Storm Water Low Impact Development Design

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INTRODUCTION

Stormwater runoff in urban areas is one of the leading sources of water pollution in the United States. It also results in increased peak flows and substantially increased runoff volumes. In an attempt to mitigate some of these impacts, Low Impact Development (LID) techniques have been developed. These techniques can mitigate some of the impacts by retaining rainfall on-site through infiltration, evaporation/transpiration and re-use. This course provides design information for many of these techniques, including ecoroofs, pervious pavement, trees, downspout extensions, rain gardens, swales, curb extensions, planters, basins, filter strips, grassy swales, soakage trenches, drywells and sumps.

Stormwater Facility Configuration

Low Impact Development stormwater management facilities can be vertically configured five ways (see Figure 1):

- Surface infiltration.
- Partial infiltration.
- Subsurface infiltration.
- Hybrid facilities (both surface and subsurface infiltration).
- Lined facilities (does not infiltrate).

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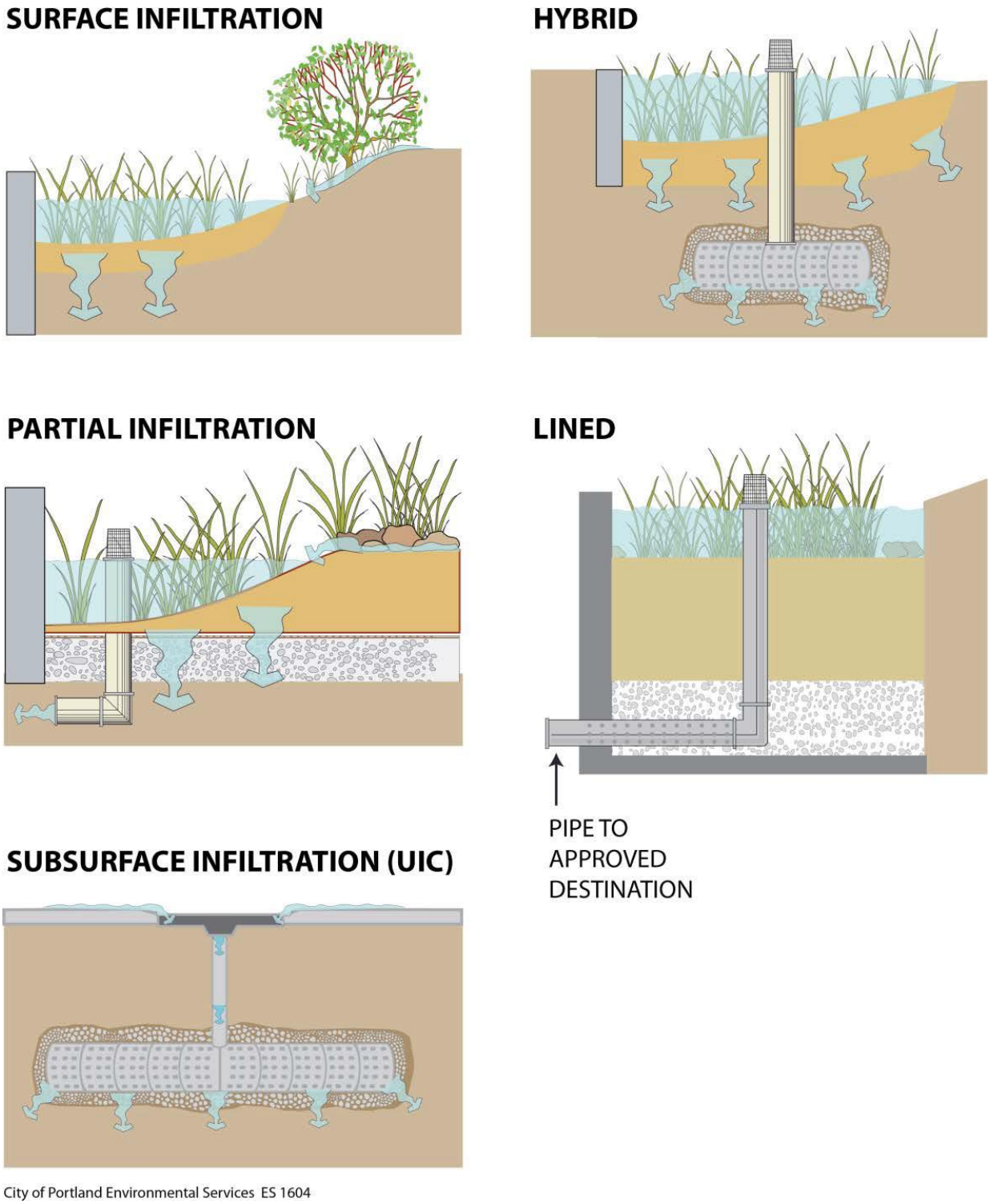


Figure 1. Vertical Stormwater Facility Configurations

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Surface infiltration facilities achieve infiltration in the upper layer of the ground surface and can include facilities such as swales, planters, and basins. In Portland, infiltration facilities manage the 10-year design storm and require a tested infiltration rate of at least 2 inches per hour. Facilities that achieve total onsite infiltration do not require an offsite discharge location.

Partial infiltration facilities are appropriate for sites with soils that drain less than 2 inches per hour. They achieve partial infiltration because they do not have a bottom or a liner but may include a surface overflow and an underdrain where flows in excess of the facility capacity are routed to an approved discharge location. Depending on site conditions, partial infiltration facilities may be used where complete infiltration is not achievable. A partial infiltration facility would be sized and designed as a lined facility, but would still achieve some infiltration.

Subsurface infiltration facilities achieve infiltration below the ground surface and include facilities such as sumps, drywells, and soakage trenches. Subsurface infiltration facilities may be classified as Underground Injection Control (UIC) system. These systems are regulated under the federal Safe Drinking Water Act. Oregon defines a UIC as any system, structure, or activity that is intended to discharge fluids below the ground surface. UICs can pollute soil and groundwater if not properly designed, sited, and operated. Stormwater systems such as, but not limited to, sumps, drywells, and soakage trenches are examples of UICs which may be subject to regulation. Local and state regulations should be reviewed to determine requirements.

Hybrid facilities combine a vegetated infiltration facility with a subsurface infiltration facility. They achieve both surface infiltration and subsurface infiltration through bypassing flows greater than the water quality storm directly to a gravel layer below the facility growing medium or to a subsurface infiltration facility. By providing a direct connection to subsurface infiltration, the designer can take advantage of higher native infiltration rates, if they exist, or utilize the below-grade storage to reduce the size of the facility. Hybrid facilities may also subject to UIC regulations.

The hybrid facility is a configuration type that is appropriate for sites with well- draining soil but with space limitations. A hybrid facility can be designed to maximize infiltration at the surface and in the subsurface.

Lined facilities include an impervious or lined bottom and do not infiltrate. They are appropriate for sites that have restrictive site conditions including steep slopes, landslide risk, high groundwater, facilities located on structures, soil or groundwater contamination, and may also be appropriate next to structures or property lines to protect foundations, basements, and adjacent properties. Lined facilities include a surface overflow and/or an underdrain in the gravel layer where treated flow is routed to an approved discharge location.

Facility and Conveyance Design Criteria

This section provides the specific design requirements for each stormwater facility or conveyance feature.

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Ecoroof



Ecoroofs reduce impervious area and provide stormwater management.

Facility Description

An ecoroof is an impervious area reduction technique which decreases stormwater management requirements on the project site. Also called a green roof, an ecoroof is a lightweight vegetated system consisting of waterproofing material, a growing medium, and low growing, drought tolerant plants. Ecoroofs reduce post-developed peak runoff rates to near-pre-developed rates and reduce annual runoff volume by at least 50 percent. Ecoroofs also help mitigate runoff temperatures by keeping roofs cool and retaining most of the runoff during dry periods.

The roof structure must be strong enough to hold the additional weight of the ecoroof. The load-bearing capacity of the roof must be evaluated by a licensed professional, and the design must comply with building code requirements.

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The design must be self-sustaining, meaning the design goal must be to minimize inputs after the first couple of years. This is in contrast to roof gardens which require more maintenance and irrigation.

Design Requirements

Sizing: Ecoroofs replace impervious area at a 1:1 ratio. They generally should not receive runoff from other impervious areas.

Slope: The maximum allowable roof slope is 25 percent, unless the designer can provide documentation of runoff control on steeper slopes.

Access: The design must provide safe access for maintenance of the ecoroof and roof fixtures.

Waterproofing: All conventional commercial materials may be used, although a root barrier may be required for asphaltic materials. No portion of the waterproof membrane may be exposed to sunlight in order to maximize the life of the ecoroof.

Flashing: The design should minimize the use of copper or galvanized metal fittings which can introduce pollutants to the runoff.

Root barrier: A root barrier is sometimes required in addition to waterproofing material. Root barriers impregnated with pesticides, metals, or other chemicals which may leach into stormwater are not allowed, unless the applicant can provide documentation that leaching does not occur. If a root barrier is used, it must extend under any gravel ballast, under the growing medium, and up the side of any vertical elements. Some waterproofing materials also act as a root barrier.

Drainage and overflow: A method of drainage must be provided. The drainage layer may include geotextile fabric, gravel, or be the growing medium itself particularly on steeper, fast-draining ecoroofs. Ecoroofs are not a full stormwater disposal system and need a conventional drainage system to manage excess runoff from the roof during periods of sustained or heavy rainfall. The applicant must provide roof drains that connect to an approvable discharge location.

Growing medium: A minimum of 4 inches of growing medium is required for the vegetated portions of the ecoroof. The medium must support the chemical, biological, and physical needs of the plants. Designers are encouraged to use a medium with significant water-holding capacity to maximize stormwater retention. The medium should be an unconsolidated mixture of mineral aggregate such as screened pumice and sandy loam, and organic matter such as aged compost or fiber compost. Incorporation of chemical additives such as fertilizers and fungicides is generally not allowed.

