A.1 BIORETENTION AREAS

Location: Market Street Family Resource Center, San Diego, California. Source: RBF Consulting.

Figure A.1-1. Bioretention in landscaped area.

A.1.1 DESIGN

The design of a bioretention area can be broken down to a nine-step process. Table A.1-1 summarizes the steps, which this chapter describes in greater detail.

Table A.1-1. Bioretention iterative design step process

Design step		Design component/ consideration	General specification
1	**Integrated Management Practice (IMP) Siting (A-3)**	Layout and site incorporation	Based on available space and maintenance access, incorporate into parking lot islands, medians, and perimeter; install along the roadway right-of-way; incorporate as landscaped areas throughout the property; or dedicate space for larger, centralized bioretention areas.
2	**Determine IMP Function and Configuration (A-4)**	Impermeable liner	If noninfiltrating, use an impermeable clay layer, geomembrane liner, and concrete (as described in Common Design Elements).
		Underdrain (required if subsoil infiltration rate is less than 0.5 inches per hour [in/hr], as in hydrologic soil groups C and D [HSG C & D])	Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. The 4-inch diameter lateral pipes should join a 6-inch collector pipe, which conveys drainage to the downstream storm network. Provide cleanout ports/observation wells for each underdrain pipe (see Common Design Elements).
		Internal water storage (IWS)	If using underdrain and infiltration, elevate the outlet to create a sump for additional moisture retention to promote plant survival and enhanced treatment. Top of IWS should be greater than 18 inches below surface.
		No underdrain	If design is fully infiltrating, ensure that subgrade compaction is minimized.
		Lateral hydraulic restriction barriers	Use a geomembrane, concrete, or bentonite clay to restrict lateral flows to adjacent subgrades, foundations, or utilities.
3	**Determine IMP Sizing Approach (A-9)**	Flow-based (common SUSMP methodology)	Refer to chapters 2 and 4 of the County SUSMP for appropriate sizing factors to determine surface area, ponding depth, and media depth. Step 4 of this design guidance section can be skipped when using this method.
		Volume-based (water quality methodology)	Per the County SUSMP, the volume of the 24-hour 85th percentile storm is required for the water quality treatment method.
4	**Size the System (A-9)**	Temporary ponding depth	6 to 18 inches (6 to 12 inches near schools or in residential areas); average ponding depth of 9 inches is recommended.
		Soil media depth	1.5 to 4 feet (deeper for increased storage and deeper rooting depths).
		Surface area (volume-based water quality)	Find surface area required to store treatment volume within temporary ponding depth, soil media depth, and gravel drainage layer depth (media porosity ≈ 0.35 and gravel porosity ≈ 0.4).
5	**Specify Soil Media (A-11)**	Composition and texture (by volume)	65 percent sand, 20 percent sandy loam, and 15 percent compost (from vegetation-based feedstock). Animal wastes or by-products should not be applied.
		Permeability	5 in/hr infiltration rate for the flow-based SUSMP method (1–6 in/hr for alternative designs, as approved by local jurisdiction).
		Chemical composition	Total phosphorus < 15 parts per million (ppm); pH 6–8; cation exchange capacity > 5 milliequivalents per 100 grams (meq/100 g) of soil; organic matter content < 5 percent by weight.

Design step		Design component/ consideration	General specification
		Drainage layer	Separate soil media from underdrain layer with 2 to 4 inches of washed sand, followed by 2 inches of choking stone (ASTM No. 8) over a 1.5-foot envelope of ASTM No. 57 stone.
6	**Design Inlet and Pretreatment (A-12)**	Inlet	Provide stabilized inlets (see Common Design Elements).
		Pretreatment	Install rock-armored forebay (concentrated flow), gravel fringe and vegetated filter strip (sheet flow), or vegetated swale.
7	**Select and Design Overflow/Bypass Method (A-14)**	Outlet configuration	Online: All runoff is routed through system; install an elevated overflow structure or weir at the elevation of maximum ponding. Offline: Only treated volume is diverted to system; install a diversion structure or allow bypass of high flows (see Common Design Elements).
		Hydromodification control	Provide additional storage and size an appropriate nonclogging orifice or weir to dewater detention volume.
8	**Select Mulch and Vegetation (A-19)**	Mulch	Dimensional chipped hardwood or triple-shredded, well-aged hardwood mulch that is 3 inches deep.
		Vegetation	See Plant Palette (Appendix E).
9	**Design for Multi-Use Benefits (A-20)**	Additional benefits	Include features to enhance habitat, aesthetics, public education, and shade.

