BR-1. Introduction

Bioretention is a versatile stormwater practice that filters runoff through plants, an engineered soil mix, and often an underdrain.

Bioretention can be used to:

- Manage the first one inch of rainfall on-site using an Infiltration Design with no underdrain (See **Table BR-1**, Level 2 design)
- Manage the first one inch of rainfall on-site using an Extended Filtration Design with an underdrain (**See Table BR-1**, Level 2 design)
- Partially manage the first one inch of rainfall on-site using a Basic Design with an underdrain (See **Table BR-1**, Level 1 design)
- Reduce pollutant loads to meet water quality targets (total maximum daily loads or TMDLs; See **Table BR-2**).
- Meet partial or full storage requirements for local stormwater detention standards
- Retrofit existing developed areas, especially highly impervious areas

Bioretention can be blended into the landscape design for many sites. As examples, the photo on the left shows a Bioretention cell in the bus loop of a high school. The photo on the right illustrates a linear and sloped Bioretention (called a "Water Quality Swale") along a residential street, using stone check dams to break the swale into individual cells.

For the purposes of this section, "Bioretention" refers to flat-bottomed cells of various shapes and configurations. Other variations of the basic Bioretention concept are included in the supplements to this section:

- Water Quality Swale (**Supplement 4.2.3.A**) -- linear and narrower applications, often with a longitudinal slope (see photo on right above).
- Urban Bioretention (**Supplement 4.2.3.B**) – adaptations for highly impervious settings; includes street Bioretention, engineered tree pits, and stormwater planters.
- Residential Rain Garden (**Supplement 4.2.3.C**) – simplified version designed for residential yards and small-scale applications.

Figure BR-1 further illustrates typical Bioretention applications. **Figure BR-2** is a schematic of a typical Bioretention area. **Tables BR-1 and BR-2** describe two levels of Bioretention design and associated volume reduction and pollutant removal performance rates. **Table BR-3** is a design checklist to help guide the design process for Bioretention practices.

BR-1.1. Planning This Practice

Figure BR-1. Typical Applications for Bioretention & Water Quality Swales

BEFORE

AFTER

Edge of Parking Lot

(Computer simulation by Center for Watershed Protection)

Parking Lot Island

(Computer simulation by Center for Watershed Protection)

BEFORE

AFTER

To Treat Rooftop Runoff

(Computer simulation by Center for Watershed Protection)

In Bus Loops & Grassy Areas Adjacent to Parking Lots and Travelways

In the Street Right-of-Way (Can be Associated with Traffic Calming (Urban Bioretention))

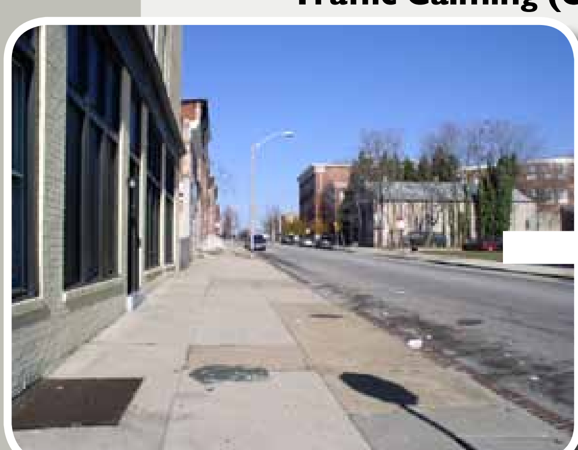

Figure BR-2. Schematic Profile for Typical Bioretention

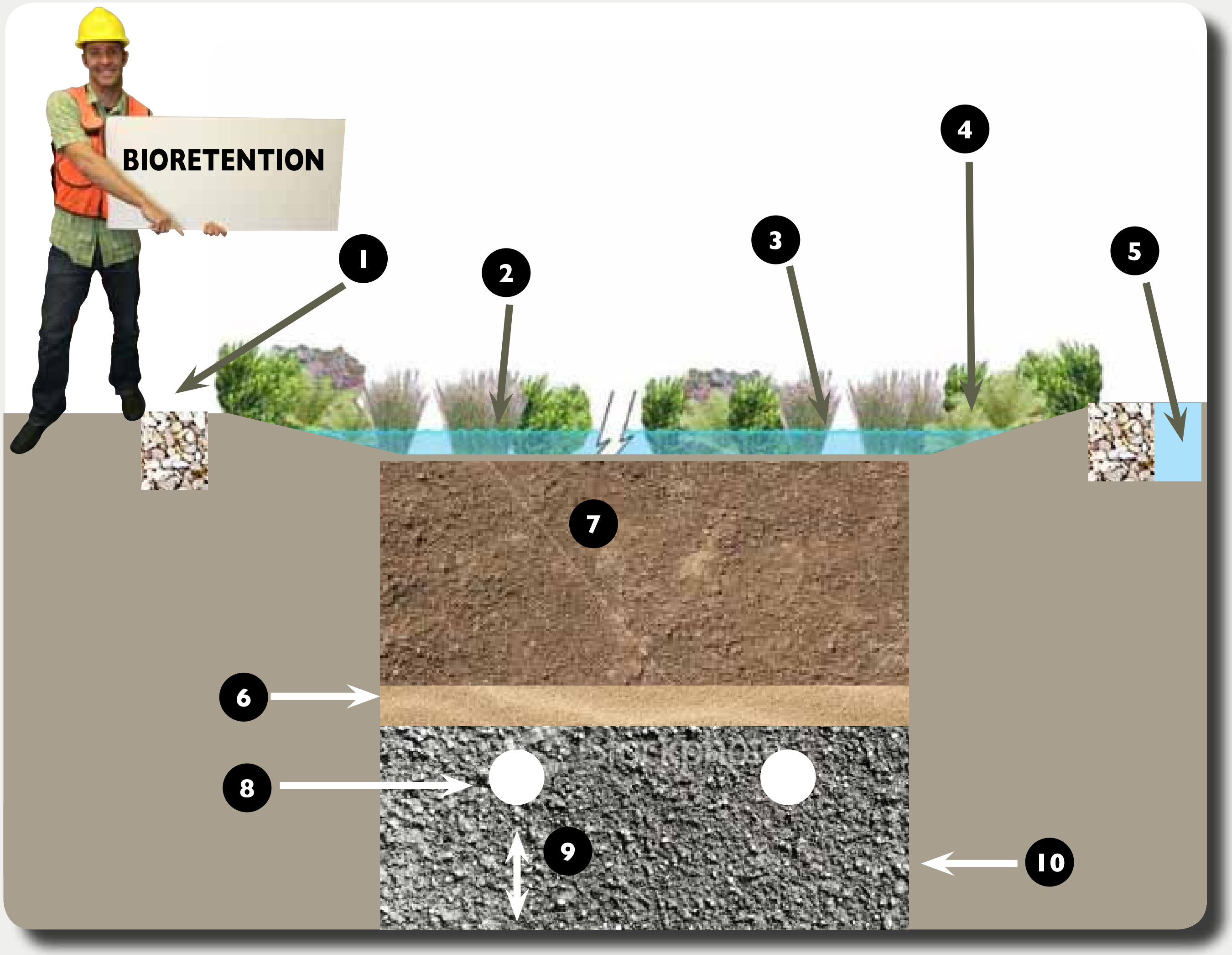

Figure 2. Schematic Profile for Typical Bioretention (Source for base graphic: San Mateo County Sustainable Green Streets and Parking Lots Guidebook (San Mateo County, CA, 2009).

1. Pretreatment (typical) - Section BR-4.3
2. Surface Cover & Plantings - Sections BR-4.9 & BR-4.17
3. Ponding Depth = 6" – 18" - Section BR-4.6
4. Side Slopes = 3:1 max (recommended) - Section BR-4.7
5. Overflow Structure for Larger Flows - Section BR-4.4
6. Choker Layer = 1" choker stone for every 1' of soil media - Section BR-4.12
7. Soil Media = 18" min. - Section BR-4.8 & Table BR-1
8. 4" – 6" Underdrain Pipes - Section BR-4.10
9. Optional Infiltration Sump Below Underdrain Pipes - Section BR-4.11
10. Underdrain Stone Layer - Section BR-4.10

BR-1.2. Bioretention Design Options & Performance

Table BR-1 describes the Level 1 and Level 2 design options for Bioretention and the practice performance in terms of reducing the volume associated with one inch of rainfall on the site. **Table BR-2** summarizes the pollutant removal performance values for Level 1 and Level 2 designs. This is for the purpose of calculating site-based pollutant load reductions in the context of TMDLs and/or watershed plans.

Table BR-1. Bioretention Design Levels: Descriptions & Performance

Design Level	Description	Applications	Performance1
Level 1	Basic Design (**Figure BR-3**) • Underdrain • At least 1.5 ft. of soil media depth, but less than 2.0 ft. • No infiltration sump below underdrain pipe(s)	Sites with vertical constraints such as high bedrock or water table or confirmed karst, stormwater hotspot, or other applications that require an impermeable liner.	60% volume reduction for the Design Volume of the practice[2]
Level 2	Infiltration Design (**Figure BR-4**) • No underdrain • Water infiltrates into the underlying soil within 48 hours. OR Extended Filtration Design (**Figures BR-5, 6, 7**) • Underdrain • At least 2.0 ft. of soil media depth, OR • At least 1.5 ft. of soil media depth with stone sump below underdrain designed to drain Design Volume within 48 hours on suitable soils (e.g., limited on fill) or upturned elbow underdrain design	Generally most sites that have good to marginal infiltration rates -- HSG A, B, and C and do not require an impermeable liner. Use the Infiltration Design for tested infiltration rates > 0.5 in. per hr., and the Extended Filtration Design for other sites.	100% volume reduction for the Design Volume of the practice[2]

[1] *Performance achieved toward reducing one inch of rainfall*

[2] *Design Volume includes storage on the surface, within the soil media, and in the infiltration sump. The Design Volume can be 100% of that needed to meet the one inch performance standard for the contributing drainage area ("Target Treatment Volume") or some proportion of it when used in conjunction with other practices. See* **Section BR-4.1** *for sizing details.*

Table BR-2. Total Pollutant Load Reduction Performance Values for Level 1 and 2 Design

Design Level	Total Suspended Solids (TSS)[1]	Nutrients: Total Phosphorus (TP) & Total Nitrogen (TN)[1]
Level 1	TSS = 70%	TP = 55% TN = 64%
Level 2	TSS = 95%	TP = 90% TN = 92%

[1] Total Pollutant Load Reduction = combined functions of runoff reduction and pollutant removal. Pollutant removal refers to the change in event mean concentration as it flows through the practice and is subjected to treatment processes, as reported in Hirschman et al. (2008).

BR-1.3. Bioretention Design Checklist

Table BR-3. Bioretention Design Checklist

CHECKLIST

This checklist will help the designer step through the necessary design steps for bioretention.

- ☐ This checklist will help the designer with the necessary design steps for Bioretention.
- ☐ Check feasibility for site – Section BR-3
- ☐ Determine whether an Infiltration or Extended Filtration Design is best for the site. Use Level 2 design unless site constraints necessitate the Level 1 Basic Design – **Table BR-1**
- ☐ Complete Design Compliance Spreadsheet to plan and confirm required Bioretention sizing, additional practices needed, and overall site compliance – Design Compliance Spreadsheet & Chapter 3 of Manual
- ☐ Check Bioretention sizing guidance and make sure there is an adequate footprint (often split into multiple areas) on the site for Bioretention – Sections BR-4.1 & BR-4.2
- ☐ Check design adaptations appropriate to the site – Section BR-6
- ☐ Design Bioretention in accordance with design criteria and typical details – Sections BR-2 & BR-4
- ☐ Provide all necessary plan view, profile, and cross-section details along with elevations, materials specifications, grading, and construction sequence notes

BR-2. Typical Details

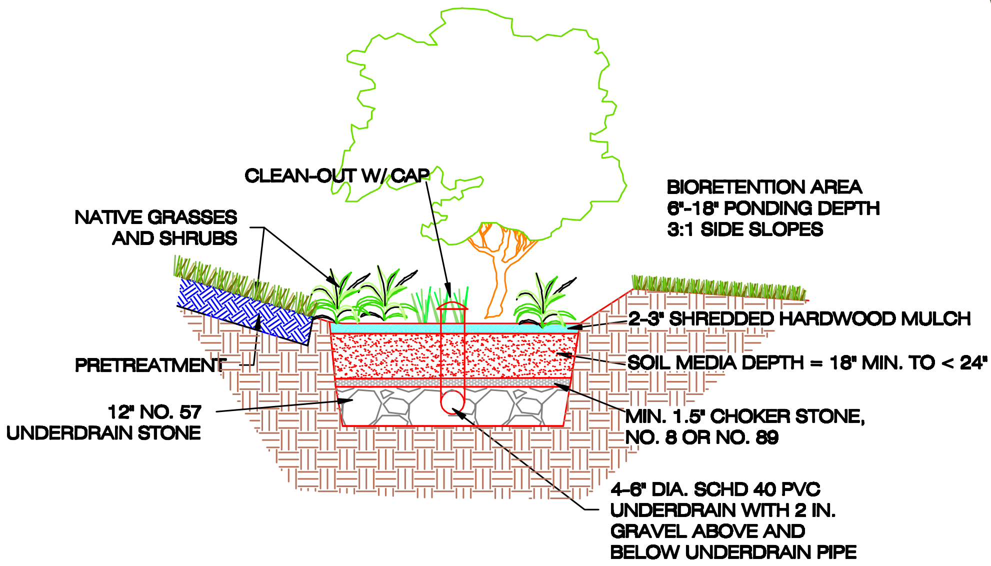

Figure BR-3. Typical Detail for Level 1 Design

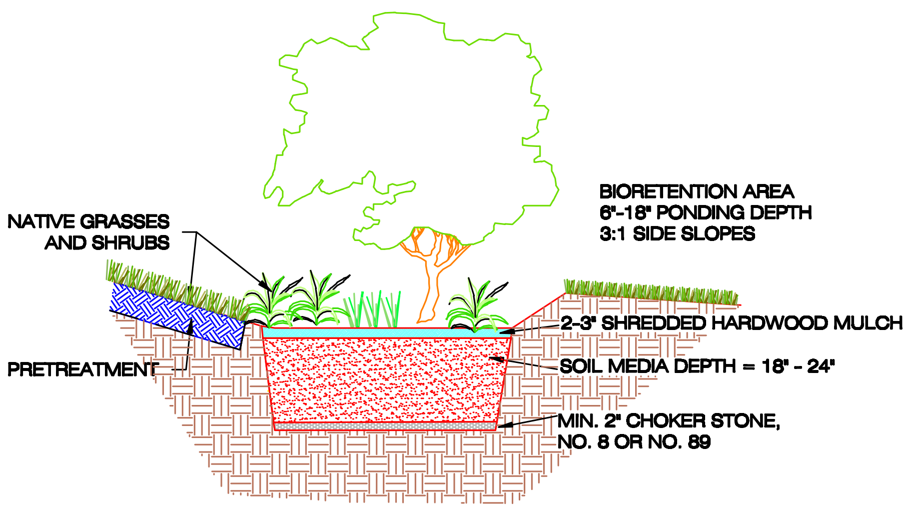

Figure BR-4. Typical Detail for Level 2 Infiltration Design (No Underdrain)