Vegetation and coverage: Drought-tolerant plants must achieve 90 percent coverage within two years. At least 50 percent of the ecoroof vegetation should be evergreen species. Ecoroof vegetation should be:

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- Drought-tolerant, requiring little or no irrigation after establishment.
- Self-sustaining, without the need for fertilizers, pesticides, or herbicides.
- Able to withstand heat and cold.
- Very low-maintenance, needing little or no mowing or trimming.
- Perennial or self-sowing.
- Fire-resistant.

A mix of sedum/succulent plant communities is recommended because these plants possess many of the attributes listed above. Although herbs, forbs, grasses and other low groundcovers can provide stormwater and aesthetic benefits, plants that require irrigation beyond what is allowed in this section for survival are not permitted.

Mulch: Gravel mulch or an alternative mulch is recommended to retain moisture and protect exposed soil from erosion.

Non-vegetated components: Non-vegetated components may comprise up to 10 percent of the ecoroof while still counting toward the total ecoroof area, though the non-vegetated area should be kept to a minimum. If additional non-vegetated area is necessary to meet fire code requirements, the 10 percent maximum may be exceeded only by that required area. Rooftop features which cannot be considered non-vegetated components of an ecoroof include: mechanical equipment and solar panels (unless vegetation is extended beneath elevated units), elevator overruns, penthouses, and skylights. Runoff from portions of the structure that penetrate the ecoroof (e.g. elevator overruns and penthouses) must meet the provisions of this manual. Examples of non-vegetated components that can be counted within the 10 percent include:

- Decking or porous materials such as gravel or pavers which are placed over sand or another substrate for the purpose of providing access to the ecoroof and other rooftop components.
- Ballast along parapets or mechanical units.

Ballast (optional): Gravel ballast is sometimes placed along the perimeter of the roof and at air vents or other vertical elements. It is sometimes used to provide maintenance access, especially to vertical elements that require regular, periodic maintenance. In many cases little, if any, ballast is needed.

Header/separation board (optional): A header or separation board may be placed between gravel ballast and adjacent elements such as soil or drains, but pressure- treated lumber is prohibited. In many cases a header is not needed, and designers are encouraged to use just one header if a header is needed.

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Protection boards or materials (optional): These materials protect the waterproof membrane from damage during construction and over the life of the system and are usually made of soft fibrous materials. They often are not needed, depending on the membrane selected.

Habitat design (optional): Designs that benefit urban wildlife are encouraged. Diversifying design elements such as soil type and depth is good for habitat: variable soil types and depths create microclimates, allowing varied species to use the ecoroof. For instance, small areas of sand, gravel or native topsoil benefit ground- nesting pollinators. Another element of a habitat-friendly ecoroof is varied vegetation. Large plant species provide additional structure, flower shapes, and bloom times, which in turn attract varied wildlife. Drought- tolerant native species are most effective at attracting native pollinators. Small areas of woody material and rock create microhabitats, encouraging more species (these elements must be secured to the roof or placed in locations where there is no risk of movement). A summer water source can be included such as a basin to collect condensate from rooftop units. Ecoroofs designed for habitat allow for areas with denser vegetation and areas with minimal vegetation.

Pervious Pavement



Two types of pervious pavement: pervious concrete (foreground) and pervious pavers (background). Pervious pavements reduce impervious area and provide stormwater management.

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Facility Description

Pervious pavements are impervious area reduction techniques that decrease the obligation of stormwater management on the project site. These methods of infiltrating stormwater provide a stable load-bearing surface without increasing the project impervious area. There are two main categories of pervious pavements: pervious concrete and pervious asphalt, which are poured in place, and permeable pavers, which are discrete units set in place.

Pervious asphalt, pervious concrete, and permeable pavers can be used in practically all pedestrian areas as well as residential driveways and commercial parking lots. Pervious asphalt and concrete will be approved on private streets and public roadways on a case-by-case basis. For all streets, the pavement design must be prepared by a registered professional engineer.

Pervious Asphalt and Concrete. Pervious asphalt and pervious concrete are similar to conventional asphalt and concrete in structure and form, except that the fines (sand and finer material) have been removed. The top lifts are thicker than traditional pavements to provide the required stability. When properly handled and installed, porous paving has a high percentage of void space (approximately 17 to 22 percent).

Pervious asphalt consists of an open-graded coarse aggregate cemented together by asphalt cement.

Pervious concrete is a structural, open-textured pervious concrete paving surface consisting of standard Portland cement, fly ash, locally available open-graded coarse aggregate, admixtures, fibers, and potable water.

Permeable Pavers. There are many types of permeable pavers on the market. Many manufacturers make specific pavers for pervious applications. Brand names and specifications must be supplied with permit applications.

Edge restraints for pavers are required to be permanent (cast-in-place or precast concrete curbs) and a minimum of 6 inches wide and 12 inches deep for private streets, public roadways, and commercial pavements. Residential restraints may be plastic and set with spikes.

Design Requirements

Additional stormwater from other impervious areas, such as rooftops, generally should not be directed to a pervious pavement system. Pervious pavements should not be located over cisterns, utility vaults, underground parking, or other impervious surfaces.

Soil Suitability: A minimum distance of five feet to seasonally high groundwater is recommended. Where the tested infiltration rate is less than 2 inches/hour, the pavement section must sheet-flow to an adequately sized filter strip (500 square foot limit for pavement),

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or the pervious pavement subsurface rock may be sized for necessary detention. If an underdrain is proposed for collection, the conveyance must lead to a vegetated facility sized to treat the entire pervious paved area.

Setbacks: There are no required setbacks, but impermeable liners between base rock and adjacent foundations are highly recommended. A liner may be required for areas located within 5 feet of structures or infrastructure.

Sizing: Sizing requirements vary by design approach.

A simplified approach to design is to size pervious pavement and permeable pavers replace impervious surfaces at a 1:1 ratio.

Pervious pavement can also be designed using more detailed analysis to directly infiltrate all stormwater from the pavement surface into a crushed rock storage layer, which must contain enough void space to store the 10-year, 24-hour storm and infiltrate it into the subgrade in less than 30 hours.

Slope: Where slopes are greater than 5 percent, the design must be engineered to specifically address under-pavement water retention. If the slope of the area is 10 percent or greater, pervious pavement is not allowed.

Subgrade: Pervious pavement must not be constructed over fill soils. The area to be paved should be leveled and lightly compacted with a plate compactor to include a slight grade away from foundations. Subgrade must not be subject to truck traffic. The subgrade should not be constructed or compacted during wet conditions.

Geotextile fabric: Subgrade geotextile for separation may be desired between subgrade (native soil) and aggregate base (gravel layer), but is not required. Specify per geotechnical professional or manufacture.

Aggregate base: 6-inch minimum of washed, crushed 2- to ¾-inch or No. 57 rock.

Top lift: See Figure 2 for the top lift depth requirements for private property. Asphalt and concrete must have at least 15 percent air voids in the completed top lift. Concrete must be 2400 to 2500 psi in 28 days. Pervious pavement requirements for public or private streets must be engineered. Public streets must also meet appropriate local design standards.

Figure 2. Pervious Pavement Requirements

	Concrete (inches)	Asphalt (inches)	Paver (inches)	Engineering Required?	Compaction Required?
Residential Driveway or Pedestrian Only	4	2.5	2 ⅜	No	No

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Construction Considerations: It is imperative during design and construction to establish protection for the pervious pavement subgrade from over-compaction. The subgrade should not be constructed or compacted during wet conditions. The design professional must show how the project will be sequenced to avoid traffic on the subgrade of the proposed paved area, and how the paving will be protected from construction traffic, and sediment accumulation after installation.

Construction sequencing should avoid heavy truck traffic and sediment on the paving. A pervious pavement protection plan may be required in order to protect the surface from compaction during construction.

Tree Credits



Trees intercept rainfall and reduce runoff.

Facility Description

Trees intercept precipitation and provide several stormwater management benefits: they hold water on their leaves and branches and allow it to evaporate, retain flow, and dissipate the energy of runoff. These functions are most measurable for storms of less than 0.5 inch over 24 hours, typical of Portland storm events. Although deciduous trees are not as effective during winter months, evergreen trees are effective year-round for these smaller storms and portions

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of larger storms. Generally, large trees with small leaves are the most efficient rainfall interceptors. Trees also facilitate stormwater infiltration and groundwater recharge.

Trees can also shade impervious area. This provides two direct benefits. First, the hard surface is protected from direct solar exposure, which reduces heat gain. The less heat gain there is in pavement, the less heat is absorbed by stormwater as it flows over the surface. Second, by shading pavement, the trees help reduce or minimize air temperature increases caused by the hot pavement.

Existing trees can have significant benefits in addition to stormwater management. Trees provide habitat for urban wildlife, energy conservation, aesthetics, visual screens, heritage value, windbreaks, recreation, and improve human health.

Trees are allowed as an impervious area reduction technique on both private property and in the public right-of-way under specific criteria and with provisions. The specifications that follow were developed to maximize the use of trees to mitigate stormwater impacts.

Design Requirements

Site applicability: The tree credit can be used for all sites. For sites with over 1,000 square feet of impervious surface to manage, no more than 10 percent of the impervious area can be mitigated through the use of trees.

New tree sizing: New broadleaf trees on private property should be at least 1.5 caliper inches at the time of planting, and new coniferous trees should be at least 5 feet tall.

New tree setbacks: New trees must be planted within 10 feet of impervious surfaces. One hundred square feet of credit is given for new broadleaf trees, and 200 square feet of credit is given for new coniferous trees (see minimum tree sizes below).

Street trees planted less than 10 feet from a water line (or other water infrastructure such as a water meter) require the installation of a tree root barrier.

Existing tree sizing and setbacks: Credit also applies to existing trees kept on a site if the trunk is within 25 feet of impervious surfaces and are at least 1.5-inch caliper or larger. Caliper is the diameter of the tree measured 6 inches above the ground surface or root ball. The tree credit for existing trees is tiered based on caliper (see Figure 3).