A.1.1.1 Step 1. IMP Siting

Bioretention can be incorporated in many places to meet more than one project-level or watershed-scale objective. Examples include the following:

- Landscaped parking lot islands
- Common landscaped areas
- Parks and along open space edges
- Rights-of-way along roads

The bioretention area's configuration will determine the required components. Figure A.1-2 shows an example of the components of a typical bioretention area. When siting bioretention, consideration must always be given to provide access for routine, intermittent, and rehabilitative maintenance activities.

Bioretention areas can be combined with other integrated management practices (IMPs) to form a treatment train that can enhance water quality treatment and reduce runoff volume and rate.

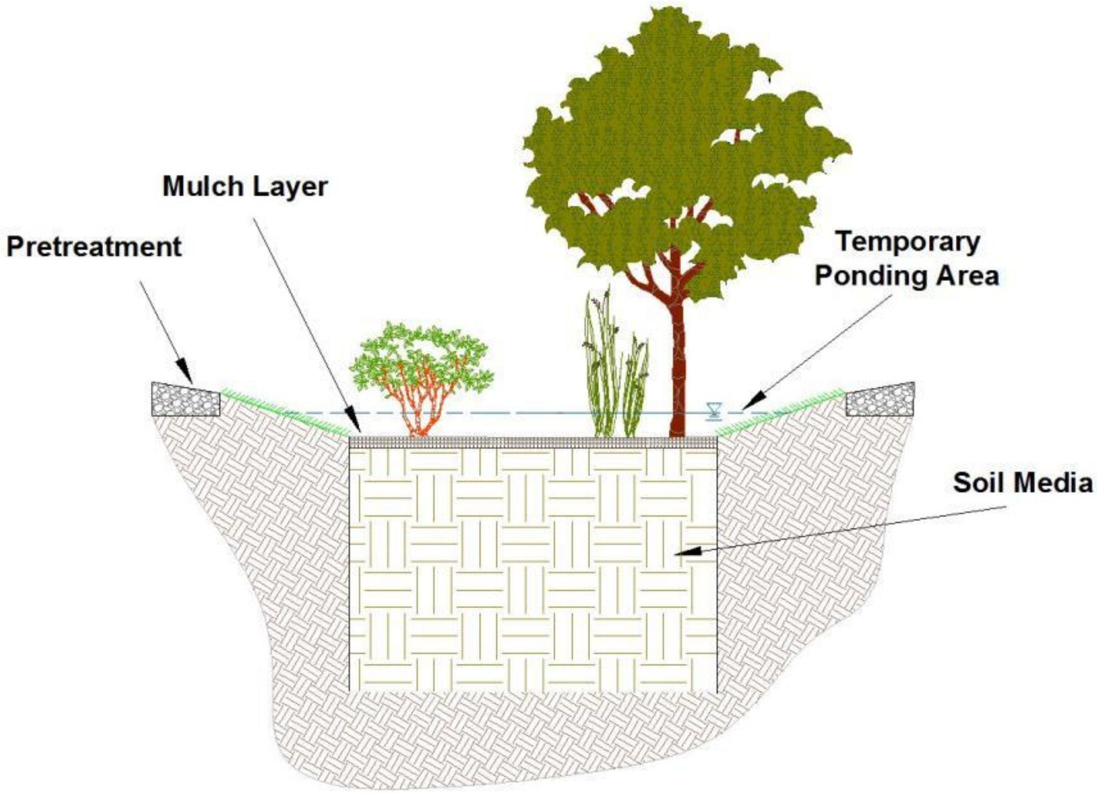

Figure A.1-2. Basic bioretention components.

A.1.1.2 Step 2. Determine IMP Function and Configuration

The following selection matrix (Figure A.1-3) and subsections describe the necessary steps to determine if the bioretention area will safely function as an infiltration or filtration IMP and provide a recommendation for the IMP configuration. Figure A.1-4 through Figure A.1-7 provide profile illustrations for each configuration.