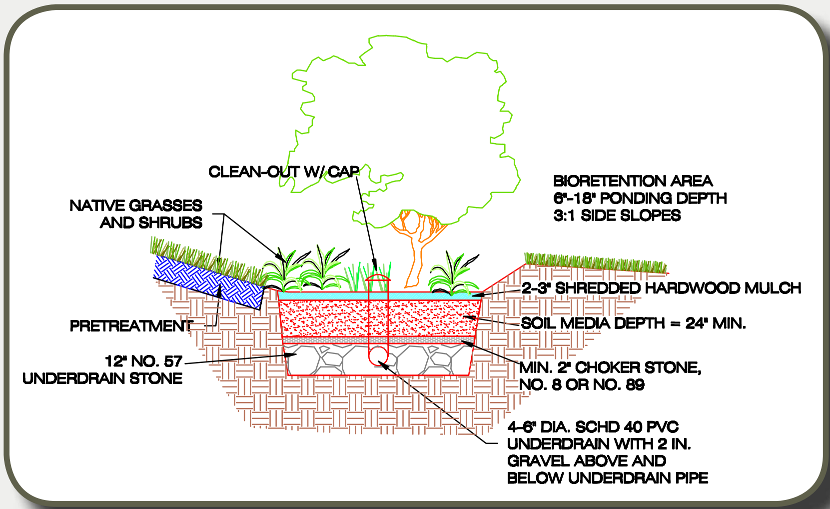

Figure BR-5. Typical Detail for Level 2 Extended Filtration Design, Option 1 (Min. 2' of Soil Media)

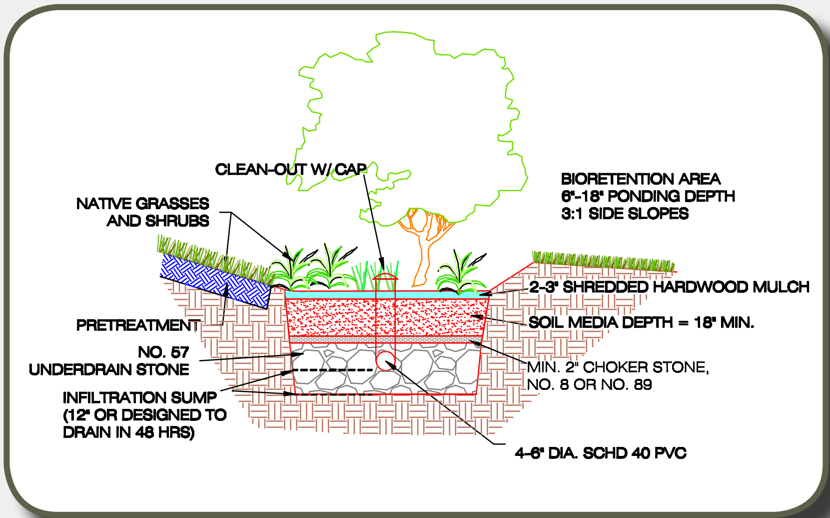

Figure BR-6. Typical Detail for Level 2 Extended Filtration Design, Option 2 (Min. 1.5' of Soil Media With Stone Sump)

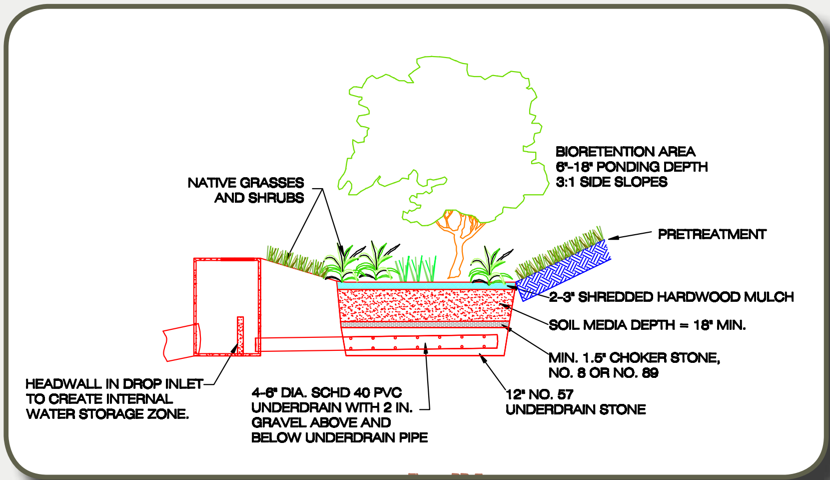

Figure BR-7. Typical Detail for Level 2 Extended Filtration Design, Option 3
(Min. 1.5' of Soil Media With Upturned Elbow Underdrain Design)

BR-3. Feasibility Criteria and Design Considerations

Bioretention can be applied in most soils or topography, since runoff simply percolates through an engineered soil bed and is infiltrated or returned to the stormwater system via an underdrain. Key constraints with Bioretention include the following:

Available Space. Planners and designers can assess the feasibility of using Bioretention facilities based on a simple relationship between the contributing drainage area (CDA) and the corresponding required surface area. The Bioretention surface area will usually be approximately 3% to 6% of the CDA, depending on the imperviousness of the CDA and the desired Bioretention ponding depth.

Site Topography. Bioretention can be used for sites with a variety of topographic conditions, but is best applied when the grade of the area immediately adjacent to the bioretention practice (within approximately 15 to 20 feet) is greater than 1% and less than 5%. For sites with steep grades, Bioretention should be split into multiple cells with adequate conveyance between the cells to take advantage of relatively flat and/or areas in cut sections (rather than fill).

Available Hydraulic Head. Bioretention is fundamentally constrained by the invert elevation of the existing conveyance system to which the practice discharges (i.e., the bottom elevation needed to tie the underdrain from the Bioretention area into the storm drain system). In general, 4 to 5 feet of elevation above this invert is needed to accommodate the required ponding and filter media depths. For infiltration designs, the available head is less important.

Water Table. Bioretention should always be separated from the water table to ensure that groundwater does not intersect the filter bed. Mixing can lead to possible groundwater contamination or failure of the Bioretention facility. A separation distance of 2 feet is required between the bottom of the excavated Bioretention area and the seasonally high ground water table.

Soils and Underdrains. Soil conditions do not typically constrain the use of Bioretention, although they do determine whether an underdrain is needed. Underdrains are needed if the measured permeability of the underlying soils is less than 0.5 inches per hour. When designing Bioretention practices without underdrains and with drainage areas greater than 0.5 acre, designers should verify soil permeability by using the on-site soil investigation methods provided in Appendix B of the Manual.

Use of Bioretention on Fill Section

In areas of significant fill, soil slips can result from infiltrating water, including use of an infiltration sump. It is preferable to use this type of design in cut sections. Geotechnical investigations are required if any design that infiltrates water will be used in a fill section. Impermeable liners and underdrains (without a sump) may be necessary, based on the outcome of the investigation (**see Section BR-4.15**).

Contributing Drainage Area. Bioretention cells work best with smaller CDAs, where it is easier to achieve flow distribution over the filter bed. Typical drainage area size for traditional Bioretention areas can range from 0.1 to 2.5 acres and consist of up to 100% impervious cover. Drainage areas to smaller Bioretention practices (Urban Bioretention, Residential Rain Gardens) typically range from 0.5 acre to 1.0.

Hotspot Land Uses. An impermeable bottom liner and an underdrain system must be employed when a Bioretention area will receive untreated stormwater hotspot runoff (e.g., vehicle maintenance facilities). However, Bioretention can still be used to treat "non-hotspot" parts of the site; for instance, rooftop runoff can go to Bioretention while vehicular maintenance areas would be treated by a more appropriate hotspot practice.

For a list of potential stormwater hotspots, please consult **Chapter 5 of the Manual.**

Floodplains. Bioretention areas should be constructed outside the limits of the 100-year floodplain, unless a waiver is obtained from the local authority.

No Irrigation or Baseflow. The planned Bioretention area should not receive baseflow, irrigation water, chlorinated wash-water or other such non-stormwater flows.

Setbacks. To avoid the risk of seepage, do not allow Bioretention areas to be hydraulically connected to structure foundations. Setbacks to structures vary based on the size of the Bioretention design:

- 0 to 0.5 acre CDA = 10 feet if down-gradient from building; 50 feet if up-gradient.
- 0.5 to 2.5 acre CDA = 25 feet if down-gradient from building; 100 feet if up-gradient.

If an impermeable liner and an underdrain are used, no building setbacks are needed for Urban Bioretention (e.g., stormwater planters) and Residential Rain Garden designs.

At a minimum, Bioretention basins should be located a horizontal distance of 100 feet from any water supply well (50 feet if the Bioretention practice is lined).

Proximity to Utilities. Interference with underground utilities should be avoided whenever possible, particularly water and sewer lines. Approval from the applicable utility company or agency is required if utility lines will run below or through the Bioretention area. Conflicts with water and sewer laterals (e.g., house connections) may be unavoidable, and the construction sequence must be altered, as necessary, to avoid impacts to existing service.

Additionally, designers should ensure that future tree canopy growth in the Bioretention area will not interfere with existing overhead utility lines.

Community Factors. Bioretention can be designed as safe and aesthetically pleasing practices. If the practice will be used in areas with heavy foot traffic, highly visible areas, residential or commercial areas, and/or areas where safety is a concern, the ponding depth should be limited to 6 to 12 inches.

Underground Injection Permits. Bioretention areas are generally not considered to be Class V wells subject to permits under the Underground Injection Control (UIC) Program (U.S. EPA, 2008). However, in certain cases the designer should confer with West Virginia Department of Environmental Protection (WVDEP) about the possible applicability of a UIC permit. These cases would include infiltration designs (or designs that include an infiltration sump) in close proximity to sensitive groundwater areas (e.g., aquifers overlain with thin, porous soils), designs with a subsurface fluid distribution system (e.g., underdrains that do not discharge to the surface or the storm drain system), and/or designs that are deeper than their widest surface dimension.

BR-4. Design Criteria

BR-4.1. Bioretention Sizing for Water Quality & Volume Reduction

A Note on Terminology Describing Volume

There are two types of volumes that the designer should consider when designing a best management practice (BMP) plan:

Target Treatment Volume (Tv) = Volume associated with managing one inch of rainfall based on the size and land cover of the CDA, as determined by the Design Compliance Spreadsheet. Any given BMP may treat the full Tv or only part of it if used in conjunction with other practices as part of a treatment train.

Design Volume (Dv) = The volume designed into a particular practice based on storage within different layers as prescribed in the BMP specification. The Dv can equal the Target Treatment Volume (Tv) if there is only one BMP in the CDA. Where multiple BMPs are used as part of a treatment train, the Dv may only be part of the overall Tv for the drainage area, with the sum of each BMP's Dv equaling or exceeding the Tv.

See Chapter 3 for more information on the runoff reduction design methodology.

For the purposes of this sizing section, the sizing relates to the Dv of the practice being designed.

Bioretention sizing includes four basic steps:

1. **Surface Ponding:** Provide adequate surface ponding to capture enough of the Design Volume and allow it to begin filtering through the soil media;
2. **Soil Media & Underdrain Gravel Storage:** Provide adequate surface area and depth of the soil media and gravel layer. The soil media serves to retain and filter the Design Volume, while the gravel layer protects the underdrain (if provided) or the infiltration capacity of the underlying soils (if available);
3. **Verify Total Design Volume:** Verify that the combination of surface ponding, soil media, and gravel storage is adequate to manage the Design Volume
4. **Other Design Features:** Provide adequate pretreatment, flow geometry, and other design features to ensure the long term performance of the system.

The selection of Level 1 or Level 2 design will determine the target sizing as defined in these basic steps. The designer is encouraged to review the feasibility criteria and design considerations in Section BR-3 in order to optimize the performance of the system with regard to possible site constraints.

Step 1: Surface Ponding:

The required surface ponding volume of Bioretention practices is a function of the surface ponding depth and the anticipated Design Volume. The following surface storage requirements apply:

- For ponding depths of less than 1 foot, surface storage should account for at least 50% of the required total Design Volume within the practice.
- For ponding depths of 1 foot or more (18 inches maximum), surface storage should account for at least 70% of the total Design Volume.

In either case, the ponding volume surface area can be larger if additional storage is desired.

These minimum surface storage requirements are based on the need to capture the one-inch runoff volume from a full range of expected storm intensities. Rainfall distribution in the mid-Atlantic includes both short intense storms, as well as long, steady, low-intensity rain events. During high intensity storm events, the Bioretention practice may fill up faster than the collected stormwater is able to filter through the soil media. In addition, the hydraulic conductivity of the surface layer of mulch and the soil media will vary over the maintenance life-cycle of the practice. Therefore, an adequate ponding volume is necessary to allow the runoff to begin to filter into the soil media before the runoff bypasses or overflows the surface storage.

The local authority may modify or reduce the 50% or 70% surface storage requirement in circumstances where it makes a Bioretention application impractical. In such cases, the following design adaptations are recommended:

- The drainage area is no larger than 0.75 acre.
- Additional plantings/landscaping is added to any additional ponding area.

Step 2: Soil Media and Underdrain Gravel Storage:

The soil media and gravel layer provide the required remaining storage volume within the void spaces to manage the Design Volume. The design of these components therefore includes a surface area and a depth. The depth can vary; however, the selection of a Level 1 or Level 2 design will require that a minimum depth of soil and/or gravel be provided in order to achieve the corresponding volume reduction credit. Refer to **Table BR-1** for Level 1 and Level 2 standards.

The surface area of these components can similarly vary. However, there is a design relationship between the minimum surface area of the soil media and the surface area of the ponding volume as described in Step 1 above. The ponding surface area can be larger than the surface area of the soil media according to the following guidelines:

- If the ponding depth is less than 1 foot, the ponding surface area can exceed the soil media surface area by up to 50%.
- If the ponding depth is 1 foot or more (up to 1.5 feet), the ponding surface area can exceed the soil media surface area by up to 25%.

These guidelines are to ensure that the soil layer provides adequate hydraulic loading capacity for the design ponding volume. **Table BR-4** provides a summary of the surface area criteria and **Figure BR-8** illustrates the additional ponding area in graphical format.

The surface ponding volume determination should take into account surface side slopes and can be computed using **Equation BR-1**:

Equation BR-1. Bioretention Surface Ponding Volume

$$\textit{Surface Ponding Volume} = (SA_{avg\text{-}ponding} \times d_{ponding})$$

Where:

Surface Ponding Volume	=	volume of storage provided above the soil media layer (ft^3)
$SA_{avg\text{-}ponding}$	=	the average ponding surface area of the practice (ft^2)
	=	0.5 x [(surface area at the top of the ponding volume) + (surface area at the bottom of the ponding volume)]
$d_{ponding}$	=	the maximum ponding depth of the practice (ft).

Refer to Sections BR-4.6 (Ponding Depth) and BR-4.7 (Side Slopes) for additional design considerations.

Table BR-4. Maximum Ponding Surface Area to Soil Media Surface Area Ratios[1]

Surface Ponding Volume	**Surface Ponding Depth (ft.)**	**Maximum Ratio of Surface Areas**
At least 50% of Design Volume	< 1	1.5
At least 70% of Design Volume	≥ 1	1.25

[1]Defined as the ratio of the ponding surface area measured at the bottom of the ponding depth to the soil media surface area measured at the top of the soil media.