Figure 3. Stormwater Credit for Existing Trees

Caliper of Existing Tree	Stormwater Credit
1.5 up to 6 inches	200 square feet
6 inches and larger	400 square feet per each 6-inch caliper inches

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Tree selection: The trees selected must be suitable species for the site conditions and the design intent. Nuisance trees cannot receive stormwater tree credit.

Downspout Extension



Downspout extensions route runoff from roof areas to adjacent landscape.

Facility Description

Directing downspouts to splash blocks is a method of stormwater management that directs roof runoff to vegetated or mulched landscape areas for onsite infiltration. This method can be utilized for small-scale projects on private property that have appropriate site conditions. Roof runoff is directed to existing landscaping where it can spread out and safely soak into the soils and remain on the property. Site conditions will determine if this is a suitable method for managing stormwater onsite. Property line and building setbacks as well as surface grade and available landscaped areas for infiltration must be considered. Proposed downspout locations and roof/gutter alignments will impact the feasibility of this option.

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Design Requirements

Site Suitability: Downspout extensions are suitable for sites that have well draining soils (>2 inches/hour) and have an overall slope of 10 percent or less. A maximum of 500 square feet of roof area is allowed to drain to each downspout. For new development or redevelopment, only small-scale projects on private property with less than 1,000 square feet of new impervious area, including garages, additions, and accessory dwelling units, are eligible to use this method. For stormwater retrofits or alterations to existing structures, the structure must be smaller than
5,000 square feet.

Setbacks: Downspouts typically discharge 2 feet from slab on grade and structures with crawl spaces and 6 feet from all foundations with basements. The point of discharge typically are set back 5 feet from property lines and 10 feet from all neighboring structures or buildings and retaining walls over 36 inches in height. Splash blocks are not considered part of the downspout extension and are included for erosion control and flow dispersal only. See Table 2-1 for more information on setbacks.

Sizing and grade: The landscape area utilized for disposal of stormwater must be at least 10 percent of the roof area that drains to each downspout. The grade of the landscape area must gently slope away from the foundation and neighboring properties and allow stormwater to spread out over the required 10 percent infiltration area. Setback requirements must be retained over the entire infiltration area.

Materials: Durable, gutter-grade materials such as aluminum, steel, copper, vinyl, and plastic downspouts can be utilized for extensions. Downspouts need to be secured to the structure and connections securely fastened together with appropriate materials (i.e., sheet metal or similar screws). Flexible downspout extensions are not approvable materials. Rain chains must be securely fastened to the structure and the ground in a vertical alignment and must meet setback standards in order to be approved. Splash blocks, rock, or flagstone must be utilized for erosion control and flow dispersal at the location of discharge. Downspouts can be directed to drain onto grass without additional erosion control measures.

Other Considerations: Downspouts must not be directed to drain onto or over impervious areas, including walkways, driveways, and patios or onto neighboring properties, including public sidewalks and streets. Downspouts and gutters may be regraded, piped, or redirected in order to convey water to a safe infiltration area. Downspouts need to drain directly to landscape areas intended for infiltration.

Landscaped areas above buried oil tanks or adjacent to retaining walls over 36 inches high cannot be utilized as infiltration areas.

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Construction Considerations: Downspouts need to be located in areas that can accommodate stormwater flows and do not cross walkways or drain onto driveways, patios, or other impervious surfaces. Downspout locations and quantity can be field-fit based on site conditions to meet required standards. The design should consider landscape grade during construction to ensure the finished landscape grade will allow stormwater to drain safely away from building foundations and property lines. Hinged downspout extensions or "flipper" extensions can be utilized for ease of landscape maintenance.

Rain Garden



Rain gardens are shallow landscape depressions which collect runoff and allow it to infiltrate.

Facility Description

Rain gardens are a method of stormwater management that directs roof and/or paved area runoff to a shallow, flat, vegetated landscape depression amended with compost to allow for onsite infiltration. Rain gardens can meet stormwater requirements for new and redevelopment projects that manage less than 5,000 square feet of roof and paved areas. Site conditions will determine if this is a suitable method for managing stormwater onsite. Property line and building setbacks as well as surface grade and available landscaped areas for infiltration must be considered. Proposed downspout locations and roof/gutter alignments will impact the feasibility of this option, as well as slope, setback, and other site considerations.

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Design Requirements

Site Suitability: Rain gardens are suitable for sites that have well-draining soils (>2 inches/hour) and have an overall slope of 10 percent or less. New development and redevelopment projects with less than 5,000 square feet of new impervious area are eligible to use this method. This requirement also applies to stormwater retrofits or alterations to existing structures.

Setbacks: A ten-foot setback from buried oil tanks or retaining walls over 36 inches high is required for safety considerations. It is also recommended to avoid installation over water service lines. The deepest point of a rain garden should be at least 10 feet from all structures. Each downspout or rain drain entering the rain garden must be at least:

- 2 feet from any onsite building foundations without a basement,
- 6 feet from any onsite building foundations with a basement,
- 10 feet from a neighbor's building,
- 5 feet from a property line,

Sizing and grade: The rain garden footprint must be at least 10 percent of the impervious area that drains to each rain garden. The footprint is the area of the rain garden capable of detaining water when full, including facility side slopes.

Each rain garden design needs to include an escape route so that stormwater safely drains in periods of heavy rainfall. Escapes routes can simply be low points in the perimeter of the rain garden that allow excess stormwater to safely drain away from building foundations to a driveway, sidewalk, street, or parking lot and without impact to adjacent properties. Escape routes should be planted or rocked to prevent potential erosion issues.

If an escape route is not available given site conditions, a piped overflow is allowed. Overflows need to have an approved disposal location such as a public storm sewer, adjacent creek, or onsite disposal system such as a drywell.

Dimensions and Slopes: The grade of the rain garden must gently slope away from the foundation and neighboring properties. Setback requirements must be retained over the entire infiltration area. Rain gardens must not be installed at locations on the site where slope is greater than 10%.

Rain gardens will be constructed to a ponding depth of 12 inches with maximum side slopes of 3 horizontal to 1 vertical and a minimum bottom width of 2ft x 2ft. Side slopes of 2 horizontal to 1 vertical may be allowed if erosion control protections are installed, such as vegetative cover and/or larger boulders.

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Materials: Water runoff from the roof may be conveyed to the point of discharge in one of the following manners:

- A gutter-grade downspout extension above ground.
- A downspout extension positioned below ground, daylighting into the facility. Where located within the 2-foot or 6-foot setback, the pipe must be watertight.
- A rock-filled drainage channel ("dry creek bed conveyance swale") lined with moisture-impervious sheeting, such as 30-mm EPDM, where located within the 2-foot or 6-foot setback.

Flexible downspout extensions are not approvable materials. Splash blocks, rock, or flagstone must be utilized for erosion control and flow dispersal where the stormwater enters the rain garden.

Growing Medium: Amend native soils with 3 inches of compost blended into the top 12 inches of native soil.

Vegetation: The entire facility area must be planted with vegetation. The facility area is equivalent to the total area of the rain garden, including bottom and side slopes, as developed in the sizing calculations.

Mulch: Rain gardens may be topped with 2" of compost cover to enhance soil moisture, prevent weeds and control erosion. Bark mulch or equivalent should only be applied above the high water line.

Construction Considerations: Infiltration areas should be clearly marked before site work begins to avoid soil compaction or sedimentation to preserve infiltration capacity. No vehicular traffic, except that specifically used to construct the facility, should be allowed within 10 feet of infiltration areas.

Rain gardens need to be located in areas that can accommodate stormwater flows and do not cross walkways or drain onto driveways, patios, or other impervious surfaces. The design should consider landscape grade during construction to ensure the finished landscape grade will allow stormwater to drain safely away from building foundations and property lines.

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Swales



Swales collect and convey runoff to a discharge location, filtering the runoff, and allowing it to infiltrate.

Facility Description

Swales are typically long, narrow, gently sloping landscaped depressions that collect and convey stormwater runoff. They are planted with dense vegetation that treats stormwater from rooftops, parking lots, and streets. As the stormwater flows along the length of the swale, the vegetation and check dams slow the stormwater down, filter it, and allow it to infiltrate into the ground. Where soils do not drain well, swales can overflow to an approved discharge location such as a drywell or sump. Swales should be integrated into the overall site design and can be used to help fulfill landscape requirements.

Design Requirements

Soil suitability: Existing infiltration rates will determine if the facility can be designed to achieve infiltration, partial infiltration, or allow the stormwater to be conveyed through the facility.

If the tested infiltration rate is greater than or equal to 2 inches per hour, the simplified swale

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design should function as a complete infiltration facility. If the tested infiltration rate is less than 2 inches per hour, the swale should be designed as a partial infiltration facility, with an overflow to an approved discharge location.

Setbacks: Infiltration swales are typically set back 5 feet from property lines and 10 feet from building foundations. There are no setback requirements for lined swales. If a basement is within 10' of an infiltration swale, a partial liner may be required on the basement side of the swale.

Dimensions and slopes: The minimum swale width is 9 feet. A 2-foot-wide flat bottom width is required where feasible. The depth is nine inches as measured from the top of the growing medium to the overflow inlet elevation. Maximum side slopes are 3 horizontal to 1 vertical; 4 horizontal to 1 vertical is required immediately adjacent to pedestrian areas. Maximum longitudinal slope is 6 percent. Freeboard for swales must be noted on the plans.

Waterproofing/Geosynthetic Liner: Full or partial liners may be required for protecting adjacent water facilities/utilities, on higher classification streets, in locations with hazardous materials or topography considerations, and in wellhead protection areas. The location determines the required liner thickness.

Drainage Layer: 12" depth of ¾" – 1 ½" washed drain rock must be used. Drain rock and growing medium must be separated by a 2- to 3-inch layer of pea gravel.

