street signs and 4 feet from bike racks.

Design

News racks should visually blend with their surroundings and complement the architectural character. Multiple news racks should be consolidated into a standard decorative stand.

Parking Meters

Parking meters can be either traditional single-space meters or consolidated multi-space meters (parking stations).

Location

Parking meters should be placed in the sidewalk furniture zone. Single-space meters should be placed at the front end of the individual stalls.

Multi-space meters are preferred over single-space meters. Multi-space meters should be placed every 8 to 10 parking spaces and spaced approximately 150 to 200 feet apart. Signs should clearly direct patrons to the meter. The signs should be spaced at approximately 100 feet on-center.

Design

Municipalities should encourage the conversion of single-space meters to multi-space units to reduce visual clutter from the urban landscape. The multi-space units should be selected to minimize their impact on the pedestrian zone.

Signs

Streetscape signs provide information specific to direction, destination, or location. The sign plans should be developed individually for each neighborhood or district. Streetscape signs are most appropriate for downtown, commercial, or tourist-oriented locations or around large institutions. Streetscape signs include parking, directional, and wayfinding signs.

Street signs (Credit: Sky Yim)

Location

Streetscape signs should be kept to a minimum and placed strategically. They should align with the existing street furnishings and be placed in the sidewalk furniture zone.

Design

The sign design should be attractively clean and simple and complement the architectural character of other street furnishings.

REFUSE RECEPTACLES

Refuse receptacles should accept both trash and recyclables. Where there is a demand, different receptacles should be provided for different recyclable materials.

Refuse receptacle
(Credit: Kimley-Horn and Associates, Inc.)

Location

Refuse receptacles should be located

- Near high activity generators such as major civic and commercial destinations
- At transit stops
- Near street corners but outside of the sidewalk pedestrian zone

There should be a maximum of one refuse receptacle every 200 feet along commercial streets and a maximum of four refuse receptacles at an intersection (one per corner).

PUBLIC ART

On a large scale, public art can unify a district with a theme or identify a neighborhood gateway. At a pedestrian scale, public art adds visual interest to the street experience.

Public art
(Credit: Sky Yim)

Location

Public art can be situated in a variety of areas and locations, including streets, public spaces with concentrations of pedestrians, or areas of little pedestrian traffic, to create a unique space for discovery.

Design

Public art should be considered during the planning and design phase of development to more closely integrate art with other streetscape elements, taking into account the following:

- Public art is a pedestrian amenity and should be presented in an area suited for pedestrian viewing. The piece should be placed as a focal element in a park or plaza, or situated along a pedestrian path and discovered by the traveler.
- Public art can be incorporated into standard street elements (light standards, benches, trash receptacles, utility boxes).
- Public art can provide information (maps, signs) or educational information (history, culture). All installations do not need to have an educational mission; art can be playful.
- Public art should be accessible to persons with disabilities and placement must not compromise the sidewalk pedestrian zone.

Sidewalk Dining

Outdoor café and restaurant seating adjacent to the sidewalk activates the street environment and encourages economic development.

Outdoor café seating: Lauderdale-By-The-Sea
(Credit: Kimley-Horn and Associates, Inc.)

<u>Location</u>

Tables and chairs are to be placed on the sidewalk directly at the front of the restaurant and allowed in the frontage zone or furniture zone of the sidewalk where sufficient width is available.

<u>Design</u>

Placement of tables and chairs must include diverters (barriers) at the end of the dining area to guide pedestrians away from the accepted area of sidewalk. Since the public purpose of allowing restaurants to have dining on the sidewalk is to stimulate activity on the street, municipalities should prohibit restaurants from fully enclosing the dining area.

Other Streetscape Features

Other features that enhance the pedestrian experience include clocks, towers, and fountains, which strengthen the sense of place and invite pedestrians to come enjoy.


Other example streetscape fixtures (Credit: Ryan Snyder)

UTILITIES

The location of underground and aboveground utilities must be considered when planning new landscaped areas in the right-of-way. Each jurisdiction should establish guidelines to organize and standardize utility location and to minimize conflicts between landscaping and utilities based on input from all affected departments and agencies.

The majority of underground utilities, including sanitary sewers and storm drains, and water, gas, and electrical mains, are typically located under the roadway. Sanitary sewers are often in the center of the street directly under the potential location of a landscaped median. They are usually relatively deep. In general, if they have at least 4 or 5 feet of cover, they should not be affected by the introduction of a landscaped median. The other utilities within the roadway are typically located closer to the curbs.

Telecommunications, street lighting conduit, traffic signal conduit, and fiber optic conduit are often located under the sidewalk. Lateral lines extend from the utility mains in the public rights-of-way to serve adjacent properties.

Benefits of well-organized utility design/placement include:

- Reduced clutter in the streetscape.
- Increased opportunity for planting areas and for soil volume to support tree growth and stormwater infiltration.

- Reduced maintenance conflicts.
- Improved pedestrian safety and visual quality.