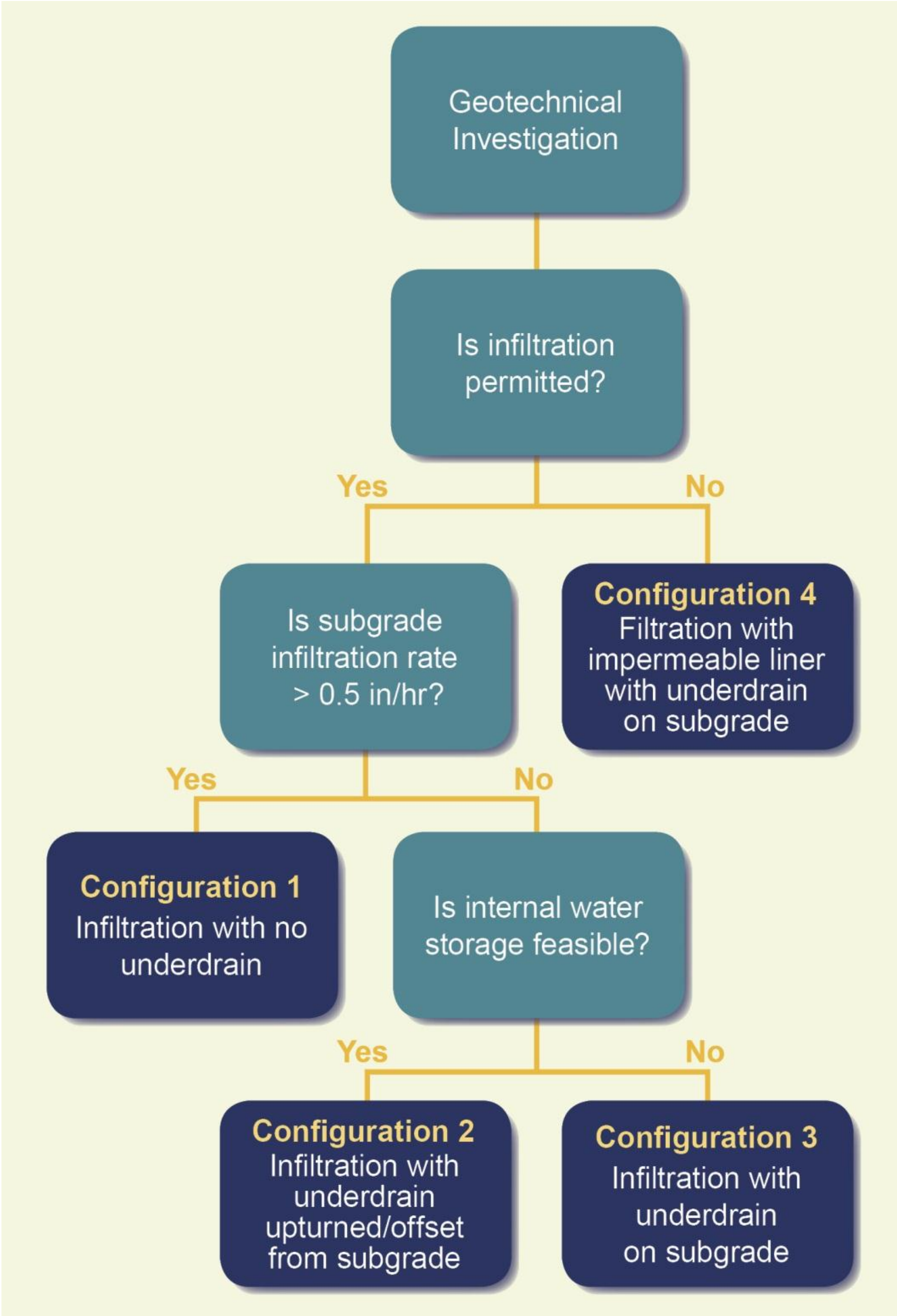

Figure A.1-3. Bioretention function selection matrix.