Check dams: They generally measure 4 to 10 inches high, depending on the depth of the facility. Width will vary depending on material.

Growing medium: The imported soil should generally be a sandy loam mixed with compost or a sand/soil/compost blend. It must be roughly one-third compost by volume, free-draining, and support plant growth. The compost must be derived from plant material; animal waste is not allowed.

If a stormwater management facility is proposed adjacent to property lines or nearby structures, then a lined facility will likely be required. Vegetation planted within water-tight stormwater management facilities cannot compromise the integrity of the facility liner and the facility design must ensure plants will survive. To provide adequate area for plants to grow, vegetation must be planted within a minimum growing medium depth of 24 inches.

Vegetation: The entire facility area must be planted with vegetation. The facility area is equivalent to the total area of the swale, including bottom and side slopes, as developed in the sizing calculations. Swales should be designed so they do not require mowing. If the total project area is over 200 square feet consider adding a tree and reducing the number of herbaceous plants and shrubs.

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Construction Considerations: Infiltration swales areas should be clearly marked before site work begins to avoid soil compaction or sedimentation to preserve infiltration capacity during construction. No vehicular traffic, except that specifically used to construct the facility, should be allowed within 10 feet of infiltration swale areas.

Curb Extensions



Curb extensions are street-side landscape areas which store, filter, and infiltrate stormwater runoff. Photo credit: J. Peterson.

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Facility Description

Stormwater curb extensions are typically used in retrofit situations to manage runoff from developed rights-of-way. They can provide locations for stormwater management when space behind an existing curb line is constrained or inadequate in size.

Stormwater curb extensions effectively intercept stormwater from the street gutter and send it into gently sloping or flat-bottomed facilities. Within the facilities, vegetation and check dams slow the stormwater down, filter it, and in many cases allow it to infiltrate into the ground. In locations where soils do not drain well, curb extensions can overflow to an approved discharge location, such as a storm sewer, sump, or open channel drainage way, such as a creek or stream.

Curb extensions can improve auto, pedestrian, and bicycle safety by narrowing the crossing distance for pedestrians, improving sight lines, and providing a visual presence in the roadway to slow cars approaching intersections.

The presence of utilities, potential loss of on-street parking spaces, and the narrowing of the road are all considerations for curb extension placement and design.

General Guidelines

Local streets typically accommodate curb extensions and the design considerations outlined below are directed primarily for this application. Curb extensions can also be accommodated on higher classification streets using similar design considerations. However, significantly more scrutiny and review are required to ensure vehicle and pedestrian safety, safety for maintenance crews, and adequate sizing of the facility for those situations. Additional considerations for higher classification streets may include analysis for future transportation system demands. These demands may call for future travel lanes, bike lanes, or turn lanes that would potentially conflict with a curb extension. Other facility types may be more appropriate for high traffic areas.

Curb extensions should be designed for optimal collection of stormwater to fit into the existing streetscape to the maximum extent practicable. Designers should take into consideration the impact to adjacent property owners and preserving existing desirable amenities within the right-of-way such as on street parking, walkways, landscaping, street trees, and utilities.

Since curb extensions occupy space typically used for on-street parking, a technique for mitigating impacts to adjacent property owners is centering surface stormwater facilities between properties (e.g. centered on property lines perpendicular to the facility). Even though this may not be the most efficient location for collection of stormwater, it reduces the

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impact to one property by spreading it over two. This technique can allow for at least one on-street parking space to be retained on each property frontage. In general, projects should avoid removing parking entirely along frontages without driveways or off-street parking areas.

For mid-block curb extension applications, it is acceptable for stormwater to flow into a facility and then back out (via a passive surface overflow). When a stormwater curb extension is combined with pedestrian ramps at corners, stormwater should be collected within the facility to the maximum extent practicable. This may include the installation of underdrains and/or overflow inlets within the stormwater facilities. Stormwater must not flow across the base of the pedestrian ramps when exiting the facility.

The development potential of adjacent property should be considered to the maximum extent practical when placing facilities. For example, an undeveloped or underdeveloped lot might require a driveway at a future time, which could conflict with a surface stormwater facility.

Street Design Requirements and Considerations

A curb extension in an existing right-of-way may considered to be an alteration. As a result, the federal law may require a curb extension project improve adjacent corners that do not have pedestrian ramps.

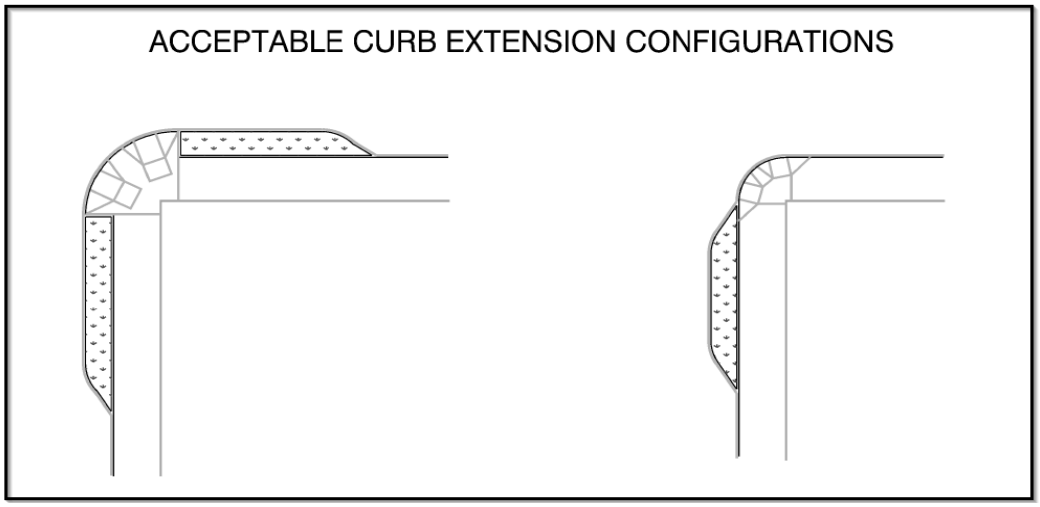
For corner applications, stormwater curb extensions must be placed at the Point of Curvature (PC) or the Point of Tangency of a corner radius or as close to the corner ramp as possible without blocking the pedestrian ramp. Where a curb extension cannot be placed at or very close to the PC of a corner radius, stormwater curb extensions must be moved back approximately 18 feet to allow for a legal parking space.

Stormwater curb extensions proposed on both sides of a street corner must be incorporated into a full curb extension including the corner ramps (See Figure 4). A single stormwater curb extension can be placed on one side of a corner without requiring that the corner ramp be incorporated into the extension. Corners with pedestrian ramps must be constructed (see Figure 4).

For midblock applications, locate stormwater curb extensions at the wing of a driveway or at least 18 feet from a driveway wing to either remove or allow for parking.

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Figure 4. Acceptable Curb Extension Configurations



The presence of existing fire hydrants and mature street trees will impact placement of curb extensions. A thickened curb and gutter should be used along the street side of all surface stormwater facilities in the public right-of-way.

Typical curb extensions vary in width from 4 to 6 feet as measured from the face of the existing curb to the street-facing face of a new curb. The actual width of the curb extension varies depending on many factors, including but not limited to: existing street width, on-street parking, bike lanes, traffic engineering considerations, and conflicts with utilities, such as water lines. A distance of 20 feet between curbs on opposite sides of the street must be maintained on all local, two-way residential streets. Existing utility locations may also impact allowable curb extension width. It may be necessary to reduce the width of a curb extension to avoid a utility conflict.

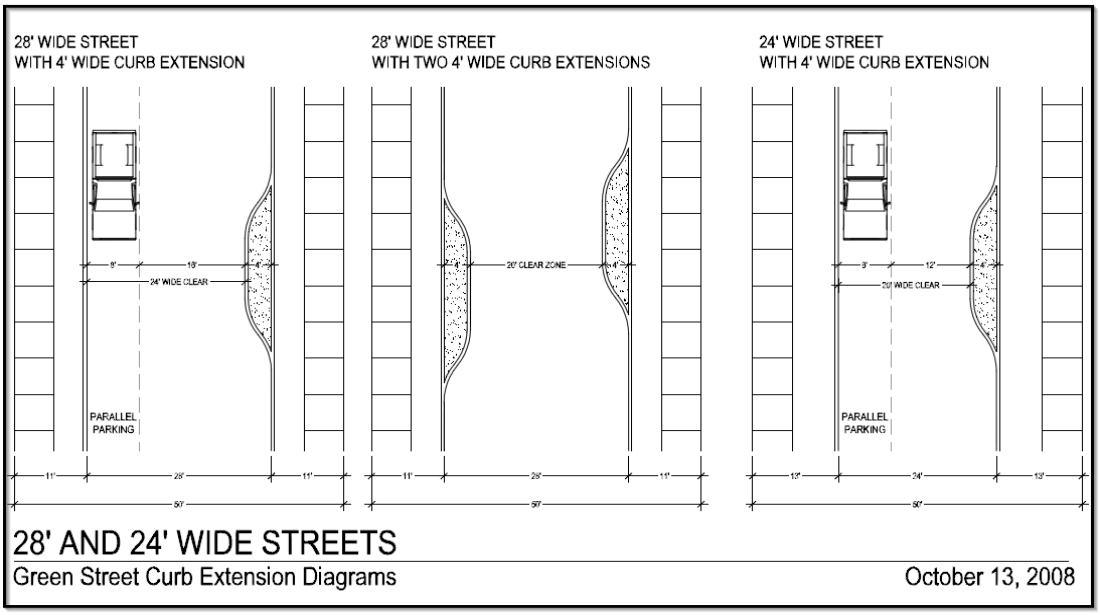
Curb extensions must be designed with a wheel stop at the inlet/outlet of a facility when adjacent to on-street parking. Significant damage to both the facility and a vehicle can occur if a vehicle enters the curb opening of a curb extension.