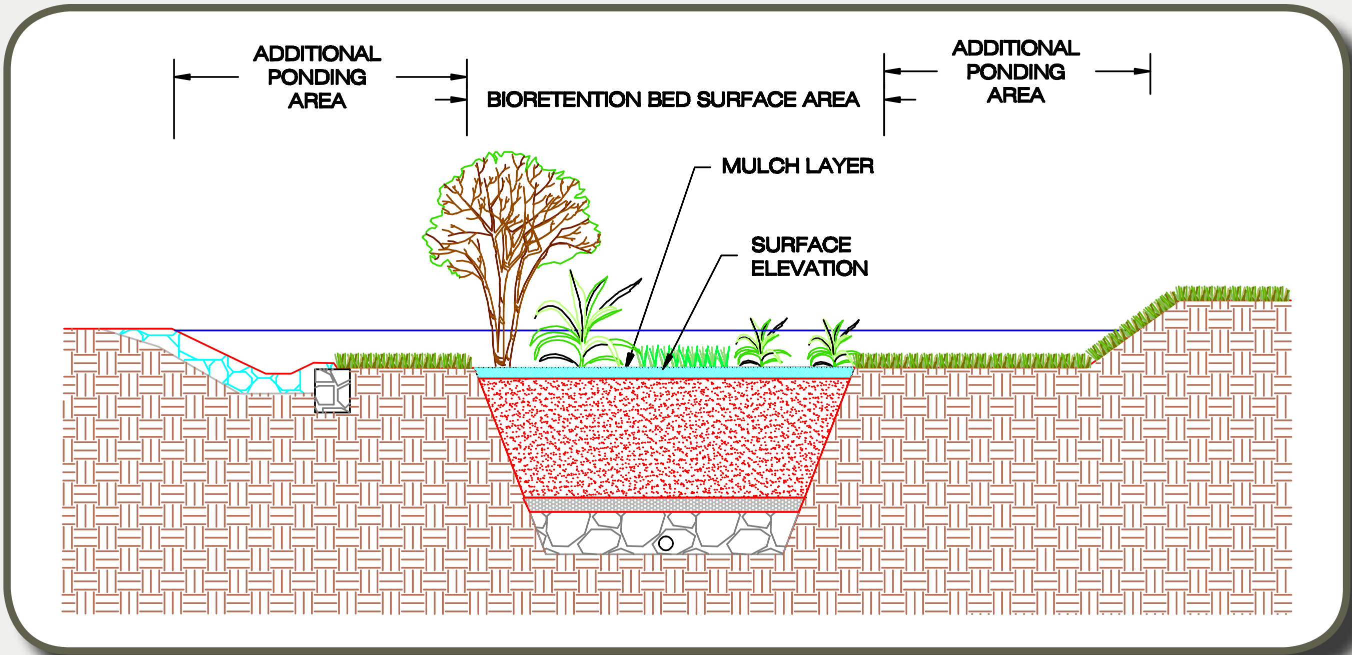

Figure BR-8. Typical section of Bioretention with additional surface ponding area

Step 3: Verify Total Design Volume:

The designer should verify that the combination of surface ponding volume and soil media and gravel storage volume is adequate to manage the Design Volume. The storage volume of the soil media and gravel is within the void spaces, referred to as porosity (η). The accepted porosity values for the storage components are illustrated in Figure BR-9 and listed below:

Surface Ponding	$= \eta_{ponding}$	= 1.0
Soil Media	$= \eta_{media}$	= 0.25
Underdrain Gravel	$= \eta_{gravel}$	= 0.40

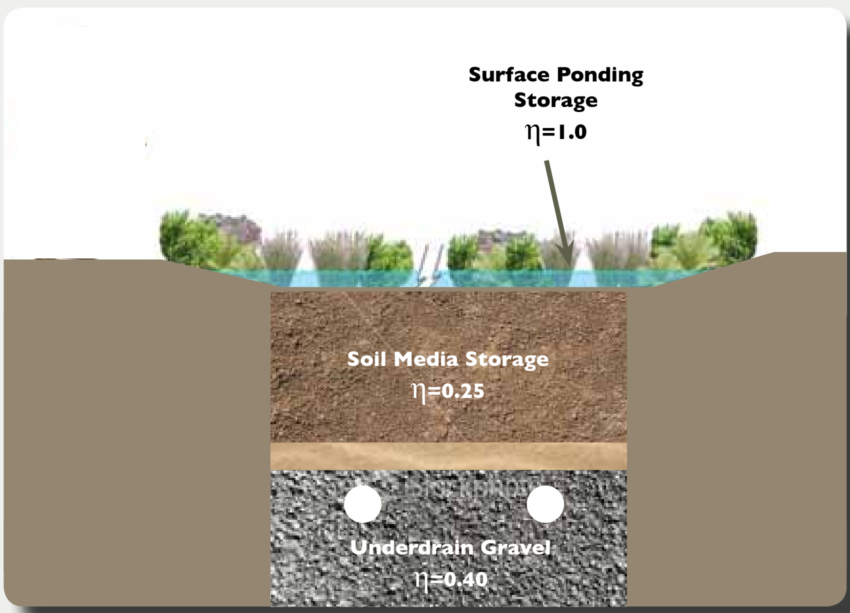

Figure BR-9. Typical Bioretention Section with Porosity (n) Values for Volume Computations

The total Design Volume of the practice can be computed using **Equation 4.2.**

Equation BR-2. Bioretention Design Volume

$$Dv_{practice} = SA_{bottom} \times [(d_{media} \times \eta_{media}) + (d_{gravel} \times \eta_{gravel})] + (SA_{avg-ponding} \times d_{ponding})$$

Where:

$Dv_{practice}$ = total design storage volume of practice (cu. ft.)
SA_{bottom} = bottom surface area of practice (sq. ft.)
d_{media} = depth of the soil filter media (ft)
η_{media} = effective porosity of the soil filter media (typically 0.25)
d_{gravel} = depth of the underdrain and underground storage gravel layer(ft)
η_{gravel} = effective porosity of the gravel layer (typically 0.40)
$SA_{avg-ponding}$ = the average ponding surface area of the practice (ft^2)
$d_{ponding}$ = the maximum ponding depth of the practice (ft).

Note: For a Level 1 design (underdrains and no infiltration sump), the gravel storage must be positioned above the underdrain in order to count as available storage. In either case, different combinations of the depth of ponding, media, and/or gravel can be evaluated for providing the required storage volume.

Equation BR-2 is conservative in that it assumes there are no subsurface side slopes. If a geotechnical evaluation determines that side slopes are required for the excavation or for long term stability, **Equation BR-2** can be modified to include the average surface areas of the various component layers as follows:

Equation 4.3. Bioretention Design Storage Volume with Subsurface Side Slopes

$$Sv_{practice} = [(SA_{avg-media} \times d_{media} \times n_{media}) + (SA_{avg-gravel} \times d_{gravel} \times n_{gravel}) + (SA_{avg-ponding} \times d_{ponding})]$$

Step 4: Other Design Features:

The remainder of Section **BR-4 (Design Criteria)** provides guidelines for other design components of Bioretention (e.g., pretreatment, geometry) to ensure performance and longevity.

BR-4.2. Bioretention Sizing for Larger Storms (Local Detention Criteria)

The Design Volume can be counted toward storage that may be required to comply with local peak flow or detention requirements on small or moderately-sized sites. Designers may be able to create additional storage by expanding the surface ponding footprint (see above) or by incorporating subsurface storage with additional gravel or storage chambers.

It should be noted that all site designs should include provisions for safe conveyance of larger flows either contained within properly sized pipe or channel systems, or as overland flood routing to a receiving waterbody so as to minimize public safety risks and property damage. While some detention storage credit can be realized by oversizing runoff reduction practices such as Bioretention (which may reduce the size or footprint of downstream detention ponds), drainage system design and flood routing should use a conservative approach and be based on the expected peak rate of discharge from the larger storm events without any downsizing credited to runoff reduction.

BR-4.3. Pretreatment

Pre-Treatment is Essential

Pre-treatment of runoff entering Bioretention areas is necessary to trap coarse sediment particles before they reach and prematurely clog the filter bed. Pre-treatment measures must be designed to evenly spread runoff across the entire width of the Bioretention area. Pre-treatment is essential to prolong the life of the practice and ensure long-term performance. At the discretion of the local plan reviewer, full pre-treatment as detailed in this specification may not be necessary for practices with small drainage areas (e.g., less than ¼ acre).

Several pre-treatment measures are feasible, depending on the type of the Bioretention practice and whether it receives sheet flow, shallow concentrated flow or deeper concentrated flows. **Figure BR-10** shows typical pretreatment options for Bioretention. For pre-treatment structures at the edge of pavement (e.g., grass filter strips, gravel diaphragms, flow splitters), it is important that there be a 2 to 4 inch drop from the edge of pavement to the top of the grass or stone in the pre-treatment structure. This is to prevent accumulation of debris and subsequent clogging at the point where runoff is designed to enter the pre-treatment structure (see **Figure BR-11**).

Figure BR-10. Examples of Pre-Treatment Applicable to Bioretention

Grass strips that are perpendicular to incoming sheet flow extend from the edge of pavement (with a slight drop of 2 to 3 inches at the pavement edge) to the bottom of the Bioretention basin at a 5:1 slope or flatter.

A Pre-Treatment Cell is located at piped inlets or curb cuts leading to the Bioretention area. It has a storage volume equivalent to at least 15% of the total storage volume (inclusive). The cell may be formed by a timber check dam (pictured), stone check dam, or an earthen or rock berm. Pretreatment cells do not need underlying engineered soil media, in contrast to the main Bioretention cell (Source: Horsley Witten Group).

A **Grass Swale** can be used to convey flow to the Bioretention cell and provide pre-treatment. See **Specification 4.2.5** for design specifications.

A **Gravel Diaphragm** located at the edge of the pavement should be oriented perpendicular to the flow path to pre-treat lateral runoff, with a 2 to 4 inch drop from the pavement edge to the top of the stone. The stone must be sized according to the expected rate of discharge.
(Source: Beckley Sanitary Board)

The **Gravel or Stone Flow Spreader** is located at curb cuts, piped inlets, downspouts, or other concentrated inflow points. The gravel or stone should extend the entire width of the opening and create a level stone weir at the bottom or treatment elevation of the basin.

An approved **Proprietary Device** with demonstrated capability of reducing sediment and hydrocarbons may be used to provide pre-treatment.

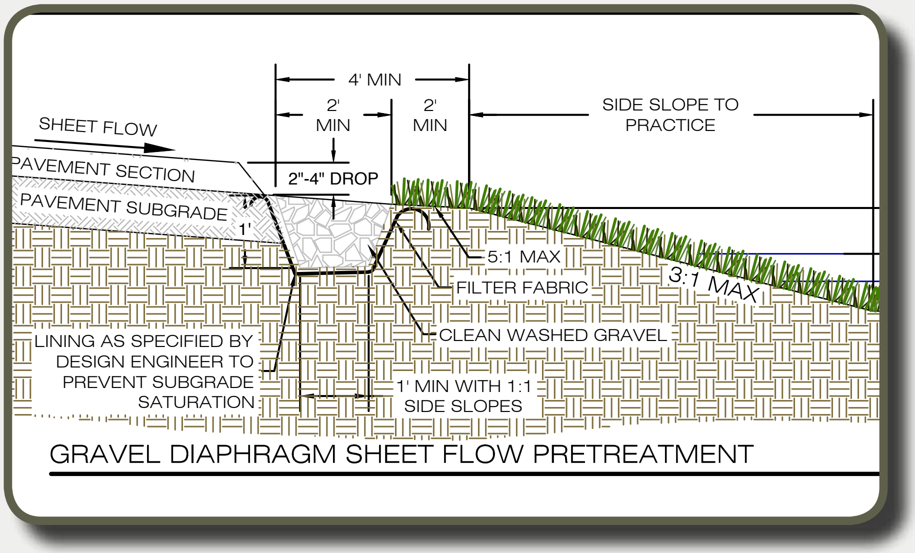

Figure BR-11. Typical Detail for Pre-Treatment at Pavement Edge – A 2 to 4 inch drop from the pavement to the top of stone helps to prevent clogging.

BR-4.4. Conveyance and Overflow

There are two basic design approaches for conveying runoff into, through, and around Bioretention practices (see **Figure BR-12**):

1. **Off-line:** Flow is split or diverted so that only the design storm or design flow enters the Bioretention area. Larger flows by-pass the Bioretention treatment and do not pass over the filter bed or through the facility. Additional flow is able to enter as the ponded water draws down by filtering through the soil media. Off-line designs can be accomplished by establishing a maximum ponding depth (at which point higher flows are diverted) or a flow diversion or flow splitter at or upgradient of the inlet. Off-line designs are usually the preferred option, especially for larger drainage areas (e.g., greater than 0.5 acres). This is particularly true if runoff is delivered by a storm drain pipe or is along the main conveyance system so that flows to do not overwhelm or damage the filter bed and plants.

2. **On-line:** All runoff from the drainage area flows into the practice. Flows that exceed the design capacity exit the practice via an overflow structure or weir. The following criteria apply to overflow structures:
- An overflow shall be provided within the practice to pass storms greater than the design storm storage to a stabilized conveyance or storm sewer system.
- The overflow should be controlled so that velocities are non-erosive at the outlet point (i.e., to prevent downstream erosion).
- Common overflow systems within Bioretention practices consist of an inlet structure, where the top of the structure is placed at the maximum ponding depth of the Bioretention area (6 to 18 inches above the filter bed surface).
- The overflow capture device should be scaled to the application – this may be a landscape grate or yard inlet for small practices or a commercial-type structure for larger installations.

It should be noted that both types of design approaches require attention to safe conveyance of larger flows in adequate conveyances and with adequate freeboard to a receiving waterbody. Drainage design should be based on expected peak discharges assuming that upstream practices may fail and/or provide marginal storage during larger events. These concerns should be addressed in a plan's overall drainage approach.

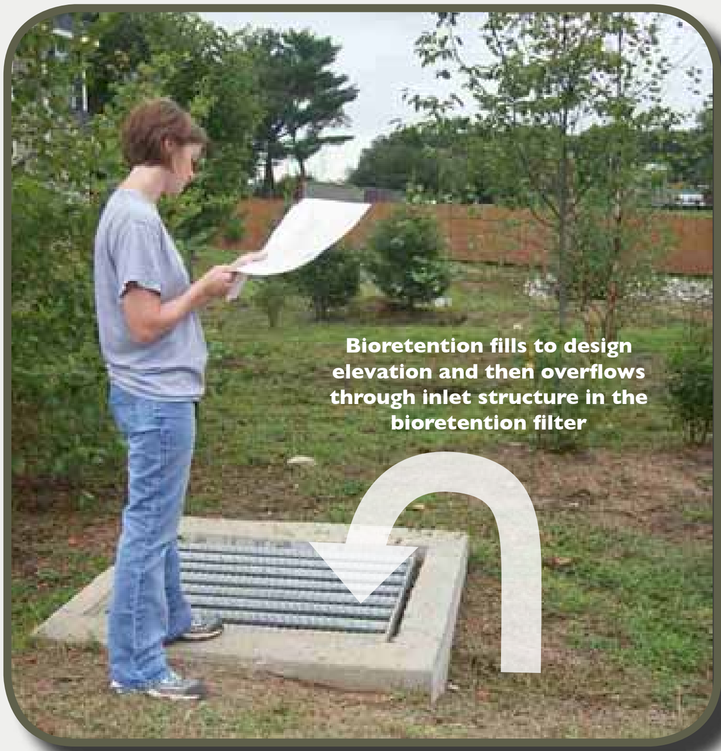

Figure BR-12. Top: Example of an off-line design where only the design volume goes to the Bioretention cell. This can also be accomplished with diversions or flow splitters upgradient from the cell. Bottom: Example of an "on-line" design where all the flow enters the Bioretention, and flows that exceed the design elevation overflow into a structure within the practice.

BR-4.5. Design Geometry

Bioretention basins must be designed with an internal flow path geometry such that the treatment mechanisms provided by the Bioretention are not bypassed or short-circuited. In order for these Bioretention areas to have an acceptable internal geometry, the "travel time" from each inlet to the outlet should be maximized by locating the inlets and outlets as far apart as possible. In addition, incoming flow must be distributed as evenly as possible across the entire filter surface area.

BR-4.6. Ponding Depth

The recommended surface ponding depth is 6 to 12 inches. Ponding depths can be increased to a maximum of 18" for management of larger storms.

Limit Applications of 18" Ponding

If an 18 inch ponding depth is used, the design must carefully consider issues such as safety, aesthetics, the viability and survival of plants, and erosion and scour of side slopes. The depth of ponding in the Bioretention area should never exceed 18". Shallower ponding depths (6 to 12 inches) are strongly recommended for all Bioretention areas in high visibility, commercial, residential, and other areas with foot traffic. The 18" ponding depth may be appropriate for larger-scale commercial, industrial, or institutional settings.