GUIDELINES

Location

- Utilities should be placed to minimize disruption to pedestrian travel and to avoid ideal locations for directing streetwater, planting trees and other vegetation, and siting street furniture, while maintaining necessary access to the utilities for maintenance and emergencies.
- Utilities within 10 feet of where a landscaped median may be located should have at least 5 feet of cover.
- Utility main lines that run laterally under the sidewalk should be located in a predetermined zone to minimize conflicts with tree roots and planting areas. The ideal location to minimize conflicts with trees would be under the pedestrian or frontage zones, although the more practical location is often under the furniture zone. Stacking dry utilities (telephone, CATV, electric, etc.) in the pedestrian or frontage zones will further reduce conflicts with the landscaped area.

Roadway/Parking Lane

- Large utility vaults and conduits running the length of a city block may be located in the roadway or parking lane where access requirements allow. Vaults in the parking lane may be located in short-term parking zones or in front of driveways to facilitate access. Each jurisdiction typically has specific design standards for vaults and utilities based on expected use and vehicle type. They can also be placed in midblock curb extensions.

Furniture Zone

- Small utility vaults, such as residential water vaults, residential water meters, gas valves, gas vaults, or street lighting access, should be located in the sidewalk furniture zone at the back of the curb wherever possible to minimize conflicts with existing or potential tree locations and landscaped areas. Vaults should be aligned or clustered wherever possible.
- Generally, utility boxes are sited in the direction of the pipe. Utility boxes that are parallel with the curb should be located in the sidewalk furniture zone when possible. Vaults perpendicular to the curb should be located between existing or potential street trees or sidewalk landscape locations (for example, in walkways through the sidewalk furniture zone to parked cars.)

- Utility laterals should not run directly under landscaped areas in the furniture zone, but instead under driveways and walkways wherever possible.

Sidewalk Pedestrian Zone

- Flush utility vaults and conduits running the length of the city block may be located in the pedestrian zone. Vaults in the pedestrian zone should have slip-resistant covers.
- Large flush utility vaults should be placed at least 3 feet from the building and 4 feet from the curb where sidewalk widths allow.
- Surface-mounted utilities should not be located in the pedestrian zone.

Sidewalk Frontage Zone

- Utility vaults and valves may be placed in the frontage zone. Placement of utility structures in this zone is preferred only when incorporating utility vaults into the furniture zone is not feasible.
- Utility vaults in the frontage zone should not be located directly in front of building entrances.

Curb Extensions

- Utility vaults and valves should be minimized in curb extensions where plantings or street furnishings are planned.
- Surface-mounted utilities may be located in curb extensions outside of crossings and curb ramp areas to create greater pedestrian through width.
- Utility mains located in the parking lane and laterals accessing properties may pass under curb extensions. With curb extensions or sidewalk widenings, utilities such as water mains, meters, and sewer vents may remain in place as they can be cost prohibitive to move.

Driveways

- Utility boxes may be located in driveways if the sponsor provides a vehicle-rated box; however, this is not a preferred solution due to access difficulties.

Pedestrian Crossings and Curb Ramps

- New utility structures should not be placed within street crossing and curb ramp areas.

- Existing vaults located in the center accessible portion of a ramp should be moved or modified to meet accessibility requirements, as feasible, as part of utility upgrades.
- Catch basins and surface flow lines associated with storm drainage systems should be located away from the crosswalk or between curb ramps. Catch basins should be located upstream of curb ramps to prevent ponding at the bottom of the ramp.

Consolidation

Utilities should be consolidated for efficiencies and to minimize disruption to the streetscape:

- Dry utility lines and conduits (telephone, CATV, electric, gas, etc.) should be initially aligned, rearranged, or vertically stacked to minimize utility zones.
- Wherever possible, utility conduits, valves, and vaults (e.g., electrical, street lighting, and traffic signals) should be consolidated if multiple lines exist within a single street or sidewalk section.
- Dry utilities (gas, telephone, CATV, primary and secondary electric, streetlights) may use shared vaults wherever possible. San Francisco has proposed shared vaults with predetermined color coded conduits per predetermined city standards.
- Street lighting, traffic signal, and light rail or streetcar catenary poles should share poles wherever possible. When retrofitting existing streets or creating new streets, pursue opportunities to combine these poles.

Other Design Guidelines

- Street design and new development should consider the overall pattern of plantings, lighting, and furnishings when placing new utilities in the street, and locate utility lines so as to minimize disruption to the prevailing streetscape rhythms.
- Utilities should be located underground wherever possible, as opposed to overhead or surface-mounted. Overhead utilities should be located in alleys where possible.
- New utilities should use durable pipe materials that are resistant to damage by tree roots and have minimal joints.
- Trenchless technologies, such as moling and tunneling, should be used wherever possible to avoid excavation and disruption of streetscape elements.

Artfully painted utility box
(Credit: Kimley-Horn and Associates, Inc.)