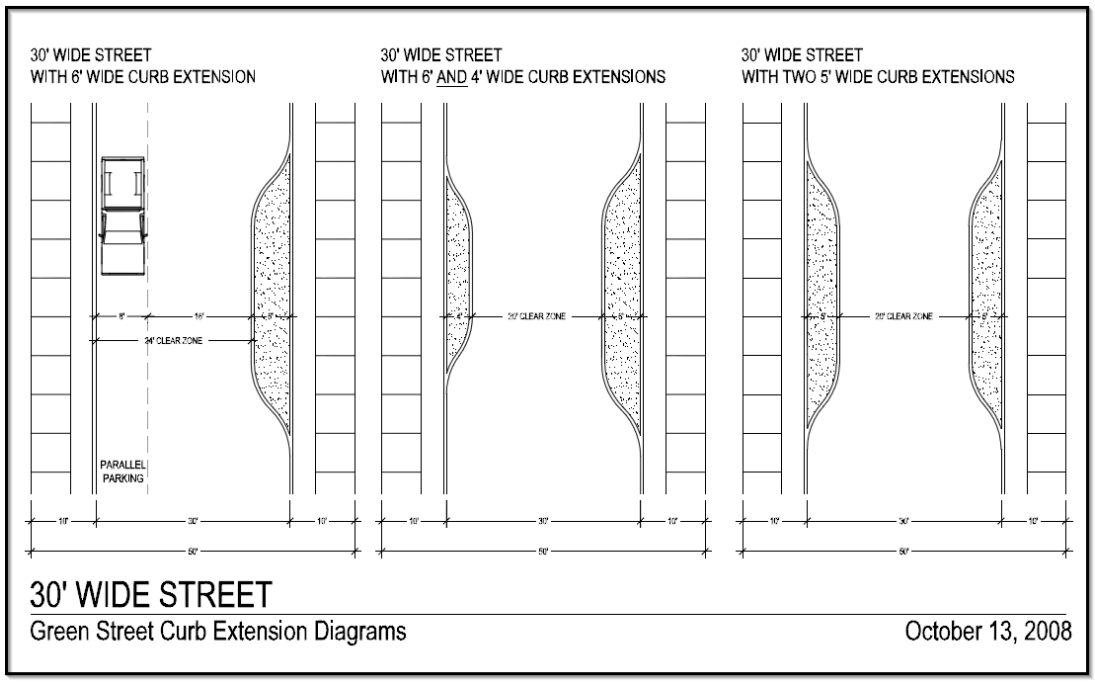
Generally, a minimum length of 30 feet is required to accommodate a mid-block curb extension ranging from 4 to 6 feet in width. Any linear length shorter than this should not be considered for a curb extension.

Existing sidewalks with a vertical or horizontal displacement greater than or equal to ½ inch must be repaired at locations where new construction meets old. Many existing sidewalks are old and not able to withstand even minimal adjacent disturbance or construction loads. The sidewalk should be restored to a condition as good as the condition that existed before construction.

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Figure 5. Street Widths for Curb Extensions





32 feet and wider streets may have up to 6 feet curb extensions on one or both sides of the street.

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Stormwater Requirements

Soil suitability: Existing infiltration rates will determine if the facility can be designed to achieve infiltration, partial infiltration, or allow the stormwater to be conveyed through the facility.

Setbacks: Infiltration curb extensions are typically set back 10 feet from building foundations. There are no setback requirements for lined curb extensions.

Sizing: Surface area and depth of facility vary. The designer needs to size stormwater facilities with respect to native infiltration rates and other unique site conditions of the project. A curb extension can be designed as a swale or planter facility type depending on site conditions and design needs.

Dimensions and slopes: The minimum curb extension width is 4 feet, and the length will vary. They may vary in ponding depth from 6 to 9 inches measured from the inlet elevation. Maximum longitudinal slope is 6 percent.

Liners: Full or partial liners may be required for protecting adjacent water facilities/utilities, on higher classification streets, in locations with hazardous materials or topography considerations, and in wellhead protection areas. The location determines the required liner thickness. Other methods may be considered where impervious or waterproof facilities are required, such as single- pour concrete forms.

Check dams: Check dams may be required perpendicular to the flow line to encourage water to pool and infiltrate into the ground.

Drainage layer: 1 ½" - ¾-inch round washed drain rock may be required. Drain rock and growing medium must be separated a 2-inch to 3-inch layer of ¾-inch to No. 4 open graded aggregate. Geotextile fabric is prohibited.

Growing medium: For curb extensions, the blended soil must be 18 inches deep, or less if native soils drain well.

Vegetation: The entire facility area must be planted with vegetation. The facility area is equivalent to the total area of the facility, including bottom and side slopes, as developed in the sizing calculations. Curb extensions should be planted so they do not block traffic sight lines or require mowing

Mulch: Fine to medium wood mulch is recommended for curb extensions. It should be placed in the facility only in areas above the high-water line. Care should be given to keeping mulch material out of a stormwater flow path to avoid any material from clogging inlets or outlets or

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otherwise escaping the facility. It must be weed-free and applied 2 to 3 inches thick to cover all soil between plants. It should not be over-applied.

Construction Considerations: Infiltration curb extension areas should be clearly marked before site work begins to avoid soil compaction or sedimentation during construction. No vehicular or foot traffic, except that specifically used to construct the facility, should be allowed within 10 feet of infiltration curb extension areas.

Planters



Planters infiltrate or treat stormwater; this planter is monolithically poured concrete in a commercial setting.

Facility Description

Planters are structural landscaped reservoirs used to collect, filter, and infiltrate stormwater, allowing pollutants to settle and filter out as the water percolates through the vegetation, growing medium, and gravel. Depending on site conditions, planters can be designed to completely or partially infiltrate the stormwater they receive. They can also be designed as lined facilities where stormwater is temporarily stored. Excess stormwater collects in a perforated pipe at the bottom of the lined planter and drains to an approved discharge location. Planters can be used to help fulfill a site's required landscaping area requirement

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and should be integrated into the overall site design. Numerous design variations of shape, wall treatment, and planting scheme can be used to fit the character of a site. Because lined planters can be constructed immediately next to buildings, they are ideal for sites with setback requirements, poorly draining soils, steep slopes, or other constraints.

Design Requirements

Soil suitability: Existing infiltration rates and design approach will determine if the facility can be designed to achieve infiltration, partial infiltration, or might be lined.
If the tested infiltration rate is greater than or equal to 2 inches per hour, the simplified planter design may be able to be designed as a complete infiltration facility. If the tested infiltration rate is less than 2 inches per hour, the planter should be designed as a partial infiltration or lined facility, with an overflow to an approved discharge location.

Setbacks: Infiltration planters are typically set back 5 feet from property lines and 10 feet from building foundations. No setbacks are required for lined planters where the height above finished grade is 30 inches or less. Lined planters can be used next to foundation walls, adjacent to property lines, or on slopes when they include a waterproof lining.

Dimensions and slopes: The minimum planter width is 24 inches (measured from inside the planter walls). Facility storage depth must be at least 12 inches (from inlet elevation of overflow to top of growing medium), unless a larger- than-required planter area is specified. Planters are flat facilities that must not slope more than 0.5 percent in any direction. A minimum of 2 inches of freeboard (vertical distance between the design water surface elevation and overtopping elevation) must be provided.

Planter walls: Planter walls must be concrete unless otherwise approved. For planters that require an impervious bottom, a monolithically poured planter without joints is required.

Waterproofing/Liner: Lined facilities that require an impervious bottom must be a single-pour concrete box, or approved equivalent. Full or partial liners may be required for protecting adjacent water facilities/utilities, on higher classification streets, in locations with hazardous materials or topography considerations, and in wellhead protection areas. The location determines the required liner thickness.

Drainage Layer: 12” depth of ¾” – 1 ½”washed drain rock should generally be used. Drain rock and growing medium must be separated by a 2- to 3-inch layer of pea gravel.

Growing medium: The imported soil should generally be a sandy loam mixed with compost or a sand/soil/compost blend. It must be roughly one-third compost by volume, free-draining, and support plant growth. The compost must be derived from plant material; animal waste is not allowed.

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If a stormwater management facility is proposed adjacent to property lines or nearby structures, then a lined facility will likely be required. Vegetation planted within water-tight stormwater management facilities cannot compromise the integrity of the facility liner and the facility design must ensure plants will survive. To provide adequate area for plants to grow, vegetation must be planted within a minimum growing medium depth of 24 inches.

Construction Considerations: Special attention should be paid to the structural waterproofing if the planter is constructed adjacent to building structures. Infiltration planter areas should be clearly marked before site work begins to avoid soil compaction and sedimentation to preserve infiltration capacity during construction. No vehicular or foot traffic, except that specifically used to construct the facility, should be allowed within 10 feet of infiltration planter areas.

Basins



Basins are shallow landscape depressions which treat and infiltrate runoff.

Facility Description

Vegetated infiltration basins are shallow landscaped depressions used to collect and hold stormwater runoff, allowing pollutants to settle and filter out as the water infiltrates into the ground. Basins are also referred to as rain gardens. They are either excavated or created with

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bermed side slopes. An inlet pipe or sheet flow over impervious area conveys the stormwater into the basin, where it is temporarily stored until it infiltrates into the ground. Basins often provide complete onsite infiltration for small storm events. They can be sized to infiltrate large storms in areas where soils drain well or overflow to an approved discharge location. Basins can have a formal or informal design that can be used to help fulfill a site's landscape requirements.

Design Requirements

Soil suitability: Existing infiltration rates will determine if the facility can be designed to achieve infiltration, partial infiltration, or allow the stormwater to be conveyed through the facility. If the tested infiltration rate is greater than or equal to 2 inches per hour, the simplified basin design meets all requirements. If the tested infiltration rate is less than 2 inches per hour, the basin should be designed as a partial infiltration facility, with an overflow to an approved discharge location.