BR-4.7. Side Slopes

Side slopes should be 3:1 or flatter. In highly urbanized or space constrained areas, a drop curb design or a precast structure can be used to create stable, vertical side wall. For safety purposes, these drop curb designs should not exceed a vertical drop of more than 12 inches.

BR-4.8. Soil Media

The soil media is perhaps the most important element of a bioretention facility in terms of long-term performance. The following are key factors to consider in determining an acceptable soil media mixture.

- **General Soil Media Composition.** The recommended bioretention soil mixture is generally classified as a loamy sand on the USDA Texture Triangle, with the following composition (see also **Table BR-5**):
  - o 70% to 88% sand;
  - o 8% to 26% topsoil; and
  - o 3% to 5% organic matter (aged compost).

The goal of the mixture as described above is to create a soil media that maintains long-term permeability while also providing enough nutrients to support plant growth. The initial permeability of the mixture will exceed the desired long-term permeability of greater than 1 to 2 in./hr. The limited amount of topsoil and organic matter is considered adequate to help support initial plant growth, and it is anticipated that the gradual increase of organic material through natural processes will continue to support growth while decreasing gradually the permeability. Finally, the root structure of maturing plants and the biological activity of a self-sustaining organic content will maintain sufficient long term permeability as well as support plant growth without the need for fertilizer inputs.

Of equal importance is the source and composition of the materials. In addition to meeting the criteria noted in **Table BR-5**, the following criteria should govern the selection of materials for soil media mixes:

- Media components from land uses with specific history and/or prior land use related to biosolids or organic waste disposal, brownfields or superfund sites are prohibited.
- Sand should be a silica-based open graded coarse sand. Limestone parent material is prohibited. Recycled, pulverized glass may be used as a local option, provided the local program authority undertakes testing to verify that the product complies with the standards for sand in this specification (e.g., particle size distribution). Art glass or any glass sources that contain heavy metals should be prohibited from being included in the source material.
- Topsoil composition should consist of material classified as Loamy sand or Sandy loam as defined by the USDA textural classification triangle.
- Organic matter should be well aged and free of viable weed seeds, debris, and stable with regard to oxygen consumption and carbon dioxide generation. (Refer to **Appendix D** of this manual).

It may be advisable to start with an open-graded coarse sand material and proportionately mix in topsoil that will likely contain anywhere from 30% to 50% soil fines (sandy loam, loamy sand) to achieve the desired ratio of sand and fines. The exact composition of organic matter and topsoil material will vary, making particle size distribution and the recipe for the total soil media mixture difficult to define in advance of evaluating the available material. Therefore, it is highly recommended that filter media be obtained from a qualified vendor that can verify conformance with the media composition and standards in this specification. If media is mixed from available on-site material, a qualified individual should test the mixture to ensure conformity to this specification. **Table BR-5** outlines soil media testing standards that qualified vendors (or soil media mixed and tested on-site) should adhere to.

The particle size distribution of the sand and top soil material is extremely important for long term performance of the bioretention system. There have been issues of premature clogging and/or failure of the media when the sand/topsoil combination contains too high a fraction of fines. Given that the media mix is primarily sand, it is worth paying special attention to the sand specification and ensuring that the particle size distribution represents coarse sand. This is also important for locally-approved sand derived from recycled or pulverized glass.

The specification for coarse sand provided in **Table BR-5** allows less material passing the smaller sieves, and also provides for an Effective Particle Size and Uniformity Coefficient that encourages coarser sand.

Table BR-5. Soil Media Criteria and Testing for Bioretention

<table>
<tr><th>Soil Media Criterion</th><th>Description</th><th colspan="3">Standard(s)</th></tr>
<tr><td>General Composition</td><td>Soil media must have the proper proportions sand, fines, and organic matter to promote plant growth, drain at the proper rate, and filter pollutants</td><td colspan="3">70% to 88% sand;
8% to 26% top soil; and
3% to 5% organic matter (aged compost)</td></tr>
<tr><td rowspan="2">Sand</td><td rowspan="2">Silica based coarse aggregate[1]

Locally-approved pulverized glass may be substituted if the local authority undertakes testing to verify compliance with the specification and also lack of heavy metals</td><td>Sieve
3/8 in
No. 4
No. 8
No. 16
No. 30
No. 50
No. 100</td><td>Size
9.50 mm
4.75 mm 2.36 mm 1.18 mm
0.6 mm
0.3 mm
0.15 mm</td><td>% Passing
100
95 to 100
80 to 100
45 to 85
15 to 60
3 to 15
0 to 4</td></tr>
<tr><td colspan="3">Effective Particle size (D10) > 0.3mm
Uniformity Coefficient (D60/D10) < 4.0</td></tr>
<tr><td>Top Soil</td><td>Loamy sand or Sandy Loam</td><td colspan="3">USDA Textural Triangle</td></tr>
<tr><td>Organic Matter</td><td>Well aged, clean compost</td><td colspan="3">Appendix D</td></tr>
<tr><td>P-Index or Phosphorus (P) content</td><td>Soil media with high P levels will export P through the media and potentially to downstream conveyances or receiving waters</td><td colspan="3">P content = 7 to 23 mg/kg</td></tr>
</table>

Soil Media Criterion	Description	Standard(s)
Cation Exchange Capacity (CEC)	The CEC is determined by the amount of humus or organic matter. Higher CEC will promote pollutant removal	CEC > 10 milliequivalents per 100 grams
Infiltration Rate	This refers to the infiltration rate of the soil media, and not the underlying soil A minimum rate is required to allow the soil media to properly drain	Minimum Infiltration Rate = 1 – 2 inches/hour (most soil media will have much higher rates)
Soil Media Depth	The depth of soil media for various applications	Soil media depths for Level 1 and Level 2 design are specified in Table BR-1. If trees are included in the bioretention planting plan, tree planting holes in the filter bed must be at least 4 feet deep to provide enough soil volume for the root structure of mature trees. In addition, higher proportions of topsoil (30%) and aged compost (20%) should be added to these planting holes compared to the rest of the soil media. Turf, perennials or shrubs should be used instead of trees to landscape shallower filter beds.

[1] *Many specifications for sand refer to ASTM C-33. The ASTM C-33 specification allows a particle size distribution that contains a large fraction of fines (silt and clay sized particles - < 0.05 mm). The smaller fines fill the voids between the larger sand sized particles, resulting in smaller and more convoluted pore spaces. While this condition provides a high degree of treatment, it also encourages clogging of the remaining void spaces with suspended solids and biological growth, resulting in a greater chance of a restrictive biomat forming. By limiting the fine particles allowed in the sand component, the combined media recipe of sand and the fines associated with the soil and organic material will be less prone to clogging, while also providing an adequate level of filtration and retention.*

BR-4.9. Surface Cover

The surface cover for Bioretention is variable and depends on the landscape context (e.g., highly-visible site versus less visible; site that will have routine mowing versus managed landscapes). The choice of surface cover also will influence the intensity of long-term maintenance activities (see Section BR-8). In general, the surface cover options are listed below.

- **Mulch**. A 2- to 3-inch layer of mulch on the surface of the filter bed enhances plant survival, suppresses weed growth, and pre-treats runoff before it reaches the filter media. Shredded hardwood bark mulch, aged for at least 6 months, makes a very good surface cover, as it retains a significant amount of pollutants and typically will not float away.

- **Alternative to Mulch Cover.** In some situations, designers may consider alternative surface covers such as turf, native groundcover, erosion control matting (coir or jute matting), river stone, or pea gravel. The decision regarding the type of surface cover to use should be based on function, cost and maintenance. Stone or gravel are not recommended in parking lot applications, since they increase soil temperature and have low water holding capacity.

- **Media for Turf Cover.** One adaptation suggested for use with turf cover is to design the filter media primarily as a sand filter with organic content only at the top. Leaf compost tilled into the top layers will provide organic content for the vegetative cover. If grass is the only vegetation, the ratio of organic matter in the filter media composition may be reduced.

BR-4.10. Underdrains

Many Bioretention designs will require an underdrain. Table BR-6 provides general guidance for when to use an underdrain and the soil testing requirements for certain conditions.

Table BR-6. Guidance for Using Underdrains

	A/B Soils	C/D Soils
Drainage Area ≤ 0.5 acre	No underdrain needed	Use underdrain; no calculation needed for 48-hour dewatering. Use 12 inches or greater of underdrain stone
Drainage Area > 0.5 acre	Conduct soil infiltration test as per Appendix B of this Manual. No underdrain needed if field-tested rate > 0.5 inches per hour	Use underdrain. If using infiltration sump (see below), design to dewater design volume within 48 hours; for a 12 inch sump, the in-situ soils shall have a field verified infiltration rate ≥ 0.25 inches/hour (Note: HSG C soils can range from 0.1 to 3 in./hr.)

The underdrain should be a 4- or 6-inch perforated schedule 40 PVC pipe (or equivalent corrugated HDPE for small Bioretention practices) with 3/8-inch perforations at 6 inches on center. The underdrain should be encased in a layer of clean, washed ASTM D448 No. 57 stone. The underdrain should be sized so that the Bioretention practice fully drains within 48 hours.

Each underdrain should be located no more than 20 feet from the next pipe.

All Bioretention practices should include at least one observation well and/or cleanout pipe. The observation wells should be tied into any Ts or Ys in the underdrain system, and should extend upwards to be flush with the surface, with a vented cap.

BR-4.11. Infiltration Sump or Upturned Elbow (Level 2 Extended Filtration Design with Less Than 24 inches of Soil Media Depth)

An elevated underdrain configuration should be used to promote greater runoff reduction for Bioretention that has less than the minimum soil media depth and/or to boost runoff reduction performance for other designs, such as adding storage to meet local detention requirements (see **Figure BR-6**). In cases where limited head is a site constraint and the bioretention practice must be designed to be relatively shallow (e.g., depth to bedrock, relatively flat sites, or other factors), an upturned elbow underdrain design can be used to achieve the Level 2 design and enhanced runoff reduction (**Figure BR-7**).

The infiltration sump or upturned elbow should be installed to create a storage layer below the underdrain or upturned elbow invert. The bottom of the infiltration sump must be at least 2 feet above the seasonally high water table. The infiltration sump should be sized so that the Design Volume drains within 48 hours (see **Appendix B** of this Manual). This will depend on the Design Volume, the depth of the infiltration sump, and the presumed infiltration rate of the underlying soil. In general, a 12 inch infiltration sump can be used where the underlying infiltration rate is 0.25 inches per hour or greater. This should be field verified. Also, procedures to protect the infiltrative capacity of the soils during construction, and enhancing the infiltrative capacity before backfilling the soil media (such as roto-tilling or scarifying the surface) should be specified on the construction plans.

The inclusion of an infiltration sump is not permitted for designs with an impermeable liner (e.g., for karst or hotspot applications). In fill soil locations, geotechnical investigations are required to determine if the use of an infiltration sump is permissible and will not lead to the possibility of soil slips.

BR-4.12. Choking Layer

The choking layer is installed on top of the underdrain layer and below the soil media layer. This consists of a layer of choker stone (typically ASTM D448 No.8 or No.89 washed gravel). The depth of the choker layer should be 1 inch of choker stone for every 1 foot of soil media. For instance, 3 feet of soil media depth would have 3 inches of choker stone.

In lieu of the choking layer, designers have the option of using a needle-punched, non-woven geotextile fabric with a flow rate of > 110 gal./min./sq. ft. placed between the underdrain and the soil media layers. This may be a desirable option if available head or depth to water table or bedrock are site constraints. However, this option should only be used when the choking layer cannot fit into the practice.

BR-4.13. Underground Storage Layer (optional)

For Bioretention systems with an underdrain, an underground storage layer consisting of chambers, perforated pipe, stone, or other acceptable material can be incorporated below the filter media layer to increase storage for larger storm events, control of which may be required by local detention or drainage regulations. The depth and volume of the storage layer will depend on the target storage volumes needed for local storage or detention criteria.

BR-4.14. Filter Fabric (optional)

Woven, monofilament filter fabric may be placed on the side slopes and/or in narrow strips (e.g., 2 feet wide) on top of the underdrain layer directly above underdrain pipes only. Filter fabric should not be used if trees will be planted in the filter bed surface. While there are many options for filter fabric, the design objective is to maintain hydraulic capacity while restricting the movement of sediment into the underdrain layer.

Do Not Use Filter Fabric over the Entire Underdrain Layer

In no case shall filter fabric be used to cover the entire underdrain layer as a substitute for the choker layer. The use of filter fabric between the soil media and underdrain stone has been a source of clogging with past installations.

BR-4.15. Impermeable Liner

This material should be used only for appropriate hotspot or karst designs, small-scale practices that are located near building foundations, or in appropriate fill applications where deemed necessary by a geotechnical investigation. Designers should use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd. non-woven geotextile.

BR-4.16. Signage

Bioretention units in highly visible areas (e.g., schools, parks, urban settings, government buildings) should be stenciled or otherwise permanently marked to designate it as a stormwater management facility.The stencil or plaque should indicate (1) its water quality purpose, (2) that it may pond briefly after a storm, and (3) that it is not to be disturbed except for required maintenance.

BR-4.17. Bioretention Landscaping Criteria

Landscaping is critical to the function and performance of Bioretention areas. It is recommended that the planting plan be prepared by a qualified landscape architect or horticulturalist who has the expertise to design a plan tailored to site-specific conditions, including landscape context, microclimates, water velocity, planting zones, potential extended ponding time, and maintenance schedule.

The Bioretention landscaping plan should include the following elements:

- Clear delineation of planting area(s), mulched areas, accent stones, river rock beds, and other landscape elements.
- Plant list with Latin and common names, size of plant material [quart containers, #1 (1 gallon container), #2 (2 gallon), 2.5" caliper tree, etc.], quantities, and any specifics desired, such as multi-stem or single stem.
- List and quantities for other materials (e.g., rock, erosion control matting).
- Note whether plant substitutions are permitted, and who can authorize substitutions.
- Construction notes about handling and watering of plants and other materials during construction and construction sequence for landscaping elements.

- Maintenance information, such as:
  - Instructions for initial watering (e.g., first growing season after installation)
  - Punch list items (e.g., erosion, damaged plants) and an identified responsible party for adjustments or repairs after the first three significant rain events.
  - Care and replacement of plant materials for a specified timeframe (e.g., 1 year after installation). It is recommended that construction contracts include a care and replacement warranty to ensure that vegetation is properly established and survives through at least the first growing season following construction.
    - Maintenance tasks and frequencies (see **Section BR-8**).
    - The intended plant community in future years. This will help the party responsible for maintenance to know how to cut, prune, replace, supplement, and otherwise maintain the landscaping to achieve the desired plant community and aesthetics. Photos, photo simulations, and/or other graphics showing the desired plant community at years 1, 3, 5, 10 and beyond are also helpful for long-term maintenance.

Native plant species are preferred over non-native species, to include "native selections" and cultivars. Some ornamental species may be used if they are proven to be "sustainable" and are not aggressive or invasive. Some popular native species which work well in Bioretention areas and that are commercially available can be found in **Appendix F.** Internet links to more detailed Bioretention plant lists developed in the Chesapeake Bay and the Mississippi River Basin regions are provided below:

- **West Virginia Division of Natural Resources**
  http://www.wvdnr.gov/
- **Wildlife Diversity Program and Natural Heritage Program (WVDNR)**
  http://www.wvdnr.gov/wildlife/wdpintro.shtm
- **West Virginia Native Plant Society**
  http://www.wvnps.org/index.html
- **West Virginia Nursery and Landscape Association**
  http://www.wvnla.org/
- **Native Plant Database - Lady Bird Johnson Wildflower Center**
  http://www.wildflower.org/plants/
- **List of Native Plants by each State (USDA):**
  http://plants.usda.gov/checklist.html
- **Invasive species list**
  http://invasipedia.org/

Planting choices for Bioretention areas (both urban and non-urban) should be selected based on the level of landscape maintenance which will be devoted to the Bioretention. Plant selection differs if the area will be frequently mowed, pruned, and weeded, in contrast to a site which will receive minimum annual maintenance. In areas where less maintenance will be provided, consider the "meadow" or "wildflower" landscaping model. In certain cases, site owners or managers may wish to have managed turf as the ground cover that can be mowed along with other turf areas on the site. While this is allowable, it is not the recommended planting type for bioretention. If used, turf cover should be integrated with herbaceous, shrub, and/or tree zones.