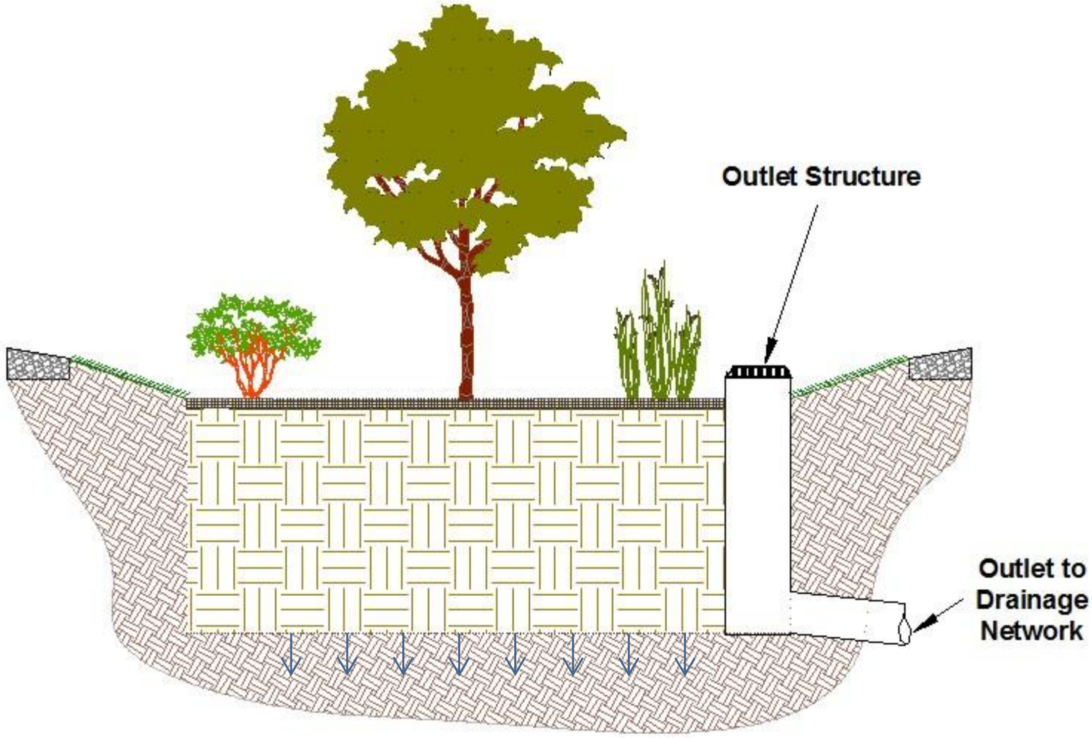

Figure A.1-4. Configuration 1 – Infiltration bioretention with no underdrain.

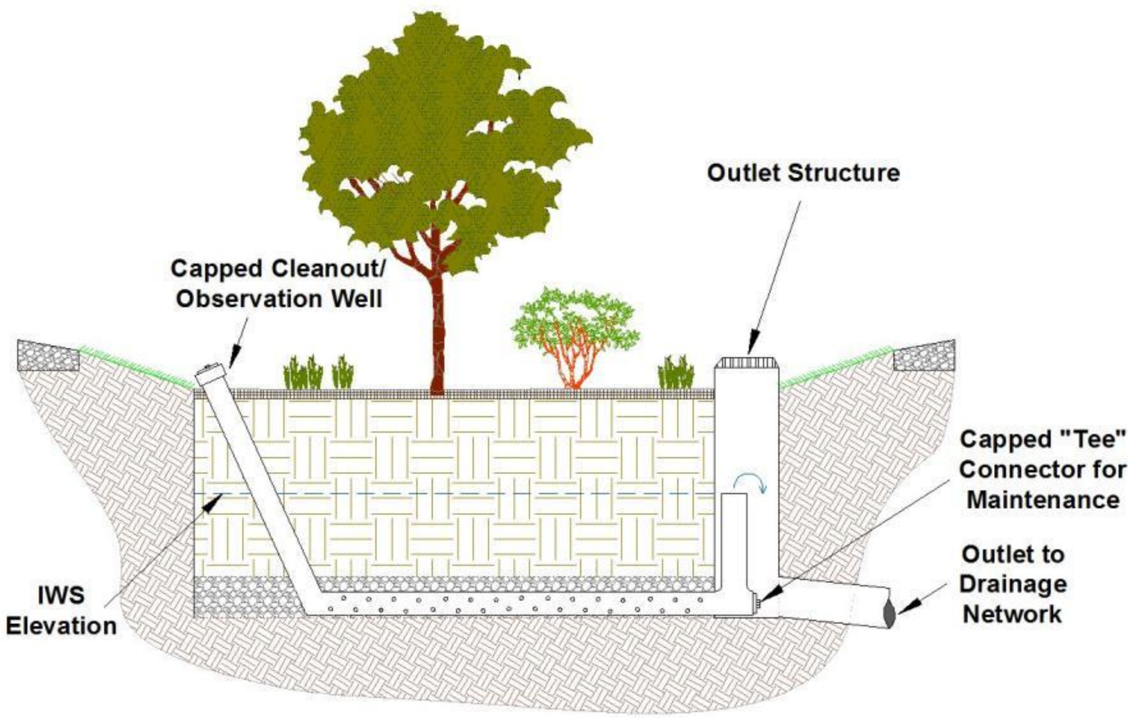

Figure A.1-5. Configuration 2 – Infiltration bioretention with upturned underdrain.