Setbacks: Infiltration basins are typically set back 5 feet from property lines and 10 feet from building foundations. There are no setback requirements for lined basins. If a basement is within 10' of an infiltration basin, a partial liner may be required on the basement side of the basin.

Dimensions and slopes: Minimum bottom width is 2 feet where feasible. Simple basins are 12 inches deep measured from the top of the growing medium to the overflow inlet elevation. Maximum side slopes are 3 horizontal to 1 vertical; 4 horizontal to 1 vertical is required immediately adjacent to pedestrian areas. A minimum of 2 inches of freeboard must be provided.

Drainage Layer: 12" depth of ¾" – 1 ½"washed drain rock must be used. Drain rock and growing medium must be separated a 2- to 3-inch layer of pea gravel.

Growing medium: The imported soil should generally be a sandy loam mixed with compost or a sand/soil/compost blend. It must be roughly one-third compost by volume, free-draining, and support plant growth. The compost must be derived from plant material; animal waste is not allowed. If a stormwater management facility is proposed adjacent to property lines or nearby structures, then a lined facility will likely be required. Vegetation planted within water-tight stormwater management facilities cannot compromise the integrity of the facility liner and the facility design must ensure plants will survive.

Vegetation: The entire facility area must be planted with vegetation. The facility area is equivalent to the total area of the basin, including bottom and side slopes, as developed in the sizing calculations. Basins should be designed so they do not require mowing.

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Construction Considerations: Infiltration basin areas should be clearly marked before site work begins to avoid soil compaction or sedimentation during construction. No vehicular or foot traffic, except that specifically used to construct the facility, should be allowed within 10 feet of infiltration basin areas.

Filter Strips



Filter strips are gently-sloped vegetated areas which manage runoff from driveways and walkways, slowing the runoff and allowing it to infiltrate.

Facility Description

Vegetated filter strips are gently sloped areas that are designed to receive sheet flows. They are typically linear facilities that run parallel to the impervious surface and are commonly used to receive the runoff from walkways and driveways. Filter strips are covered with vegetation, including grasses and groundcovers, which filter and reduce the velocity of the stormwater. As the stormwater travels downhill, it infiltrates into the soils below.

Driveway center filter strips are used between the drive aisles of residential driveways. They are typically 3 feet wide and placed between two 3-foot-wide paved sections. (The minimum width of a residential driveway is 9 feet, of which the inner 3-foot section could be pervious

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and used for infiltration as long as all other code requirements are met.) The strip is used exclusively to treat and infiltrate the stormwater from the impervious area of the drive aisles. The drive aisles must be sloped toward the driveway center filter strip.

Design Requirements

Soil Suitability: Filter strips are appropriate for all soil types.

Setbacks: Filter strips are typically 5 feet from the property line; 10 feet from buildings; and 50 feet from wetlands, rivers, streams, and creeks.

Sizing: The filter strip is typically sized at 20 percent of impervious area treated for a maximum of 500 square feet of impervious area to be managed by the filter strip.

Dimensions and slopes: Filter strips must slope between 0.5 and 6 percent. Slope of pavement area draining to the strip must be less than 6 percent. Filter strips must have a minimum length of 5 feet, measured in the direction of the flow.

Level spreaders: A grade board or sand/gravel trench may be required to disperse the runoff evenly across the filter strip. The top of the level spreader must be horizontal and at an appropriate height to provide sheet flow directly to the soil without scour. Level spreaders must not hold a permanent volume of runoff. Grade boards can be made of any material that will withstand weather and solar degradation. Trenches used as level spreaders can be filled with washed crushed rock, pea gravel, or sand.

Check dams: If necessary, check dams must be constructed of durable, nontoxic materials such as rock or brick or graded into the native soils. Check dams must be 3 to 5 inches high, and run the length of the filter.

Growing medium: The imported soil should be a sandy loam mixed with compost or a sand/soil/compost blend. It should be roughly one-third compost by volume, free- draining, and support plant growing. The compost must be derived from plant material; animal waste is not allowed. The growing medium must be 12 inches deep for filter strips.

Vegetation: The entire filter strip must have 100 percent coverage by grasses, ground covers, or any combination thereof.

Grassy Swales

Facility Description

Grassy swales are long, narrow grassy depressions used to collect and convey stormwater runoff, allowing pollutants to settle and filter out as the water infiltrates into the ground or flows through the facility. In addition to providing pollution reduction, they can also manage

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flow rates and volumes. Grassy swales should be integrated into the overall site design and can be used to help fulfill a site's required landscaping area requirement.

Design Requirements

Soil suitability: Grassy swales are appropriate for all soil types.

Setbacks: Grassy swales are typically set back 5 feet from centerline of the swale to property lines and 10 feet to building foundations, unless the swale is lined with impermeable fabric.

Sizing: The swale width and profile must be designed to convey runoff from the design storm intensity at:

- Maximum design velocity of 0.9 feet per second.
- Minimum hydraulic residence time (time for Q_{design} to pass through the swale) of 9 minutes.
- A Manning *n* value of 0.25.

A maximum ponding depth of 4" is required to maximize contact with the grass, unless otherwise approved.

A minimum of 1 foot of freeboard above the water surface must be provided for facilities not protected by high-flow storm diversion devices. Swales without high- flow diversion devices must be sized to safely convey the 25-year storm event.

Velocity through the facility must not exceed 3 feet per second during the high-flow events.

Figure 6, Figure 7 and Figure 8 can be used to determine minimum required swale length and the swale bottom width given the peak flow rate.

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Figure 6. Swale Length at 1.5% Longitudinal Slope

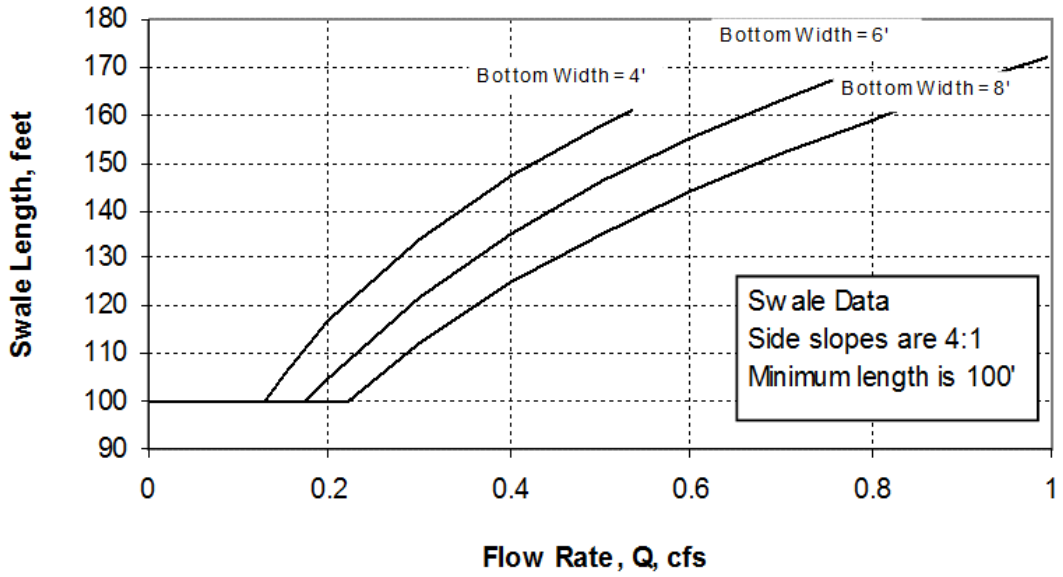
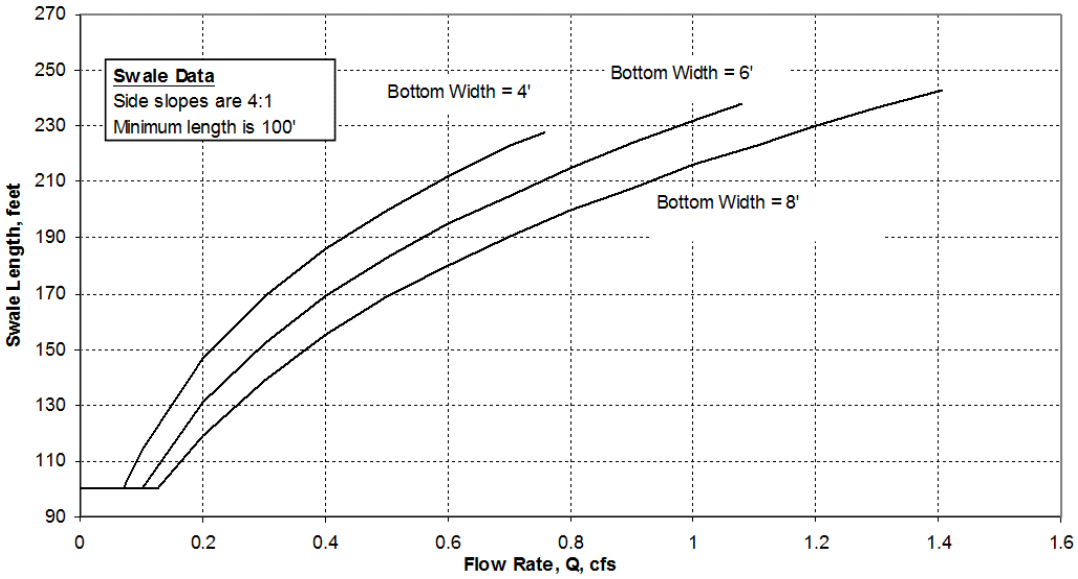
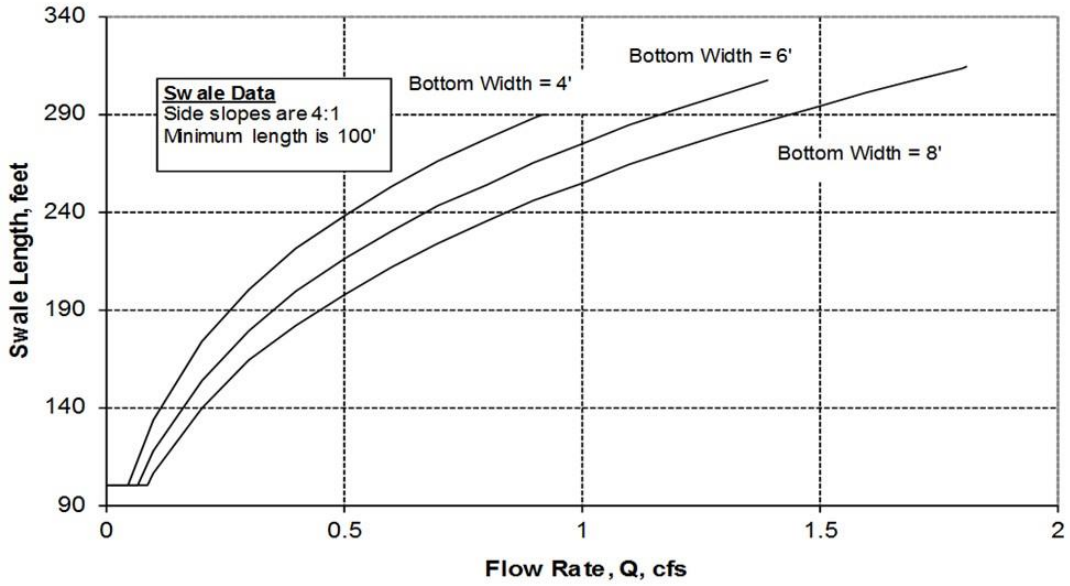