The Objective of the Planting Plan is to cover the Surface of the Filter Bed

The primary objective of the planting plan is to cover the surface area as quickly as possible so that the plants establish their roots in order to promote the beneficial biological activity in the soil media. Herbaceous or ground covers plantings are more beneficial than more trees and shrubs because they establish and spread quickly throughout the filter bed.

Additional guidance for Bioretention landscaping is provided below:

- Woody vegetation should not be located at points of inflow.
- "Wet footed" species (OBL or FACW) should be planted near the center, whereas upland species (FACU and UPL) do better planted near the edge.
- Shrubs and herbaceous vegetation should generally be planted in clusters and at higher densities (i.e., shrubs at approximately 6 to 10 feet on-center and herbaceous plantings at approximately 1 to 1.5 feet on-center (depending on the species).
- Trees should not be planted directly above underdrains, but should be located closer to the perimeter.
- If trees are part of the planting plan, a tree density of approximately one tree per 250 square feet, or 15 feet on-center, is recommended.
- Designers should note that planting holes for trees must be at least 4 feet deep to provide enough soil volume for the root structure of mature trees. This applies even if the remaining soil media layer is shallower than 4 feet.
- If trees are used, plant shade-tolerant ground covers within the drip line (depending on species).
- If the Bioretention area is to be used for snow storage, or will potentially receive runoff from snowmelt, the designer may want to consider salt-tolerant, herbaceous perennials.

4.2.3 Bioretention

BR-5. Materials Specifications

Recommended material specifications for Bioretention areas are shown in **Table BR-7**.

Table BR-7. Bioretention Material Specifications

Material	Specification	Notes
Filter Media	• 70%-88% sand • 8%-26% top soil • 3%-5% organic matter in the form of leaf compost • Supplied by qualified vendor • Refer to **Table BR-5** for specific media material composition	Minimum depth of 24 in.; 36 in. recommended; (18 in. if an infiltration sump is used) The volume of filter media used should be based on 110% of the plan volume, to account for settling or compaction.
Filter Media Testing	Between 7 and 21 mg./kg. of P in the soil media. CECs greater than 10	Qualified vendors should test media in batches.
Mulch Layer	Use aged, shredded hardwood bark mulch	Lay a 2 to 3 in. layer on the surface of the filter bed.
Alternative Surface Cover	Use river stone or pea gravel, coir and jute matting, or turf cover.	Lay a 2 to 3 in. layer to suppress weed growth.
Top Soil For Turf Cover	Loamy sand or sandy loam texture, with less than 5% clay content, pH corrected to between 6 and 7, and an organic matter content of at least 2%.	3 inches tilled into surface layer.
Filter Fabric (optional)	Woven monofilament fabric or non-woven geotextile as per AASHTO M-288 (do not use silt fence)	Apply only to the side slopes and, optionally, in a 2 ft. wide strip directly above the underdrain pipes.
Choking Layer	Layer of choker stone (typically No.8 or No.89 washed gravel), which is laid over the underdrain stone at a depth of 1 in. of choker stone for every 1 ft. of overlying soil media. An alternative is needle-punched, non-woven geotextile with the flow rate of > 110 gal./min./sq. ft. (ONLY if stone choking layer cannot fit into the practice).	

Material	Specification	Notes
Underdrain Stone	1-in. diameter stone should be double-washed and clean and free of all fines (e.g., ASTM D448 No. 57 stone).	12 in. depth
Infiltration Sump (As Needed)	1-in. diameter stone should be double-washed and clean and free of all fines (e.g., ASTM D448 No. 57 stone).	Designed to drain the sump design volume (gravel layer below underdrain or with an upturned elbow) within 48 hours; can use standard 12 in. depth below the underdrain invert if soil at the infiltration sump elevation has a verified infiltration rate ≥ 0.25 in./hr.
Storage Layer (optional)	To increase storage for larger storm events, chambers, perforated pipe, stone, or other acceptable material can be incorporated below the filter media layer	
Impermeable Liner (optional)	Use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd. non-woven geotextile. Note: This is used only for stormwater hotspots, Karst, and small practices near building foundations, or in fill soils as determined by a geotechnical investigation.	
Underdrains, Cleanouts, and Observation Wells	Use 4- or 6-in. rigid schedule 40 PVC pipe (or equivalent corrugated HDPE for small Bioretention practices), with 3/8-in. perforations at 6 in. on center; each underdrain should be located no more than 20 feet from the next pipe.	Lay the perforated pipe under the length of the Bioretention cell, and install non-perforated pipe as needed to connect with the storm drain system or to daylight in a stabilized conveyance. Install Ts and Ys as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface with vented caps at the Ts and Ys.
Plant Materials	See Section BR-4.17	Establish plant materials as specified in the landscaping plan and the recommended plant list.

BR-6. Design Adaptations

BR-6.1. Karst Terrain

Karst regions are found in much of the Ridge and Valley and Panhandle. Karst complicates both land development and stormwater design. While Bioretention areas produce shallower ponding than conventional stormwater practices (e.g., ponds and wetlands), infiltration designs (without an underdrain) are not recommended in any area with a moderate or high risk of sinkhole formation (Hyland, 2005). On the other hand, Level 1 designs (with an underdrain but NO infiltration sump) that meet separation distance requirements (3 feet) and possess an impermeable bottom liner should work well. In general, small-scale Bioretention and Bioretention basins with contributing drainage areas not exceeding one-half acre are preferred (compared to Bioretention with larger drainage areas), in order to prevent possible sinkhole formation. However, it may be advisable to increase standard setbacks to buildings.

BR-6.2. Steep Slopes

Bioretention can be used on sites with steep slopes, provided the following design issues are considered:

- If the site has steep slopes, the site grading should provide for a relatively flat area immediately surrounding the Bioretention practice. The recommendation is for slopes within 15 to 20 feet of the practice to be at a slope of 5% or less.
- Bioretention can be split into multiple cells to take advantage of relatively level areas on the site. Adequate conveyance should be provided between the cells.
- For designs that require a longitudinal slope, use the Water Quality Swale design (**Supplement 4.2.3.A**). Use check dams to flatten the longitudinal slope between the cells, with adequate conveyance and armoring (river stone or appropriate lining) between sections.
- For designs with moderate to steep slopes surrounding the practice, additional engineering design should be applied at the inlets to pretreatment and the practice itself, ensuring that energy dissipaters and drops are engineered to create non-erosive flow conditions. Off-line designs (**Section BR-4.4**) are strongly encouraged.
- For practices near or adjacent to steep slopes, a geotechnical review may be needed to ensure that there will not be a slip or slope instability issue. This would be particularly relevant to practices that utilize an infiltration design or have an infiltration sump.

BR-6.3. Cold Climate and Winter Performance

Many different kinds of salting and sanding materials are applied in West Virginia during winter conditions. These can clog Bioretention areas if the proper design approach is not used, particularly for practices that treat road and highway runoff. In these cases, pre-treatment cells or separate upgradient sediment storage areas should be employed to try to keep as many of these materials as possible off of the filter bed.

Bioretention areas can be used for snow storage as long as an overflow is provided and they are planted with salt-tolerant, non-woody plant species. Tree and shrub locations should not conflict with plowing and piling of snow into storage areas.

While several studies have shown that Bioretention facilities operate effectively in winter conditions, it is a good idea to extend the filter bed and underdrain pipe below the frost line and/or oversize the underdrain by one pipe size to reduce the freezing potential.

BR-6.4. Stormwater Retrofitting

Bioretention is one of the most versatile practices for retrofitting. Some of the chief considerations for retrofitting are space available to accommodate the practice and head available to tie underdrains into an existing drainage structure or to daylight. Many retrofit practices cannot meet the full sizing requirements outlined in **Section BR-4.1**, so it is important to define retrofit objectives and the desired Design Volume necessary to meet TMDL or watershed restoration goals.

For more information on retrofitting, see the Center for Watershed Protection's manual, Urban Stormwater Retrofit Practices (Schueler et al., 2007).

4.2.3 Bioretention

BR-7. Construction & Installation

BR-7.1. Erosion and Sediment Controls

Bioretention areas should be fully protected by appropriate and approved erosion and sediment control measures (e.g., silt fence, super silt fence, diversion dikes, and/or other approved measures to keep construction site runoff away from intended Bioretention areas (see WVDEP, 2006). Ideally, Bioretention should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment.

At the discretion of the plan approving authority, large Bioretention applications may be used as sediment traps or basins during construction. However, these must be accompanied by notes and graphic details on the erosion and sediment control plan specifying that (1) the maximum excavation depth of the trap or basin at the construction stage must be at least 1 foot higher than the post-construction (final) invert (bottom of the facility), and (2) the facility must contain an underdrain. The plan approving authority may authorize alternative means to ensure that the co-location of erosion control measures and permanent bioretention meets the design objectives of both erosion control and the ultimate bioretention practice. Some of the main objectives for bioretention are that the soil interface at the bioretention invert not be clogged with construction sediments, and that the geometry, slopes, and grading of the final bioretention practice adhere to the specification and good design practice.

The plan must also show the proper procedures for converting the temporary sediment control practice to a permanent Bioretention facility, including dewatering, cleanout and stabilization. Of course, in cases where the practices are co-located, the practice location would not be outside of the limits of disturbance.

Drainage Areas Should be Stabilized Before Installation of Underdrains & Soil Media

The #1 source of failure for Bioretention is installation too early during the construction process and/or lack of erosion control measures during installation. Construction sediment will readily clog underdrain stone and soil media. Drainage areas to Bioretention areas should be stabilized with vegetation prior to installation of these materials.

BR-7.2. Bioretention Installation

The following is a typical construction sequence to properly install a Bioretention basin. The construction sequence for Residential Rain Gardens (see Supplement 4.2.3.C) is more simplified. These steps may be modified to reflect different Bioretention applications or expected site conditions:

Step 1. Construction of the Bioretention area may only begin after the entire CDA has been stabilized with vegetation. It may be necessary to block certain curb or other inlets while the Bioretention area is being constructed. The proposed site should be checked for existing utilities prior to any excavation.

Step 2. The designer and the installer should have a preconstruction meeting, checking the boundaries of the CDA and the actual inlet elevations to ensure they conform to original design. Since other contractors may be responsible for constructing portions of the site, it is quite common to find subtle differences in site grading, drainage and paving elevations that can produce hydraulically important differences for the proposed Bioretention area. The designer should clearly communicate, in writing, any project changes determined during the preconstruction meeting to the installer and the plan review/inspection authority.

Step 3. Temporary approved erosion and sediment controls are needed during construction of the Bioretention area to divert stormwater away from the Bioretention area until it is completed. Special protection measures such as erosion control fabrics may be needed to protect vulnerable side slopes from erosion during the construction process. In cases where the Bioretention is co-located with erosion and sediment control practices (e.g., sediment traps), the conditions noted in Section BR-7.1 must be followed.

Step 4. Any pre-treatment cells should be excavated first and then sealed to trap sediments.

Step 5. Excavators or backhoes should work from the sides to excavate the Bioretention area to its appropriate design depth and dimensions. Excavating equipment should have scoops with adequate reach so they do not have to sit inside the footprint of the Bioretention area. Contractors should use a cell construction approach in larger Bioretention basins, whereby the basin is split into 500 to 1,000 sq. ft. temporary cells with a 10-15 foot earth bridge in between, so that cells can be excavated from the side.

Step 6. It may be necessary to rip the bottom soils to a depth of 6 to 12 inches to promote greater infiltration.

Step 7. If using a filter fabric, place the fabric on the sides of the Bioretention area with a 6-inch overlap on the sides. If an underdrain stone storage layer will be used, place the appropriate depth of No.57 stone on the bottom, install the perforated underdrain pipe, pack No.57 stone to 3 inches above the underdrain pipe. On top of the No.57 stone, add 2 inches of choker stone (No.8 or No.89 stone) and then 2 to 4 inches of construction sand as a filter between the underdrain and the soil media layer. If no stone storage layer is used, start with 6 inches of No.57 stone on the bottom, and proceed with the layering as described above.

Step 8. Deliver the soil media from an approved vendor, and store it on an adjacent impervious area or plastic sheeting. Apply the media in 12-inch lifts until the desired top elevation of the Bioretention area is achieved. Wait a few days to check for settlement, and add additional media, as needed, to achieve the design elevation.

Step 9. Prepare planting holes for any trees and shrubs, install the vegetation, and water accordingly. Install any temporary irrigation.

Step 10. Place the surface cover in both cells (mulch, river stone or turf), depending on the design. If coir or jute matting will be used in lieu of mulch, the matting will need to be installed prior to planting (Step 9), and holes or slits will have to be cut in the matting to install the plants.

Step 11. Install the plant materials as shown in the landscaping plan, and water them during weeks of no rain for the first two months.

Step 12. If curb cuts or inlets are blocked during Bioretention installation, unblock these after the drainage area and side slopes have good vegetative cover. It is recommended that unblocking curb cuts and inlets take place after two to three storm events if the drainage area includes newly installed asphalt, since new asphalt tends to produce a lot of fines and grit during the first several storms.

Step 13. Conduct the final construction inspection (see below), then log the GPS coordinates for each Bioretention facility and submit them for entry into the local maintenance tracking database.

An example construction phase inspection checklist is available in Appendix A of the Manual.

4.2.3 Bioretention

BR-8. Maintenance Criteria

Consider Maintenance during the Design Process

One of the critical maintenance issues is to understand how design choices influence the long-term maintenance obligations of a practice. The context of the site and maintenance capabilities of the owner should be considered during the design process. **Table BR-8** notes several design issues that can result in lower or higher levels of maintenance.

Table BR-8. Design Decisions That Influence Long-Term Maintenance Activities

Design Feature	Lower Maintenance	Higher Maintenance
Surface Cover (Section BR-4.9)	Grass cover that can be mowed; recommend interspersing with trees; Meadow or wildflower cover with native grasses	Mulch cover with perennials and shrubs that must be weeded routinely and have the mulch replaced
Ponding Depth (Section BR-4.6)	Shallow ponding at 6 in. to 12 in. creates less stress on plants and side slopes	> 12 in. may lead to erosion of slide slopes and stress on plants
Pre-Treatment (Section BR-4.3)	Pre-treatment cell or grass filter strips with a 2 in. to 4 in. drop from the pavement surface	Curb cuts that accumulate grit and debris that must be removed periodically in order to prevent clogging of inlet
Conveyance (Section BR-4.4)	Off-line designs where only the design volume enters the practice; higher flows are diverted to the storm sewer system and/or adequate conveyance.	On-line designs where all flows enter the practice; higher flows exit through an overflow that is internal to the practice. High flows may create periodic damage to structural elements as well as increased routine maintenance, such as replacing mulch or damaged vegetation.

Maintenance agreements must be executed between the owner and the local authority. The agreements will specify the property owner's primary maintenance responsibilities and authorize local agency staff to access the property for inspection or corrective action in the event that proper maintenance is not performed.

All Bioretention areas must be covered by a drainage easement to allow inspection and maintenance by local authority staff.

When Residential Rain Gardens are applied on private residential lots, homeowners will need to (1) be educated about their routine maintenance needs, (2) understand the long-term maintenance plan, and (3) be subject to modified maintenance agreements as described above.

Maintenance of Bioretention areas should be integrated into routine landscape maintenance tasks. If landscaping contractors will be expected to perform maintenance, their contracts should contain specifics on unique Bioretention landscaping needs, such as maintaining elevation differences needed for ponding, proper mulching, sediment and trash removal, and limited use of fertilizers and pesticides.