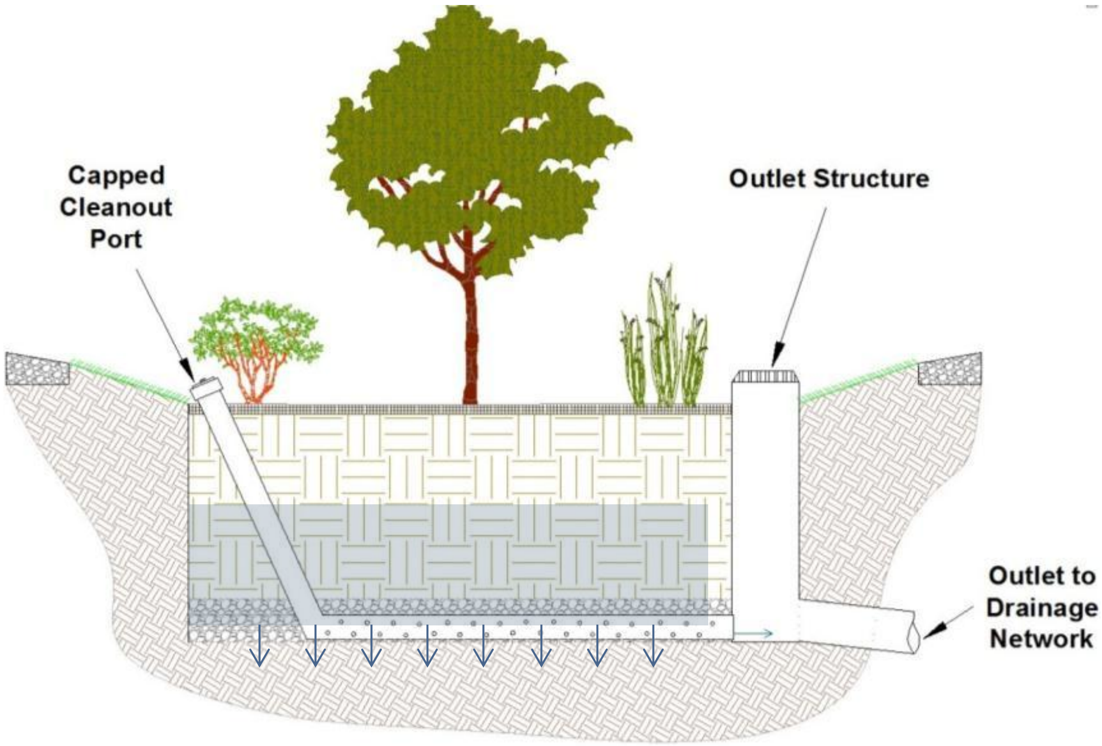

Figure A.1-6. **Configuration 3 – Infiltration bioretention with underdrain on the subgrade**.