Figure 7. Swale Length at 3.0% Longitudinal Slope



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Figure 8. Swale Length at 5.0% Longitudinal Slope



Dimensions and slopes: The minimum grassy swale width on private property is 10 feet, with a minimum 2-foot flat bottom. The minimum grassy swale width on public property is 12 feet, with a minimum 4-foot flat bottom. Maximum side slopes for both are 4 horizontal to 1 vertical. The minimum length for both is 100 feet.

When designing grassy swales, slopes and depth should be kept as mild as possible to avoid safety risks and prevent erosion within the facility. To minimize flow channelization, the grassy swale bottom must be smooth, with uniform longitudinal slope. Maximum surrounding ground slopes must not exceed 10 percent.

Flow spreader: The grassy swale must incorporate a flow-spreading device at the inlet. The flow spreader must provide a uniform flow distribution across the swale bottom. In swales with a bottom width greater than 6 feet, a flow spreader must be installed at least every 50 feet.

Growing medium: Blended topsoil should be used within the top 18 inches of the facility to support plant growth.

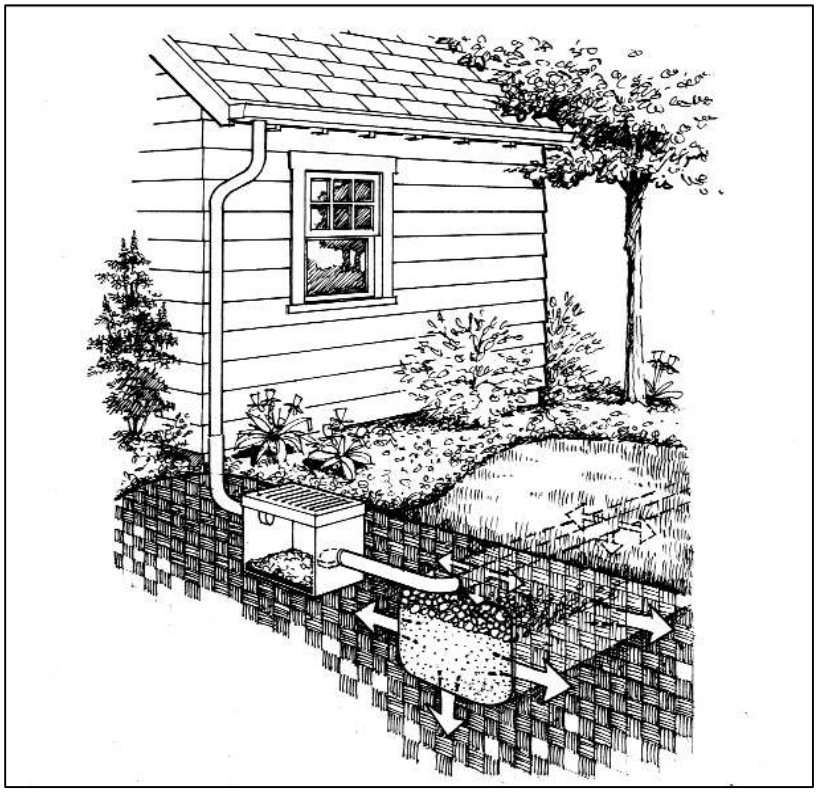
Vegetation: Grasses must be established as soon as possible after the swale is completed and before water is allowed to enter the facility. Unless vegetation is established prior to completion of construction, biodegradable erosion control matting appropriate for low-velocity flows (approximately 1 foot per second) must be installed in the flow area of the swale before water is allowed to be conveyed through the swale.

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For the swale flow path, approved native grass mixes are preferable. Seed must be applied at the rates specified by the supplier. Plants must be established at the time of facility completion (at least 3 months after seeding). Trees and shrubs may be allowed in the flow path within swales. Native wildflowers and grasses may be used but must be designed to not require mowing. Where mowing cannot be avoided, facilities must be designed to require mowing no more than once or twice annually. Lawn-type areas are not recommended.

Construction Considerations: Infiltration areas should be clearly marked before site work begins to avoid soil compaction or sedimentation during construction. No vehicular or foot traffic, except that specifically used to construct the facility, should be allowed within 10 feet of infiltration areas. No concentrated flows are allowed into the facility until the vegetation is fully established.

Soakage Trenches



Soakage trenches allow water to soak into the ground through underground trenches.

Facility Description

A soakage or infiltration trench is a shallow trench in permeable soil that is backfilled with washed drain rock. The trench surface may be covered with grass, stone, sand, or plantings.

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Private soakage trenches can be used to provide stormwater discharge by collecting and recharging stormwater runoff into the ground. The use of soakage trenches is highly dependent on the soil type and height of the groundwater table. Soakage trenches are not allowed in the right-of-way.

Underground Injection Control (UIC)

Soakage trenches may be classified as "Class V Injection Wells" under the federal UIC regulations. Since the UIC Program states that these types of trenches can have a direct impact on groundwater, pollution reduction is generally required before discharging stormwater into them.

Design Requirements

Soil suitability: Soil conditions are critical to the success of soakage trenches. Supporting geotechnical analysis is required for slopes of 20 percent or greater, or when requested.

A 2-inch/hour infiltration rate is required at the facility base.

All trenches must be constructed in native soil and must not be subject to vehicular traffic or construction work that will compact the soil, thus reducing permeability.

There must be a 5-foot separation distance from the bottom of the trench to any impervious layer or water table. Soakage trenches are not allowed in areas of shallow groundwater where the separation distance from the bottom of the trench to seasonally high groundwater is less than 5 feet.

Setbacks: Soakage trenches typically have 5-foot setbacks from property lines and 10-foot setbacks from building foundations, unless an appeal is approved by BDS. One hundred-foot setbacks are typical for slopes 20 percent or greater. See Table 2-1 for more information on setbacks. Trenches may not be constructed under current or future impervious surfaces.

Sizing: Sizing requirements vary by design approach. Pore space of the fill material should be 30 percent, with vertical infiltration area only. The trench must infiltrate the entire design storm without overflow. The maximum impervious area to be served by a soakage trench is 10,000 square feet.

Soakage trenches are designed with minimum infiltration rate of 2.00 inches per hour. The minimum length is 20', width is 2.5' and depth is 1.5'

Drainage Layer: A minimum of 12 or 18 inches of open graded washed ¾- to 2½-inch round or crushed rock separated from soil by one layer of geotextile fabric.

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Geotextile fabric: Use appropriate filter fabric between the medium and native soils and covering the perforated pipe to prevent clogging.

Traps: Silt traps are optional for all installations and are strongly encouraged because they will lengthen the life of the facility. If installed, the silt trap must be between the dwelling and the trench, a minimum of 5 feet from the dwelling.

Gravel Pits

Gravel pits must be sized and permitted the same as soakage trenches but can only treat up to 250 square feet.

Manufactured Chamber Technologies

Corrugated plastic stormwater chambers are generally made of high-density polypropylene or polyethylene. They are arched systems that can be rated for H-10 or H-20 loading, depending on the manufacturer, amount of cover, and type of cover.

Chamber systems function similarly to the standard soakage trench, but are often used in areas with limited infiltration because of high groundwater or shallow (<5 feet) infiltration barriers such as dense silt and clay layers. They provide temporary storage of stormwater prior to infiltration and may be able to be used with soils that infiltrate less than 2 inches per hour. Chambers may be UICs.

Sizing: The chambers must be designed to at least the same requirements as trenches. Pore space of the fill material is assumed to be 0.30. Figure 9 shows manufactured chamber technologies dimensions.

Figure 9. Manufactured Chamber Technology Dimensions

Impervious Area Ratio	Design Infiltration Rate (in/hr)	Length (in)	Width (in)	Height (in)
1 per 600sf IA*	2.00	~90	34	16 + 6” base rock

Based on standard chamber sizing

Setbacks: Manufactured chambers are typically 10 feet on center from all foundations and 5 feet from property lines.

Fill: Six inches of open graded washed drain rock is required below chamber. Additional depth or length will be required for infiltration rates less than the infiltration rates specified.

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Construction Considerations: Soakage trench areas must be clearly marked before site work begins to avoid soil disturbance during construction. No vehicular construction traffic, except that specifically used to construct the facility, should be allowed within 10 feet of soakage trench areas.