Maintenance tasks and frequency will vary depending on the size and location of the Bioretention, the landscaping template chosen, and the type of surface cover in the practice. A generalized summary of common maintenance tasks and their frequency is provided in **Table BR-9**.

Table BR-9. Recommended Maintenance Tasks for Bioretention Practices

Maintenance Tasks	Frequency
▪ For the first 6 months following construction, the practice and CDA should be inspected at least twice after storm events that exceed 1/2 in. of rainfall. Conduct any needed repairs or stabilization. ▪ Inspectors should look for bare or eroding areas in the CDS or around the Bioretention area, and make sure they are immediately stabilized with grass cover. ▪ One-time, spot fertilization may be needed for initial plantings. ▪ Watering is needed once a week during the first 2 months, and then as needed during first growing season (April-October), depending on rainfall. ▪ Remove and replace dead plants. Up to 10% of the plant stock may die off in the first year, so construction contracts should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction.	Upon establishment
▪ Mowing of grass filter strips and Bioretention with turf cover ▪ Check curb cuts and inlets for accumulated grit, leaves, and debris that may block inflow	At least 4 times a year
▪ Spot weeding, trash removal, and mulch raking	Twice during growing season

Maintenance Tasks	Frequency
▪ Add reinforcement planting to maintain desired the vegetation density ▪ Remove invasive plants using recommended control methods ▪ Remove any dead or diseased plants ▪ Stabilize the CDA to prevent erosion	As needed
▪ Conduct a maintenance inspection ▪ Supplement mulch in devoid areas to maintain a 3 inch layer ▪ Prune trees and shrubs ▪ Remove sediment in pre-treatment cells and inflow points	Annually
▪ Remove sediment in pre-treatment cells and inflow points ▪ Remove and replace the mulch layer	Once every 2 to 3 years

The most common non-routine maintenance problem involves standing water. If water remains on the surface for more than 48 hours after a storm, adjustments to the grading may be needed or underdrain repairs may be needed. The surface of the filter bed should also be checked for accumulated sediment or a fine crust that builds up after the first several storm events. There are several methods that can be used to rehabilitate the filter. These are listed below, starting with the simplest approach and ranging to more involved procedures (if the simpler actions do not solve the problem):

- Open the underdrain observation well or cleanout and pour in water to verify that the underdrains are functioning and not clogged or otherwise in need of repair. The purpose of this check is to see if there is standing water all the way down through the soil. If there is standing water on top, but not in the underdrain, then there is a clogged soil layer. If the underdrain and stand pipe indicates standing water, then the underdrain must be clogged and will need to be cleaned out.
- Remove accumulated sediment and till 2 to 3 inches of sand into the upper 6 to 12 inches of soil.
- Install sand wicks from 3 inches below the surface to the underdrain layer. This reduces the average concentration of fines in the media bed and promotes quicker drawdown times. Sand wicks can be installed by excavating or augering (using a tree auger or similar tool) down to the top of the underdrain layer to create vertical columns which are then filled with a clean open-graded coarse sand material (ASTM C-33 concrete sand or similar approved sand mix for Bioretention media). A sufficient number of wick drains of sufficient dimension should be installed to meet the design dewatering time for the facility.
- Remove and replace some or all of the soil media.

It is highly recommended that a spring maintenance inspection and cleanup be conducted at each Bioretention area. Example maintenance inspection checklists for Bioretention areas can be found in **Appendix A of the Manual**.

Supplement 4.2.3.A. Water Quality Swale (WQS)

WQS-1. Water Quality Swales

Water Quality Swales are essentially Bioretention cells that are configured as linear channels, usually have a longitudinal slope, often with check dams to break to swale in "cells," and are covered with turf, herbaceous plants (e.g., meadow grasses), or other surface material. See **Figure WQS-1** for typical applications. The design specifications for Water Quality Swales are the same as for Bioretention, except for the additional information contained within this appendix.

Figure WQS-1. Typical Applications for Water Quality Swales

Water Quality Swale with check dams along roadway

Water Quality Swale at edge of parking lot

Turf-covered Water Quality Swale with curb cuts and stone pre-treatment

Table WQS-1 describes the Level 1 and Level 2 design options for **Water Quality Swales a**nd the practice performance in terms of reducing the volume associated with one inch of rainfall on the site. **Table WQS-2** summarizes pollutant removal performance values for Level 1 and Level 2 designs. This is for the purpose of calculating site-based pollutant load reductions in the context of TMDLs and/or watershed plans.

Table WQS-1. Water Quality Swale Design Levels: Descriptions & Performance

Design Level	Description	Applications	Performance[1]
Level 1	Basic Design • Swale longitudinal slope between 2 and 4% with use of check dams • Bottom width 2 to 4 ft. • Underdrain • At least 1.5 ft. of soil media depth, but less than 2.0 ft. • No infiltration sump below underdrain pipe(s)	See **Table BR-1** in main Bioretention specification Also, sites where slopes dictate use of practice with longitudinal slope or where this configuration better suits the site design.	55% volume reduction for the Design Volume of the practice[2]
Level 2	• Swale longitudinal slope between 0.5 and 2% with use of check dams • Bottom width 4 to 8 ft. Infiltration Design • No underdrain • Water infiltrates into the underlying soil within 48 hours. OR Extended Filtration Design • Underdrain • At least 2.0 ft. of soil media depth, OR • At least 1.5 ft. of soil media depth with stone sump below underdrain designed to drain Design Volume within 48 hours on suitable soils (e.g., limited on fill).		100% volume reduction for the Design Volume of the practice[2]

[1] Performance achieved toward reducing one inch of rainfall
*[2]Design Volume includes storage on the surface, within the soil media, and in the infiltration sump. The Design Volume can be 100% of that needed to meet the one-inch performance standard or some proportion of it when used in conjunction with other practices. See Section **BR-4.1** of the Bioretention specification for sizing details.*

Table WQS-2. Pollutant Removal Performance Values for Level 1 and 2 Design[1]

Design Level	Total Suspended Solids (TSS)	Nutrients: Total Phosphorus (TP) & Total Nitrogen (TN)
Level 1	TSS = 65%	TP = 52% TN = 55%
Level 2	TSS = 90%	TP = 76% TN = 74%

[1] Total Pollutant Load Reduction = combined functions of runoff reduction and pollutant removal. Pollutant removal refers to the change in event mean concentration as it flows through the practice and is subjected to treatment processes, as reported in Hirschman et al. (2008).

WQS-2. Typical Details

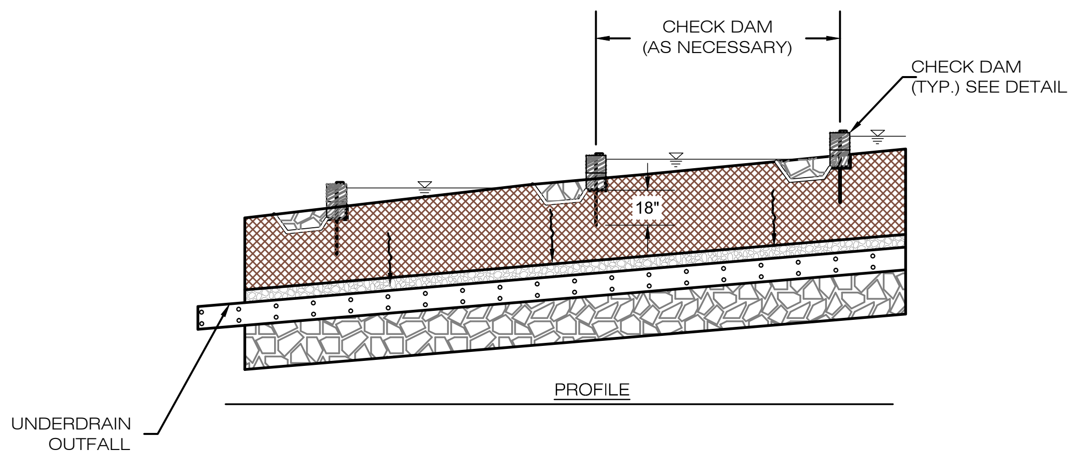

Figure WQS-2. Typical profile for Water Quality Swale with check dams

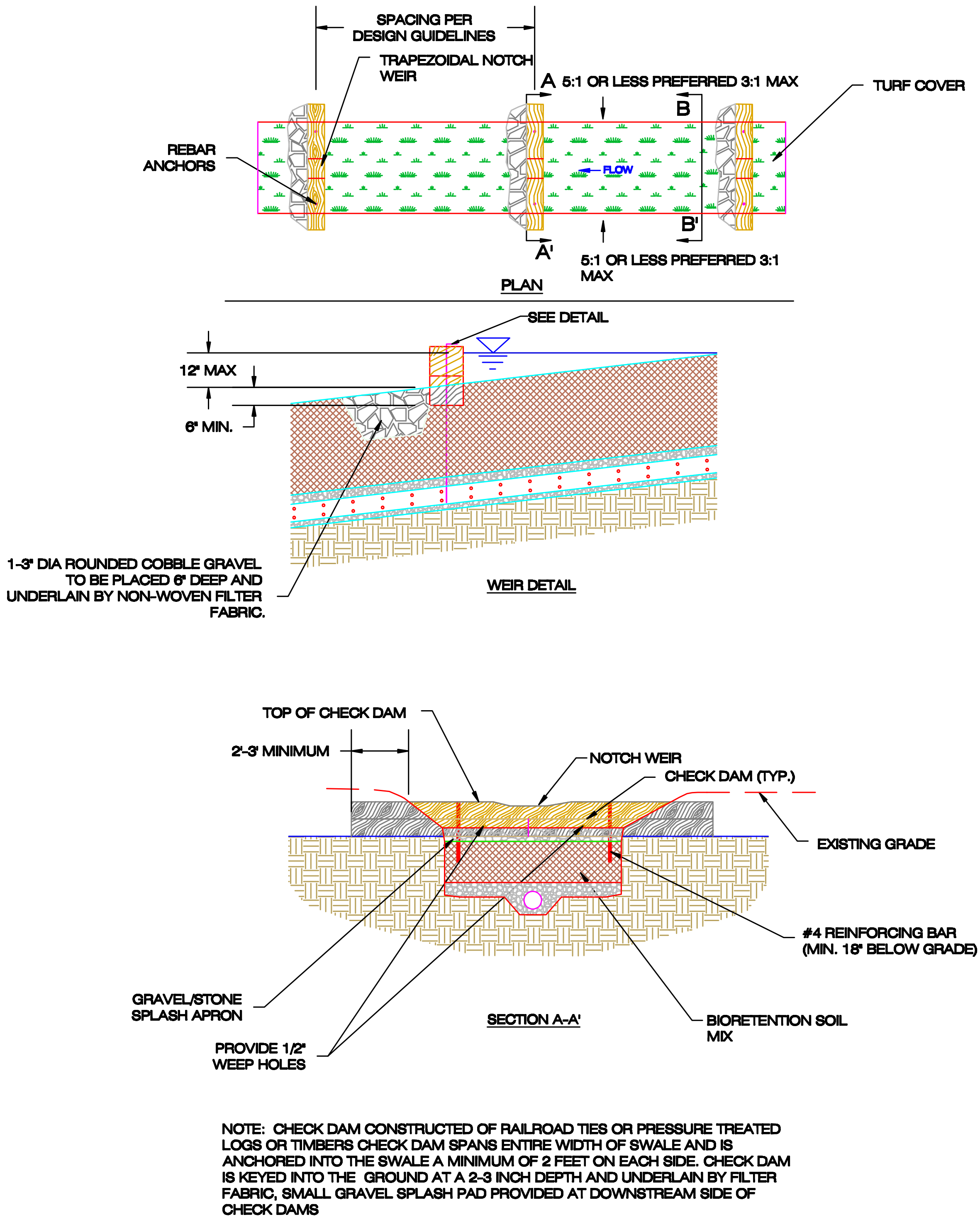

Figure WQS-3. Typical details for check dams

WQS-3. Sizing

The sizing for Water Quality Swales is the same as for Bioretention, except that the surface ponding volume is the volume captured behind the check dams, so must be calculated as wedge. The surface ponding requirements that apply to Bioretention (at least 50% of total design volume for ponding depths less than 1 foot and 70% for ponding depths of 1 foot or greater) do not apply to Water Quality Swales.

WQS-4. Side Slopes

The side slopes of Water Quality Swales should be no steeper than 3H:1V for maintenance considerations (i.e., mowing). Flatter slopes are encouraged where adequate space is available, to enhance pre-treatment of sheet flows entering the swale.

WQS-5. Conveyance

The bottom width and slope of a Water Quality Swale should be designed such that the velocity of flow from a one-inch rainfall will not exceed 3 feet per second. Check dams may be used to achieve the needed runoff reduction volume, as well as to reduce the flow velocity. Check dams should be spaced based on channel slope and ponding requirements, consistent with the criteria in **Table WQS-1**.

The swale should also convey the locally required design storms (e.g., 2- and 10-year storms) at non-erosive velocities with at least 3 inches of freeboard. The analysis should evaluate the flow profile through the channel at normal depth, as well as the flow depth over top of the check dams.

A Water Quality Swale may be designed as an off-line system, with a flow splitter or diversion to divert runoff in excess of the design capacity to an adjacent conveyance system. Alternately, strategically placed overflow inlets may be placed along the length of the swale to periodically pick up water and reduce the hydraulic loading at the downstream limits.

WQS-6. Check Dams

Check dams may be used for pre-treatment, to break up slopes, and to increase the hydraulic residence time in the channel. Design requirements for check dams are as follows:

- Check dams should be spaced based on the channel slope, as needed to increase residence time, provide design storm storage volume, or any additional volume attenuation requirements. In typical spacing, the ponded water at a downhill check dam should not touch the toe of the upstream check dam. More frequent spacing may be desirable in Water Quality Swales to increase the ponding volume.
- The maximum desired check dam height is 12 inches (for maintenance purposes). However, for some sites, a maximum of 18 inches can be allowed, with additional design elements to ensure the stability of the check dam and the adjacent and underlying soils. In these cases, the average ponding depth throughout the channel should be 12 inches.
- Armoring may be needed at the downstream toe of the check dam to prevent erosion.
- Check dams must be firmly anchored into the side-slopes to prevent outflanking; check dams must also be anchored into the channel bottom so as to prevent hydrostatic head from pushing out the underlying soils.
- Check dams must be designed with a center weir sized to pass the channel design storm peak flow (10-year storm event for man-made channels).
- Check dams should be composed of wood, concrete, stone, compacted soil, or other non-erodible material, or should be configured with elevated driveway culverts.
- Check dams should be constructed of a non-erosive material such as wood, stone, riprap, concrete, or compacted soil (with a stone spillway). All check dams should be underlain with filter fabric conforming to local design standards.
- Wood used for check dams should consist of pressure treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak or locust.

Check dams for Water Quality Swales should be spaced to reduce the effective slope to the desired slope (see **Table WQS-1**), as indicated in **Table WQS-3**.

Table WQS-3. Typical Check Dam Spacing to Achieve Effective Channel Slope

Channel Longitudinal Slope	Spacing [1] of 12-inch High (max.) Check Dams [3, 4] to Create an Effective Slope of 2%	Spacing [1] of 12-inch High (max.) Check Dams [3, 4] to Create an Effective Slope of 0 to 1%
0.5%	–	200 ft.to –
1.0%	–	100 ft.to –
1.5%	–	67 ft.to 200 ft.
2.0%	–	50 ft.to 100 ft.
2.5%	200 ft.	40 ft.to 67 ft.
3.0%	100 ft.	33 ft.to 50 ft.
3.5%	67 ft.	30 ft.to 40 ft.
4.0%	50 ft.	25 ft.to 33 ft.
4.5% [2]	40 ft.	20 ft.to 30 ft.
5.0% [2]	40 ft.	20 ft.to 30 ft.

Notes:

[1] The spacing dimension is half of the above distances if a 6-inch check dam is used.