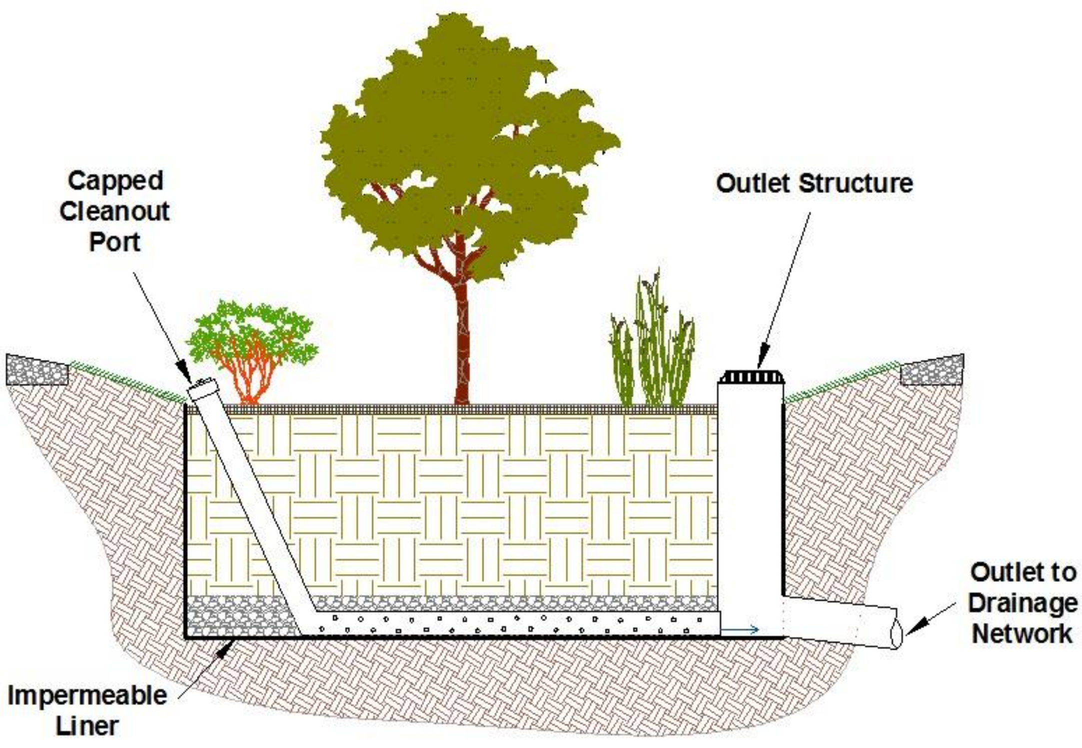

Figure A.1-7. Configuration 4 – Filtration bioretention with impermeable liner and underdrain on the subgrade.

A.1.1.2.1 Geotechnical Investigation

A licensed soil scientist or geotechnical engineer should conduct a geotechnical investigation before the IMP design. The investigator should determine the infiltration rate of the soils at the potential subgrade of the bioretention call, the depth to the seasonally high groundwater table, the presence of expansive clay minerals, and the risk for sinkhole formation. Site location with respect to aquifer recharge zones, steep slopes, water supply wells, and septic drain fields must also be assessed. See Common Design Elements for more details.

A.1.1.2.2 Determine if Infiltration is Permitted

Infiltration is not permitted if:

- Soil contamination is expected or is present.
- Runoff could unintentionally be received from a stormwater hotspot (as determined in the Standard Urban Stormwater Mitigation Plan [SUSMP]).
- Seasonal high groundwater table is within 10 feet of the proposed subgrade.
- Site is within 100 feet of a water supply well or septic drain field.
- Site is within 10 feet of a structure or foundation.
- Infiltrated water could interfere with utilities.
- Underlying geology presents risks for sinkholes or liquefaction.
- Site is within 50 feet of a steep, sensitive slope (as determined in the geotechnical analysis; see Common Design Elements).

A.1.1.2.3 Design Underdrain and Internal Water Storage

If infiltration is not permitted, an underdrain is required. For recommended underdrain specifications, see Common Design Elements. To provide internal water storage (IWS) the underdrain outlet should be elevated above the subgrade and the outlet invert should be at least 1.5 feet below the bioretention bed surface (Clark and Pitt 2009; Hunt et al. 2012). It is typically most convenient to upturn the underdrain within the receiving outlet structure using a tee connection for ease of construction and maintenance (**Error! Reference source not found.**).

A.1.1.2.4 Determine if Lateral Hydraulic Restriction Barriers are Needed

When bioretention areas are near sensitive infrastructure, such as pavement subgrades or buried utilities, hydraulic restriction barriers are often required to prevent lateral seepage. Hydraulic restriction barriers are often installed the full depth of excavation. Occasionally they are keyed in to greater depths to ensure deep vertical infiltration; the geotechnical investigator should determine the required extent of hydraulic restriction barriers. Common Design Elements provides specific details concerning lateral hydraulic restriction barrier design.

A.1.1.3 Step 3. Determine IMP Sizing Approach

The bioretention area must be sized according to the methods outlined in San Diego County's Standard Urban Stormwater Mitigation Plan (County SUSMP). The County SUSMP allows a flow-based sizing and volume-based sizing methodology. If sizing using the flow-based methodology, chapters 2 and 4 of the County SUSMP present relevant sizing regulatory requirements, and step 4 of this design guidance section can be bypassed. If sizing using the volume-based methodology, step 4 of this section presents the relevant sizing requirements.

A.1.1.4 Step 4. Size the System (Volume-Based)

Chapter 4 of the County SUSMP addresses the methods for determining the size of the IMP area. The following sections present additional considerations when using this method, such as targeted pollutant removal and the media depths required for supporting the desired vegetation.