The bottom of the soakage trench must be level, or clay check dams may be used to prevent water from collecting near the downstream end. Soakage trench and perforated pipe must be installed level and parallel to the contour of the finish grade.

Drywells



Drywells allow stormwater to soak into the ground through underground rings (above shows drywell ring being lowered into ground).

Facility Description

The typical drywell is a precast concrete ring in 5-foot-tall sections perforated to allow for infiltration. These facilities are vertical in nature and can range from 5 to 20 feet in depth. Drywells require a minimum of 5 feet of vertical separation between the bottom of the drywell and seasonal high groundwater. Drywells should not be located in dense silt or clay soils, and

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may only be located in areas with soils suitable for infiltration. A dry will often be classified as a UIC, as noted above.

Design Requirements

Soil suitability: Soil conditions are critical to the success of drywells. An infiltration test or bore-log feasibility test must be performed. Drywells should be used only if the soils infiltrate at least 2 inches per hour. Installation of drywells in fill material is not permitted. All drywells must be installed in native soils. Supporting geotechnical evidence is required for all slopes of 20 percent or greater.

Setbacks: The drywell is typically 10 feet on center from all foundations and 5 feet from property lines. The top of the perforated drywell sections must be located downgrade from foundations and at a lower elevation than local basements. See Table 2-1 for more information on setbacks. Drywells sized using volume as part of the calculation must keep the maximum water surface elevation for the required design storm at least 1-foot below the lowest finished floor elevation (including that of neighboring properties).

If drywell is approved for within building setbacks or under building foundations via plumbing code appeal, it will require design to accommodate 100-year storm event in lieu of an escape route. In addition, system capacity must be protected with sedimentation control devices and the O&M must specify requirements that will protect long-term capacity and escape routes. For infiltration systems proposed underlying structures, a geotechnical report will be required which addresses the effect of the system on the performance of the foundation as well as the effect of foundations loads on the infiltration system.

Drywells that have more than the typical 12- inches of rock around the ring must measure setbacks from the edge of the rock gallery or get approval from the geotechnical and structural engineers to place the drywell closer to foundations.

Sizing: The chart provided in Figure 10 can be used to appropriately size the drywell(s) based on the amount of impervious area that each drywell is designed to manage. Dark gray boxes indicate acceptable.

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Figure 10. Drywell Sizing Chart

Impervious Area (sf)	28" Diameter				48" Diameter			
	5'	10'	15'	20'	5'	10'	15'	20'
1000								
2000								
3000								
4000								
5000								
6000								
7000								
8000								
9000								
10000								
11000								
12000								

Drywells can also be sized on a flow-rate basis or a single storm hydrograph-based analysis. Flow-rate based facility design can use the Rational Method and should only count the bottom area when determining infiltration capacity. Hydrograph-based designs should use a time-based model and may account for storage within the drywell and in the associated rock gallery.

In all cases infiltration rates can be calculated using the bottom area of the drywell and rock gallery. Infiltration rates through side-walls may be accounted for if a time-based model is used for the sizing and a geotechnical engineer determines it is appropriate for the local soils. Fine grained soils can be smeared during construction, this prevents infiltration and may be difficult to control for. Upper layers of soil may have different infiltration rates than deeper soils. These factors must be considered when making the decision to include side-wall infiltration rates.

Traps: Silt traps are optional for all installations and are strongly encouraged because they will lengthen the life of the facility. If installed, the silt trap must be between the dwelling and the drywell, a minimum of 5 feet from the dwelling.

Manufactured Plastic Drywells

Manufactured plastic "mini-drywells" are made of hard plastic (foam polyolefin) and are very versatile. The excavations for these facilities can be hand-dug, and the drywells can be placed by hand rather than using equipment (as with typical concrete drywells).

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Dimensions: Two-foot diameter, two-foot depth, plus one-foot gravel lens below and on the sides.

Sizing: One (1) unit for every 500 square feet of impervious area.

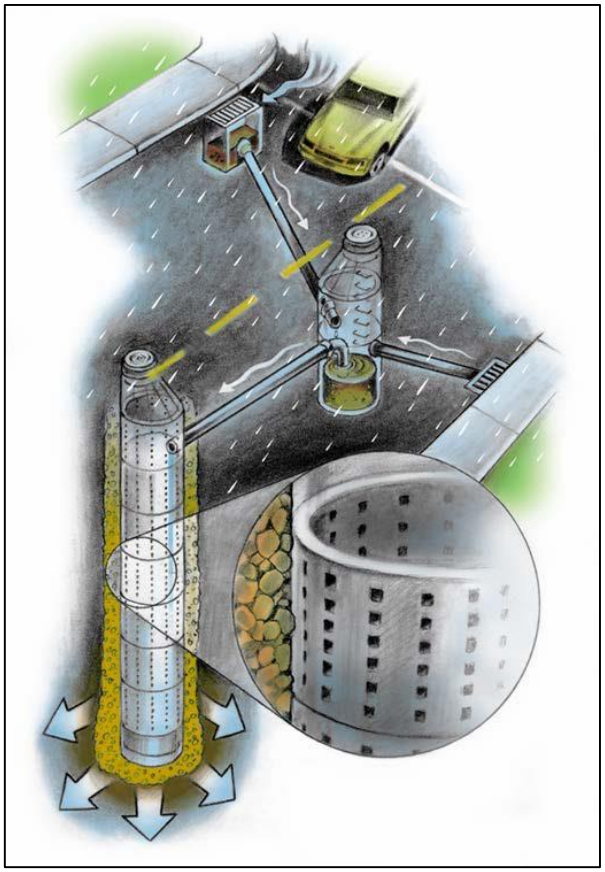
Setbacks: From center:

One unit: Five feet to property line, eight feet to any foundation, and 20 feet to existing cesspools.

Multiple units or in-line units: Five feet to property line, ten feet to any foundation, and 20 feet to existing cesspools.

Construction Considerations: If smooth excavation tools are used, scratch the sides and bottom of the excavation hole with a sharp pointed instrument and remove the loose material from the bottom of the excavation. This will break-up any smearing that could potentially limit infiltration rates.

Sumps



A sump allows stormwater to infiltrate into the ground through underground rings.

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Facility Description

Sumps are a disposal method for managing stormwater runoff. Public infiltration sump systems can be used to provide drainage from public streets by collecting stormwater and infiltrating it into the ground. The use of sumps is dependent on soil type and depth to seasonal groundwater. Sumps are different from drywells in that they are designed using precast 4-foot-diameter concrete rings with perforations, typically 30 feet deep and located in the public right-of-way. Like drywells, sumps require a minimum 5 feet of vertical separation between the bottom of the sump and seasonal high groundwater.

A sump system is the total of all sump components at a single location (e.g., an intersection) and consists of inlets, piping, a sedimentation manhole, and a sump. If one sump lacks adequate capacity to handle the design flow, a second sump may be placed in series with the first to provide additional capacity.

Sedimentation manholes with oil traps receive runoff from inlets before stormwater enters the sumps. The sedimentation manholes settle out most of the large particulate material that can clog sump drainage holes, which decreases maintenance needs and increases long-term effectiveness.

When constructed according to the standard design procedures, the sump system achieves pollution reduction benefits. The sedimentation manhole reduces pollution through removal of sediment, oils, and grease. Other types of facilities (e.g., swales or planters) may be used to provide pollution reduction instead of sedimentation manholes and may be required in certain circumstances. Sumps are likely to be classified as UICs, as noted previously.

Design Requirements

Soil suitability: Soil conditions are critical to the success of sump systems. The use of sumps will not be approved without supporting geotechnical evidence and a documented sump test to demonstrate they will work in the particular area of interest. The geotechnical evidence must include test sump data to provide information about local underground soil conditions and the potential infiltration capacity of the surrounding soil.

Sizing: Public sump systems must be designed to handle twice the flow from the calculated design storm.

- Sumps should be designed for a 10-year design storm, with a safety factor of 2.
- The time of concentration for sump design should be 5 minutes.

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Dimensions:

- A maximum of two sumps must be used in series.
- The minimum distance between sumps must be 25 feet.
- The desired distance between the sump and sedimentation manhole is 25 feet. This figure is a guideline and depends on site conditions.
- Sumps must not be located in areas with a constant or seasonally high groundwater table or shallow bedrock. The bottom of the sump must be at least 5 feet above the seasonal high water table and at least 3 feet above bedrock.
- Sumps must not be located within 200 feet from the tops of slopes more than 10 feet high and steeper than 2h:1v.
- The sedimentation manhole depth should be 10 feet.

Public Sump System Testing

Before being accepted, all public sumps should be tested after construction to ensure they meet or exceed the design capacity. Standard sump notes on the plan set should be required to document design rates and sump testing. The notes should include the following:

1. Design flows reflect a factor of safety of 2.
2. Sump testing must take place after sump construction is complete and before the construction of the sedimentation manhole. Should a sump test fail to verify adequate capacity, an additional sump, constructed in series with the first sump (a maximum of two sumps per system) must be required. Should a test of two sumps in series fail to verify adequate capacity, an alternative public stormwater destination must be required.
3. Provide water flow from fire hydrants to sump being tested using an 8-inch nominal diameter pipe. Deliver clean potable water to sumps. Introduction of sediment is not acceptable and may result in failure of sump capacity test and reconstruction of sump.
4. The test may be completed using flow from one fire hydrant. However, a second fire hydrant may be necessary to complete the sump test.
5. Fill sump with water at an initial rate of 300 gallons per minute (gpm), and record water elevation below sump rim after five minutes. Maintain initial flow rate and continue taking recordings of the water elevation at five-minute intervals until the water surface reaches a constant elevation. Then increase flow rate by 300 gpm, and record the water elevation at the new flow rate as described in the initial process. Continue the sump test by increasing the flow rate at increments of 300 gpm until the sump has reached its maximum capacity.

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6. Upon completion of each sump test, compare tested sump capacity flow rate to the minimum flow rate noted in the Plans.

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