[2] Open channels with slopes greater than 4% require special design considerations, such as drop structures to accommodate greater than 12-inch high check dams (and therefore a flatter effective slope), in order to ensure non-erosive flows.

[3] All check dams require a stone energy dissipater at the downstream toe.

[4] Check dams require weep holes at the channel invert. Swales with slopes less than 2% will require multiple weep holes (at least 3) in each check dam.

Supplement 4.2.3.B Urban Bioretention (UB)

UB-1. Urban Bioretention

Urban Bioretention practices are similar in function to regular Bioretention practices except they are adapted to fit into "containers" within urban landscapes. Typically, Urban Bioretention is installed within an urban streetscape or city street right-of-way, urban landscaping beds, tree pits and plazas, or other features.

Urban Bioretention features hard edges, often with vertical concrete sides, as contrasted with the more gentle earthen slopes of regular Bioretention. These practices may be open-bottomed, to allow some infiltration of runoff into the sub-grade, but they generally are served by an underdrain.

Stormwater planters (also known as vegetative box filters or foundation planters) take advantage of limited space available for stormwater treatment by placing a soil filter in a container located above ground or at grade in landscaping areas adjacent to buildings and/or between buildings and roadways. The small footprint of the planter is typically contained in a precast or cast-in-place concrete vault. Stormwater planters combine an aesthetic landscaping feature with a functional form of stormwater treatment. They generally receive runoff from adjacent rooftop downspouts and are landscaped with plants that are tolerant to periods of both drought and inundation.

Extended tree boxes are installed in the sidewalk zone near the street where urban street trees are normally installed. The soil volume for the tree pit is increased and used for stormwater treatment. Treatment is increased by using a series of connected tree planting areas together in a row. The surface of the enlarged planting area may be mulch, grates, permeable pavers, or conventional pavement. The large and shared rooting space and a reliable water supply increase the growth and survival rates in this otherwise harsh planting environment.

Stormwater curb extensions (also known as street Bioretention) are installed in the road right-of way either in the sidewalk area or in the road itself. In many cases, curb extensions serve as a traffic calming or street parking control device. The basic design adaptation is to create a shallow ponding area above soil media and underdrain layers by installing a raised concrete curb adjacent to or into the street. Street runoff is diverted into the ponding area through inlets or curb cuts.

Each Urban Bioretention variant is planted with a mix of trees, shrubs, and grasses as appropriate for its size and landscaping context. **Figure UB-1** shows some typical applications for Urban Bioretention.

Figure UB-1. Typical applications for Urban Bioretention

Adjacent to building to catch roof runoff

In plaza or courtyard

Street Bioretention – curb extension linked with tree box

Extended tree pits within right-of-way

Table UB-1 describes practice performance in terms of reducing the volume associated with one inch of rainfall for Urban Bioretention. Urban Bioretention is assumed to have only one design level, under the assumption that practices will have at least 1.5 feet of soil media and an underdrain (sometimes with an impermeable liner and without an infiltration sump). It is further assumed that the extended filtration function of Urban Bioretention is limited due to limited surface area and practice sizing. Additional storage (and runoff reduction capacity) can be built into Urban Bioretention by increasing the soil media and/or underdrain layer depth, or, in rare cases, by designing an open-bottomed system that allows for infiltration.

Table UB-2 summarizes pollutant removal performance values for Urban Bioretention. This is for the purpose of calculating site-based pollutant load reductions in the context of TMDLs and/or watershed plans.

Table UB-1. Urban Bioretention Design: Descriptions & Performance

Design Level	Description	Applications	Performance[1]
Level 1	Basic Design • Underdrain, often with a liner if close to building foundation or street sub-base • At least 1.5 ft. of soil media depth • No infiltration sump below underdrain pipe(s)	Ultra-urban settings, streetscapes, areas with limited space	60% volume reduction for the Design Volume of the practice[2]

[1] Performance achieved toward reducing one inch of rainfall
[2] Design Volume includes storage on the surface and within the soil media. The Design Volume can be 100% of that needed to meet the one-inch performance standard or some proportion of it when used in conjunction with other practices. See Section BR-4.1 of the Bioretention specification for sizing details.

Table UB-2. Pollutant Removal Performance Values for Level 1 and 2 Design1

Design Level	Total Suspended Solids (TSS)[2]	Nutrients: Total Phosphorus (TP) & Total Nitrogen (TN)[2]
Level 1	TSS = 70%	TP = 55% TN = 64%

[1] Total Pollutant Load Reduction = combined functions of runoff reduction and pollutant removal. Pollutant removal refers to the change in event mean concentration as it flows through the practice and is subjected to treatment processes, as reported in Hirschman et al. (2008).
[2]These removal rates apply to practices sized for the full Treatment Volume (Tv) – in other words, sized to capture the full one-inch Tv from the drainage area. Practices that do not meet this sizing objective should multiply the removal rate by the percentage of the full Tv. For instance, if a practice is sized for ½ of the full Tv, then the TSS removal rate would be 70 x 0.5 = 35%.

UB-2. Typical Details

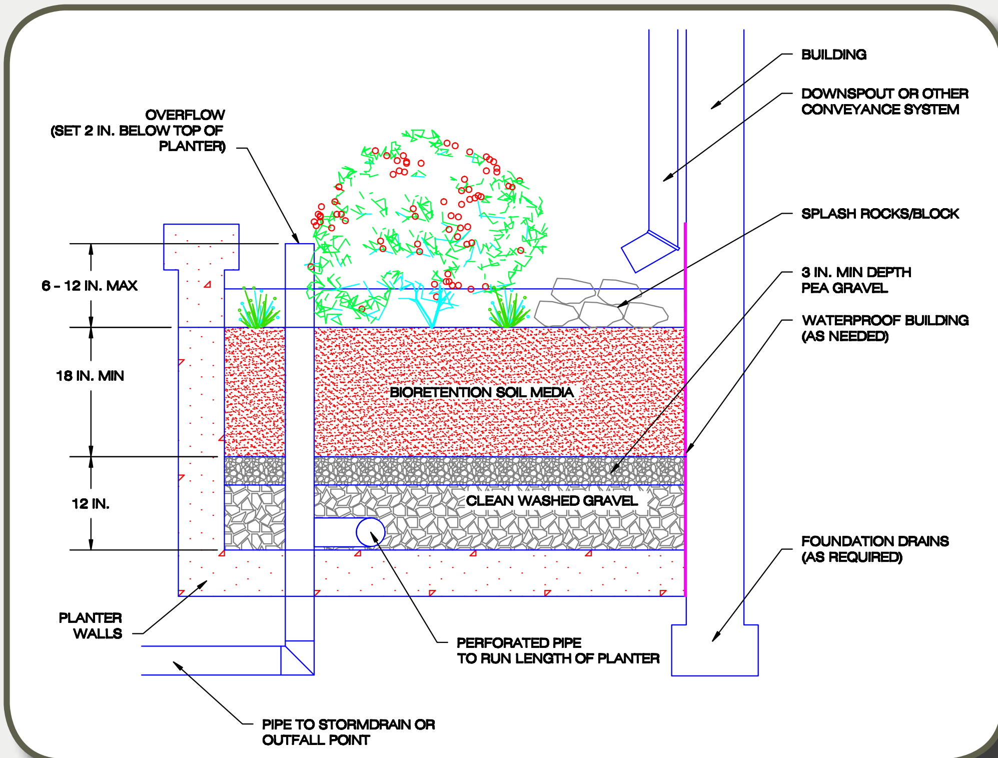

Figure UB-2. Stormwater Planter Cross-Section

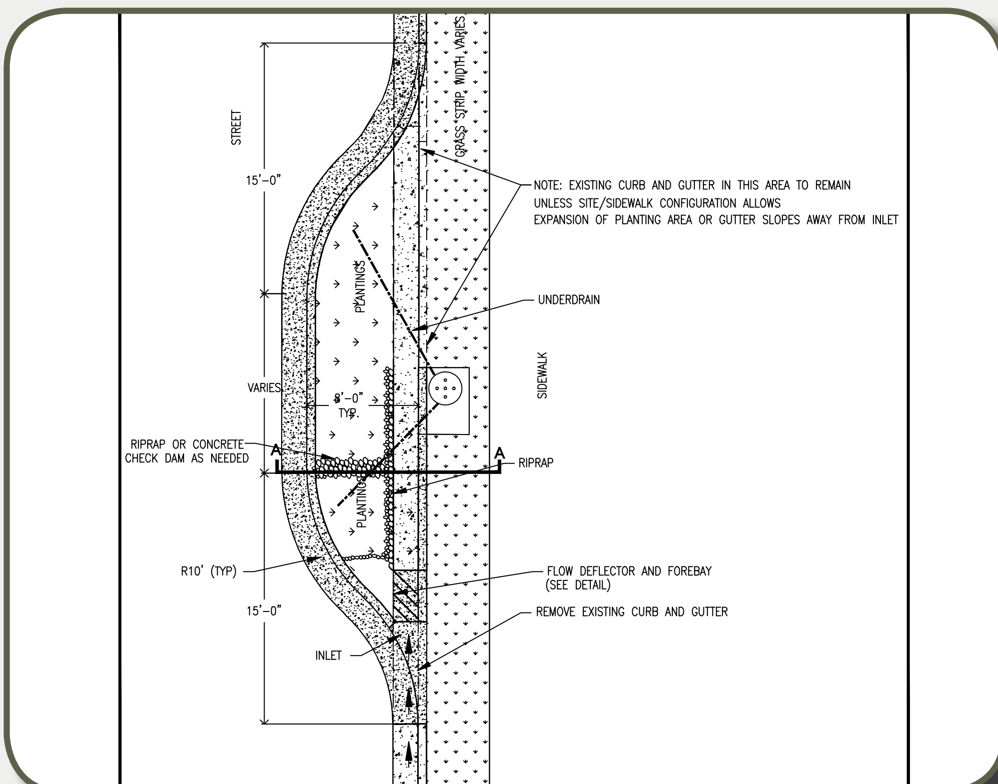

Figure UB-3. Typical plan view for stormwater curb extension tied to existing inlet structure. See Figure UB-4 for detail of cross-section A-A.

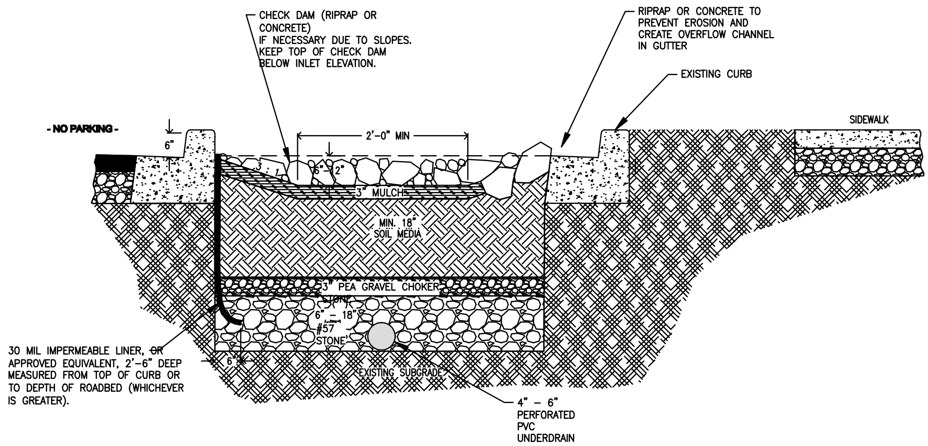

Figure UB-4. Typical cross-section for stormwater curb extension. See Figure UB-3 for location of cross-section A-A.

UB-3. Feasibility Criteria and Design Considerations

In general, Urban Bioretention has the same constraints as regular Bioretention, along with a few additional constraints as noted below:

Contributing Drainage Area. Urban Bioretention is usually limited to 2,500 square feet of drainage area to each individual unit. However, this is considered a general rule; larger drainage areas may be allowed with sufficient flow controls and other mechanisms to ensure proper function, safety, and community acceptance. The drainage areas in these urban settings are typically considered to be 100% impervious. While multiple units can be installed to maximize the treatment area in ultra-urban watersheds, Urban Bioretention is not intended to be used as treatment for large impervious areas (such as parking lots).

Available Hydraulic Head. In general, 3 to 5 feet of elevation difference is needed between the downstream storm drain invert and the inflow point of the Urban Bioretention practice. This is generally not a constraint, due to the standard depth of most storm drain systems.

Setbacks from Buildings. If an impermeable liner and an underdrain are used, no setback is needed from the building. Otherwise, the standard 10 foot down-gradient setback applies.

Proximity to Underground Utilities. Urban Bioretention practices frequently compete for space with a variety of utilities. Since they are often located parallel to the road right-of-way, care should be taken to provide utility-specific horizontal and vertical setbacks. However, conflicts with water and sewer laterals may be unavoidable, and the construction sequence must be altered, as necessary, to avoid impacts to existing service.

Overhead Wires. Designers should also check whether future tree canopy heights achieved in conjunction with Urban Bioretention practices will interfere with existing overhead telephone, cable communications and power lines.

Minimizing External Impacts. Because Urban Bioretention practices are installed in urban settings, individual units may be subject to higher public visibility, greater trash loads, pedestrian traffic, vandalism, and even vehicular loads. Designers should design these practices in ways that prevent, or at least minimize, such impacts. In addition, designers should clearly recognize the need to perform frequent landscaping maintenance to remove trash, check for clogging, and maintain vigorous vegetation. The urban landscape context may feature naturalized landscaping or a more formal design. When Urban Bioretention is used in sidewalk areas of high foot traffic, designers should not impede pedestrian movement or create a safety hazard. Designers may also install low fences, grates or other measures to prevent damage from pedestrian short-cutting across the practices.

UB-4. Inlets and Energy Dissipation

Where appropriate, the inlet(s) to Urban Bioretention systems should be stabilized using No.3 stone, splash blocks, river stone or other acceptable energy dissipation measures. The following types of inlets are recommended:
- Downspouts to stone energy dissipaters.
- Sheet flow over a depressed curb with a 3-inch drop.
- Curb cuts allowing runoff into the Bioretention area.
- Covered drains that convey flows across sidewalks from the curb or downspouts.
- Grates or trench drains that capture runoff from a sidewalk or plaza area.

UB-5. Ponding Depth

The recommended ponding depth for Urban Bioretention is 6 inches, especially in areas with high visibility, pedestrian traffic, and/or exposure to the public. In some cases where the Urban Bioretention is not as visible or architectural design considerations are used for aesthetics and public safety, a 12-inch ponding depth can be used.

UB-6. Specific Design Issues for Stormwater Planters

The two basic design variations for stormwater planters are the infiltration planter and the filter planter.

An **infiltration planter** filters rooftop runoff through soil in the planter followed by infiltration into soils below the planter. This type of design would be used rarely in cases where geotechnical testing indicates an adequate soil infiltration rate (see **Appendix B** of this Manual) and that infiltrated water will not create a problem for building foundations, road subgrades, and other infrastructure elements. The shape, length, and depth are determined by architectural and infrastructure considerations. As a general rule, the planter should be sized to treat at least 1/2-inch of runoff from the contributing rooftop area. Infiltration planters should be placed at least 10 feet away from a building to prevent possible flooding or basement seepage damage.

A **filter planter** does not allow for infiltration and is constructed with a watertight concrete shell or an impermeable liner on the bottom to prevent seepage. Since a filter planter is self-contained and does not infiltrate into the ground, it can be installed right next to a building. The minimum planter depth is 18 inches, with the shape and length determined by architectural considerations. Runoff is captured and temporarily ponded above the planter bed. Overflow pipes are installed to discharge runoff when maximum ponding depths are exceeded, to avoid water spilling over the side of the planter. In addition, an underdrain is used to carry runoff to the storm sewer system.