Chapter 2 of the County SUSMP describes an alternative method to meet required water quality treatment volume. This method can be used to determine the volume of water that must be treated. Once the treatment volume is determined, vertical dimensions should be selected on the basis of pollutants of concern and site constraints before calculating the IMP footprint. The following subsections provide guidance on sizing the surface ponding depth, media depth, and footprint of bioretention areas.

A.1.1.4.1 Surface Ponding Depth

Bioretention area ponding depths should be designed following recommendations in Table A.1-2.

Table A.1-2. Bioretention design ponding depths

Surface ponding	Depths	Selection guidance
Minimum	6 inches	Provides additional storage to offset media depth requirements.
Recommended	9 inches	Ensures public safety while reducing the bioretention footprint.
Maximum	12 to 18 inches	Only use 18 inches if hydromodification mitigation is desired (details provided in Step 7).

Source: Heasom et al. 2006; Hunt et al, 2012.

A.1.1.4.2 Soil Media Depth

Soil media depth should be optimized to meet hydrologic and water quality goals, but should have a minimum depth of 1.5 feet. (Three feet is recommended for systems with IWS; Hunt et al. 2012.) The soil media provides a beneficial root zone for the chosen plant palette and adequate water storage for the water quality volume. Table A.1-3 presents recommended media depths based on vegetation type. Table A.1-4 summarizes the minimum recommended media depths for targeted removal of various pollutants (as detailed in section 3.2.1).

Table A.1-3. Bioretention design media depths

Media	Depths	Selection guidance
Minimum	1.5 feet	Vegetation is limited to shallow roots. Majority of sediment pollutant removal occurs within first 18 inches of soil.
Recommended	3 feet	Vegetation can include trees and shrubs. All pollutants, with the exception of thermal pollutants, are typically mitigated. Minimum recommended depth for IWS systems.
Maximum	4 feet	Vegetation is typically unrestrained. Depths greater than 4 feet result in high excavation costs disproportionate to pollutant removal benefit.

Source: Hunt et al. 2012.

Table A.1-4. Minimum bioretention media depth to treat pollutants of concern

Pollutant of concern	Removal zone	Recommended depth
Sediment	Surface, top 2 to 8 inches	1.5 feet
Total nitrogen	At depth in IWS layer (>2 feet)	3 feet
Total phosphorus	Top 1 to 2 feet	2 feet
Pathogens	Top 1 to 2 feet	2 feet
Metals	Top 1 to 2 feet	2 feet
Oil and grease	Surface	2 feet
Temperature	At depth	4 feet

Source: Hunt et al. 2012.

A.1.1.4.3 Size Surface Area

Using the alternative method in chapter 2 of the County SUSMP, the footprint of the bioretention area should be calculated after the desired ponding and soil media depths have been selected. Bioretention areas should be sized to fully capture the treatment volume, determined in the County SUSMP chapter 2, within the surface ponding zone and subsurface pore space. Available storage in the subsurface soil media and gravel drainage layer should be determined on the basis of the laboratory-measured porosity of materials that will be installed on-site; this information is typically available from suppliers or quarries. The porosity, n, of bioretention media can be estimated as 0.35, and the porosity of ASTM No. 57 gravel can be estimated as 0.40 for preliminary calculations (Brown et al. in press).

$$n = \frac{V_v}{V_T}$$

where

n = porosity (volume/volume)
V_v = volume of void space
V_T = total volume

The equivalent storage depth for a unit bioretention cross section can be calculated as:

$$D_{eq} = \left(D_{surface}\right) + \left(n_{media} \times D_{media}\right) + \left(n_{gravel} \times D_{gravel}\right)$$

where

D_{eq} = equivalent depth of water stored in representative cross sectional of bioretention
$D_{surface}$ = average depth of temporary surface ponding (maximum 12 inches)
n_{media} = porosity of soil media
D_{media} = depth of soil media
n_{gravel} = porosity of gravel drainage layer
D_{gravel} = depth of gravel drainage layer

If the bioretention area is being used for peak flow mitigation, the detention storage depth (volume that will bypass the soil media) cannot be included in $D_{surface}$. Step 7 provides more information.