- New infrastructure projects should use resource-efficient utility materials. Re-used or recyclable materials should be incorporated wherever possible.
- Utility boxes may be painted as part of a public art program.
- Tree removal should be avoided and minimized during the routing of large-scale utility undergrounding projects.
- Any utility-related roadway or sidewalk work should replace paving material in kind (e.g., brick for brick) where removed during maintenance, or replace with new upgraded paving materials.

New Development and Major Redevelopment

- Alleys for vehicle, utility, and service access should be incorporated to enable a more consistent streetscape and minimize above-ground utilities.
- New utilities should be located to minimize disruption to streetscape elements per guidelines in this section.

Abandonment

- Currently abandoned dry conduits should be reused or consolidated if duplicate lines are discovered during street improvement projects. Utilities should be contacted for rerouting or consolidation. Where it is not possible to reuse abandoned mains, conduits, manholes, laterals, valves, etc., they should be removed per agency recommendations when possible to minimize future conflicts.
- Abandoned water and sewer lines may be retrofitted as dry utility conduits where available or if possible to minimize the need for future conduit installations.

Process

- Utility installation and repair should be coordinated with planned street reconstruction or major streetscape improvements.
- New development should submit utility plans with initial development proposals so that utilities may be sited to minimize interference with potential locations for streetscape elements.
- Utility work also offers opportunities to make other changes to the street after the work is completed and should be coordinated with planned improvements to avoid duplication of efforts or making new cuts in new pavement. Examples of improvements to streets that can be done at low cost after utility work include restriping for bike lanes if utility work requires total street repaving, as well as building sidewalks in conjunction with utility work occurring outside the traveled way.

LIGHTING

Lighting provides essential nighttime illumination to support pedestrian activity and safety as well as vehicle safety. Well-designed street lighting enhances the public realm while providing safety and security on roadways, bike paths, and lanes as well as pedestrian paths including sidewalks, paths, alleys, and stairways.

Historically significant street light poles and fixtures should be maintained and upgraded where appropriate.

Pedestrian lighting should be coordinated with building and property owners to provide lighting attached to buildings for sidewalks, alleys, pedestrian paths, and stairways where separate lighting poles are not feasible or appropriate.

Street lamps (Credit: Sky Yim)

Guidelines

Location and Spacing
(1) Street and pedestrian lighting should be installed in the sidewalk furniture zone; (2) light fixtures should not be located next to tree canopies that may block the light; (3) where pedestrian lighting is not provided on the street light pole, special pedestrian lamps should be located between street light poles.

Light Color
All light sources should provide a warm white (yellow, not blue) color light. Low pressure sodium lights are recommended for areas near sea turtle nesting beaches.

Light Poles and Fixtures
Design should relate to and be coordinated with the design of other streetscape elements and recognize the history and distinction of the neighborhoods where the light poles are located.

Dark-Sky Sea Turtle Compliant Lighting
As appropriate, dark sky-compliant lighting should be selected to minimize light pollution cast into the sky while maximizing light cast onto the ground. Lighting near sea turtle nesting beaches, which includes all beaches in Broward County, cannot trespass onto the beach. The Florida Fish and Wildlife Conservation Commission provides guidance on sea turtle friendly lighting at:
http://www.myfwc.com/wildlifehabitats/managed/sea-turtles/ .

Sea Turtle Nesting Sign
(Credit: Kimley-Horn and Associates, Inc.)

Energy Efficiency

Solar light fixtures should be utilized where possible for new installations or for retrofit projects. Where solar light fixtures are not appropriate or possible, LED or a future more energy-efficient technology should be used.

Pedestrian Lighting

Retrofits of existing street lights and new installations should provide lighting on pedestrian paths. Pedestrian lighting should be added to existing street light poles where feasible unless spacing between street light poles does not support adequate pedestrian lighting, in which case pedestrian lighting may need to be provided between existing street light poles.

Light Levels and Uniformity

All optic systems should be cut off with no light trespass into the windows of residential units. Local jurisdictions should develop a set of standards for pedestrian lighting levels based on Table 12.3 to achieve adequate lighting.

Table 12.3 Pedestrian Light Levels

STREETSCAPE TYPE	LIGHT LEVEL
Commercial	1 fc
Mixed-Use	0.5 fc
Residential	0.4 fc
Industrial	0.3 fc
Alleys and Paseos	0.3 fc
Special	Varies

Note: Light levels are measured in foot candles (fc). Suggested light levels are consistent with ANSI/IES RP-8-00 American National Standard Practice for Roadway Lighting

ADDITIONAL RESOURCES

Lancaster, B. *Rainwater Harvesting for Drylands and Beyond*, http://www.harvestingrainwater.com/

Landscape Architecture Foundation's Landscape Performance Series, www.lafoundation.org/lps

NatureScape Broward, http://www.broward.org/NaturalResources/NatureScape/Pages/Default.aspx

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