Additional design considerations for the filter planter include the following:
- Planters should be sized to allow captured runoff to drain out within four hours after a storm event.
- Plant materials should be capable of withstanding moist and seasonally dry conditions.
- Planting media should have an infiltration rate of at least 2 inches per hour.
- The sand and gravel on the bottom of the planter should have a minimum infiltration rate of 5 inches per hour.
- The planter can be constructed of stone, concrete, brick, wood or other durable material. If treated wood is used, care should be taken so that trace metals and creosote do not leach out of the planter.

UB-7. Specific Design Issues for Extended Tree Boxes

When designing engineered tree boxes, the following criteria should be considered:

- The bottom of the soil layer must be a minimum of 4 inches below the root ball of plants to be installed.
- Engineered tree box designs sometimes cover portions of the filter media with pervious pavers or cantilevered sidewalks. In these situations, it is important that the filter media is connected beneath the surface so that stormwater and tree roots can share this space.
- Installing an engineered tree pit grate over the filter bed media is one possible solution to prevent pedestrian traffic and trash accumulation.
- Low, wrought iron fences can help restrict pedestrian traffic across the tree pit bed and serve as a protective barrier if there is a dropoff from the pavement to the filter bed surface.
- A removable grate may be used to allow the tree to grow through it.
- Each tree needs a minimum of 400 cubic feet of root space.

UB-8. Specific Design Issues for Street Bioretention

Street Bioretention design requires more engineering than typical Bioretention. Capturing the desired drainage area (which may include both sides of a crowned roadway), conveying water into and through the facility, tying the system into the existing storm sewer, and integrating the practice with sidewalks, landscaping, and pedestrian and bike facilities all require detailed engineering analysis and design.

In addition, roadway stability can be a design issue where streetscape Bioretention practices are installed. Designers should consult design standards pertaining to roadway drainage. It may be necessary to provide an impermeable liner on the road side of the Bioretention area to keep water from saturating the road's sub-base.

UB-9. Planting and Landscaping Considerations

The degree of landscape maintenance that can be provided will determine some of the planting choices for Urban Bioretention areas. The planting cells can be formal gardens or naturalized landscapes.

In areas where less maintenance will be provided and where trash accumulation in shrubbery or herbaceous plants is a concern, consider a "turf and trees" landscaping model. Spaces for herbaceous flowering plants can be included.

Native trees or shrubs are preferred for Urban Bioretention areas, although some ornamental species may be used. As with regular Bioretention, the selected perennials, shrubs, and trees must be tolerant of salt, drought, and inundation. Additionally, tree species should be those that are known to survive well in the compacted soils and polluted air and water of an urban landscape.

UB-10. Materials Specifications for Urban Bioretention

Please consult Table BR-7 for the typical materials needed for filter media, stone, mulch and other Bioretention features. The unique components for Urban Bioretention may include the inlet control device, a concrete box or other containing shell, protective grates, and an underdrain that daylights to another stormwater practice or connects to the storm drain system.

UB-11. Construction of Urban Bioretention

The construction sequence and inspection requirements for Urban Bioretention are generally the same as micro-Bioretention practices. Consult the construction sequence and inspection guidance provided in Section BR-7.2 of the Bioretention specification. In cases where Urban Bioretention is constructed in the road or right-of-way, the construction sequence may need to be adjusted to account for traffic control, pedestrian access and utility notification.

Urban Bioretention areas should only be constructed after the drainage area to the facility is completely stabilized. The specified growth media should be placed and spread by hand with minimal compaction, in order to avoid compaction and maintain the porosity of the media. The media should be placed in 8 to 12 inch lifts with no machinery allowed directly on the media during or after construction. The media should be overfilled above the proposed surface elevation, as needed, to allow for natural settling. Lifts may be lightly watered to encourage settling. After the final lift is placed, the media should be raked (to level it), saturated, and allowed to settle for at least one week prior to installation of plant materials.

UB-12. Maintenance of Urban Bioretention

Routine operation and maintenance are essential to gain public acceptance of highly visible Urban Bioretention areas. Weeding, pruning, and trash removal should be done as needed to maintain the aesthetics necessary for community acceptance. During drought conditions, it may be necessary to water the plants, as would be necessary for any landscaped area.

For infiltration planters, inspectors should check that stormwater infiltrates properly into the soil within 24 hours after a storm. If excessive surface ponding is observed, corrective measures include inspection for soil compaction and underdrain clogging. Consult the maintenance guidance outlined in Section BR-8 of the Bioretention specification.

4.2.3 Bioretention

Supplement 4.2.3.C. Residential Rain Garden (RG)

RG-1. Residential Rain Garden

The term "Rain Garden" generally refers to a less rigorous design specification than Bioretention since the contributing drainage area is limited and the design is simplified. Rain Gardens are small, distributed practices designed to treat runoff from small areas, such as individual rooftops, driveways and other on-lot features in single-family residential developments. Inflow is typically sheet flow, or can be concentrated flow with energy dissipation, when located at downspouts.

Rain Gardens are one option for "Impervious Surface Disconnection" outlined in **Specification 4.2.2**. They can be a stand-alone practice, or used as part of a "rooftop to stream" treatment train that may include Simple Disconnection, Disconnection to a soil compost-amended filter path (see **Figure RG-2**), and Disconnection to other runoff reduction Compensatory Practices (see **Figure RG-1** for example of Disconnection to Rain Garden). **Specification 4.2.2** provides more detail on the design and runoff reduction capabilities of various treatment train approaches.

If drainage areas exceed 2,500 square feet (to each individual Rain Garden), then the main specifications for Bioretention should be used.

Figure RG-1. Example of Residential Rain Garden

Table RG-1 outlines practice performance in terms of reducing the volume associated with one inch of rainfall for Rain Gardens. Rain Gardens are assumed to have only one design level, with the requirement that practices have at least 1.5 feet of soil media and an underdrain to ensure adequate drainage within residential settings. Additional storage (and runoff reduction capacity) can be built into Rain Gardens by increasing the soil media and/or underdrain layer depth, adding an infiltration sump, or, in limited cases, by designing for infiltration by eliminating the underdrain.

Table RG-2 summarizes pollutant removal performance values for Rain Gardens. This is for the purpose of calculating site-based pollutant load reductions in the context of TMDLs and/or watershed plans.

Table RG-1. Residential Rain Garden Design: Descriptions & Performance

Design Level	Description	Applications	Performance[1]
Level 1	Basic Design • At least 1.5 feet of soil media depth • Underdrain with perforated HDPE pipe or equivalent • Landscaping according to context	Mostly residential settings to treat rooftops, driveways, yards, and other areas of on-lot impervious cover	60% volume reduction for the Design Volume of the practice[2]

[1] *Performance achieved toward reducing one inch of rainfall*

[2] *Design Volume includes storage on the surface and within the soil media. The Design Volume can be 100% of that needed to meet the one-inch performance standard or some proportion of it when used in conjunction with other practices. See **Section BR-4.1** of the Bioretention specification for sizing details.*

Table RG-2. Pollutant Removal Performance Values for Level 1 and 2 Design1

Design Level	Total Suspended Solids (TSS)[2]	Nutrients: Total Phosphorus (TP) & Total Nitrogen (TN)[2]
Level 1	TSS = 70%	TP = 55% TN = 64%

[1] *Total Pollutant Load Reduction = combined functions of runoff reduction and pollutant removal. Pollutant removal refers to the change in event mean concentration as it flows through the practice and is subjected to treatment processes, as reported in Hirschman et al. (2008).*
[2]*These removal rates apply to practices sized for the full Treatment Volume (Tv) – in other words, sized to capture the full one-inch Tv from the drainage area. Practices that do not meet this sizing objective should multiply the removal rate by the percentage of the full Tv. For instance, if a practice is sized for ½ of the full Tv, then the TSS removal rate would be 70 x 0.5 = 35%.*

RG-2. Typical Details

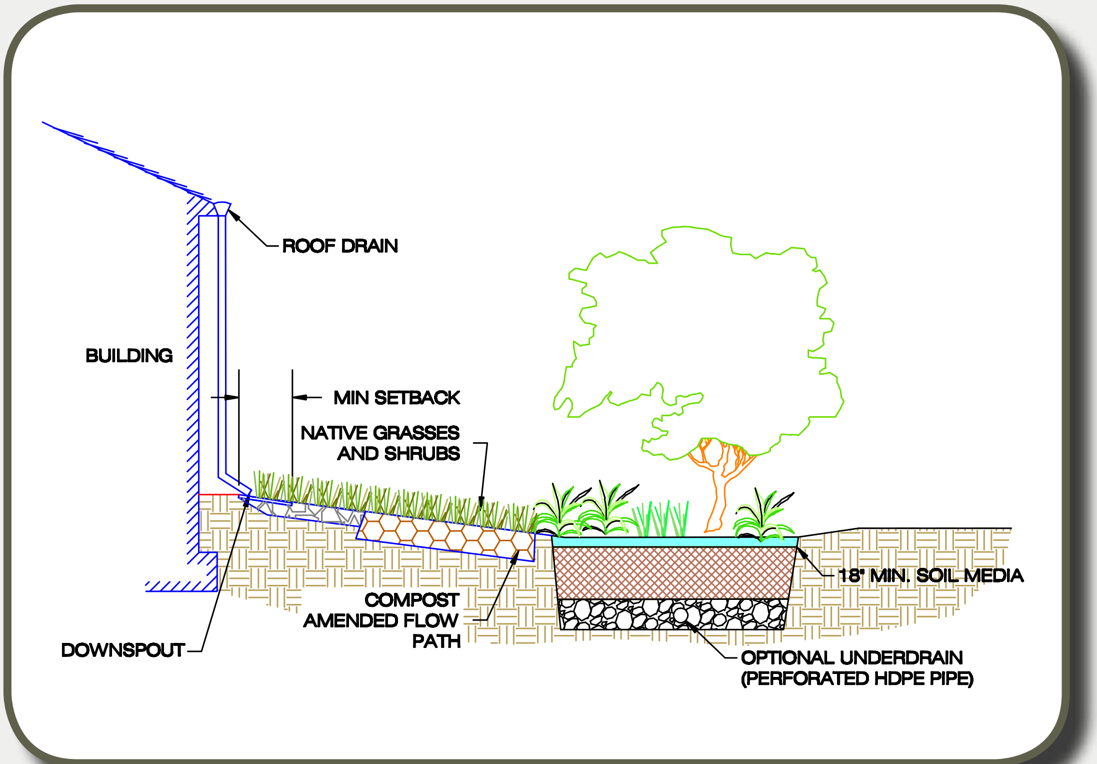

Figure RG-2. Example of Rain Garden used in conjunction with a soil compost-amended flow path (see Specification 4.2.2. Impervious Surface Disconnection).

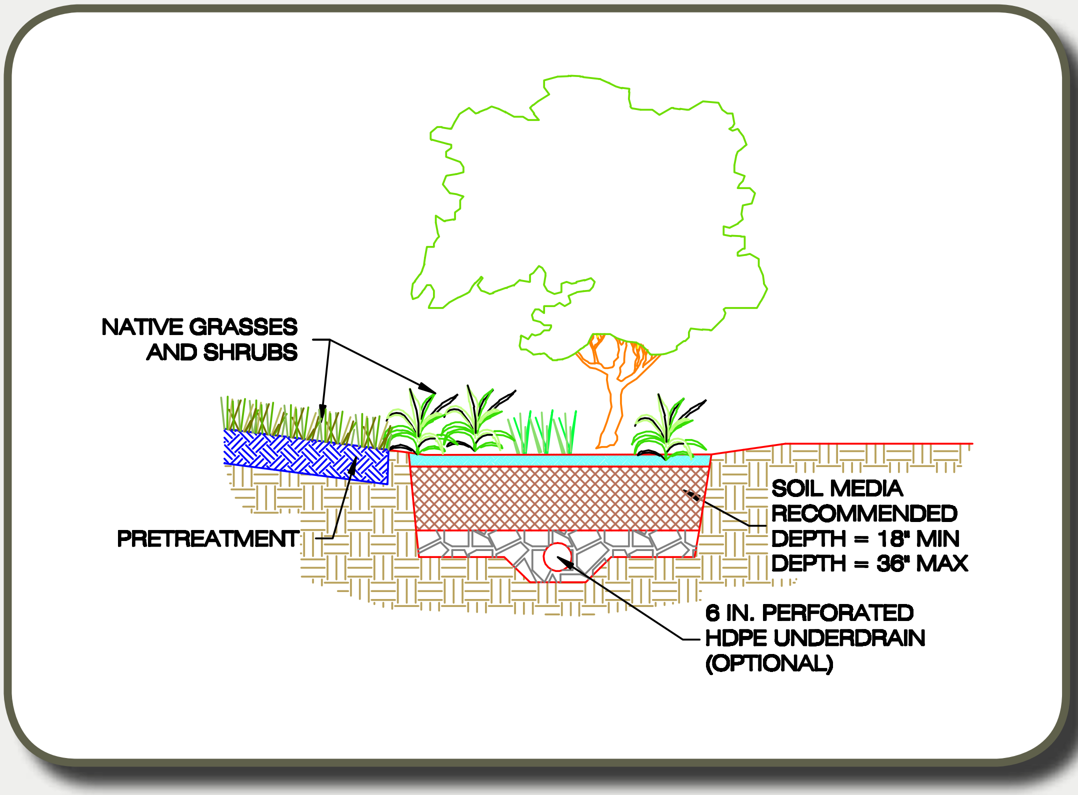

Figure RG-3. Typical detail for Rain Garden

RG-3. Design Considerations for Rain Gardens

Table RG-3 outlines specific design criteria for Rain Gardens.

Table RG-3. Design criteria for Rain Gardens.

Design Factor	Rain Garden Design
Impervious Area Treated[1]	2,500 sq. ft.
Type of Inflow	Sheet flow; Concentrated flow with level spreader or energy dissipater
Minimum Soil Infiltration Rate	0.5 in./hr. (or use underdrain)
Observation Well/Cleanout Pipes	No
Pretreatment	Energy dissipater, grass filter (e.g., flow through several feet of yard before flow reaches Rain Garden)

Design Factor	Rain Garden Design
Ponding Depth	6-in. in most cases
Underdrain	Yes, in most cases.[1] Underdrains to daylight in yard, road ditch, or storm sewer (e.g., in the street)
Impermeable Liner	For hotspot or karst designs, or adjacent to foundations.
Gravel Layer	12 in.
Minimum Filter Media Depth	18 in.
Media Source	Can be mixed on-site
Head Required	Nominal, 1 to 3 ft.
Sizing	See **Section BR-4.1 in main Bioretention specification**
Landscaping	**See Section BR-4.17 in the main Bioretention specification.** Simple landscape plans are best, and can include turf, herbaceous layers, shrubs, and trees
Required Soil Borings	One, only when an underdrain is not used
Building Setbacks	5 ft. down-gradient, 25 ft. up-gradient (or use an impermeable liner)

[1] *Refer **Section BR-4.10 in main Bioretention specification***

RG-4. Conveyance for Rain Gardens

Rain Gardens should include provisions to bypass flows around the practice when the rain event exceeds the Design Volume. The adjacent pervious areas should be designed to safely convey design and large storm events away from the practice and to a receiving area without causing erosion. Since the rooftop drainage systems (roof leaders) typically limit the flow, there are generally no detailed conveyance criteria related to a design storm or peak flow rate.

RG-5. Construction Considerations for Rain Gardens

Sequencing of construction for Rain Gardens is critical, especially for on-lot practices. The Rain Garden should not be installed until the drainage area is stabilized with vegetation. Early installation will likely result in practice failure. This can be tricky because it involves close coordination between contractors (building the road), builders, and subcontractors. See the main Bioretention specification for more detail on construction sequence.

RG-6. Maintenance Considerations for Rain Gardens

Rain Gardens require regular mowing and/or landscape maintenance to perform effectively. It is recommended that Rain Gardens be located in an expanded right-of-way or stormwater easement so that they can be easily accessed for inspection, maintenance, or in the event that they fail to drain properly.

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