The treatment volume (V_{wq}) is divided by the equivalent depth (D_{eq}) to calculate the required bioretention footprint:

$$A = \frac{V_{wq}}{D_{eq}}$$

where

A = required bioretention footprint (area)
V_{wq} = water quality treatment volume (determined in County SUSMP chapter 2)
D_{eq} = equivalent depth

A.1.1.5 Step 5. Specify Soil Media

Soils must be allowed to dry out periodically to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, maintain adequate soil oxygen levels for healthy soil biota and vegetation, and to provide proper soil conditions for biodegradation and retention of pollutants. Soil media should be designed to meet the drawdown times specified in Table A.1-5.

Table A.1-5. Bioretention drainage drawdown times

Drawdown time	Media drainage guidance
12 hours	Recommended design surface storage drawdown time
24 hours	Maximum surface storage drawdown time permitted
48 hours	Maximum media storage drawdown time
96 hours	Maximum drainage layer drawdown time

High background levels of phosphorus in the media have been identified as the main cause of bioretention areas exporting nutrients (Hunt and Lord 2006). All bioretention media should be analyzed for background levels of nutrients. All soil properties should be measured by a qualified soils laboratory.

Soil media should meet the specifications listed in Table A.1-6. If the existing soils meet the criteria, it can be used as the soil media. If the existing soils do not meet the criteria, soils should be amended with the appropriate components or a substitute media must be used.

Table A.1-6. Bioretention soil media specifications

Parameter	Specification[1]
Texture and composition (by volume)	Soil media should consist of a loamy sand conforming to the following specifications: • 65 percent sand, 20 percent sandy loam, 15 percent compost with 2–5 percent organic matter
Organic matter material	Aged bark fines, hardwood chips, leaf litter, or similar plant-derived organic material. Studies have also shown newspaper mulch to be an acceptable additive (Davis 2007; Kim et al. 2003). Organic matter should not include animal manure or by-products.
Infiltration rates	5 in/hr required by the flow-based SUSMP sizing method
pH	6 to 8
Cation exchange capacity	Greater than 5 milliequivalents per 100 grams (meq/100 g) of soil
Phosphorus	Total phosphorus should not exceed 15 parts per million (ppm).

[1] Refer to Appendix G for further details on bioretention soil media specifications.

A.1.1.6 Step 6. Design Inlet and Pretreatment

Inlets must be designed to convey the design storm volume into the bioretention area, while limiting ponding or flooding at the entrance to the bioretention area and protecting the interior of the bioretention area from damage. Table A.1-7 provides a few examples of pretreatment recommendations and design options.

Table A.1-7. Inlet and pretreatment design parameters

Inflow type	Typical inlets	Energy dissipation/ pretreatment	Pretreatment size	Figure
Sheet (overland)	Curb cuts[1]	Mild grades, gravel fringe	2-inch layer of ASTM No. 57 stone (underlain by filter fabric) extending 2 to 3 feet from pavement edge. Slope should not exceed 3:1 (horizontal : vertical)	Figure A.1-8
Concentrated	Channel, conduit, or swale	Rock-armor forebay Rock apron (if no pretreatment required)	Forebay: 10 percent of total IMP area. Flow velocities should not exceed 3 feet per second for grassed surfaces and 1 foot per second for mulched surfaces.	Figure A.1-9 Figure A.1-10

[1] Design guidance is provided in The Common Design Elements section.

Figure A.1-8. Gravel fringe and vegetated filter strip pretreatment.

Figure A.1-9. Inlet and pretreatment provided by mortared cobble forebay and energy dissipater.

Source: RBF Consulting

Figure A.1-10. Rock apron.

A.1.1.7 Step 7. Select And Design Outlet/Bypass Method

Two design configurations (offline or online) can be used to treat storms that are larger than the bioretention area is designed to store. If peak flow cannot be fully mitigated by the flow rate through the soil media, the outlet can be adapted to meter the rate of outflow. Table A.1-8 compares the available outlet/bypass configurations for bioretention. Table A.1-9 outlines the recommended outlet type based on the IMP siting factors discussed in section A.1.1.1.

Table A.1-8. Outlet/bypass configuration details

	Offline	Online	
Outlet design	Bypass at inlet (Figure A.1-11)	Vertical riser (Figure A.1-12)	Flow spreader (Figure A.1-13)
Description	Stormwater bypasses the bioretention area once capacity has been exceeded.	Elevated outlet structure that is connected to the underdrain or directly to the drainage system (concrete drop inlet or PVC pipe depending on flow rates).	Diffuses overflows along the exit edge. Covered with stable, watertight material. If sod is desired, a turf reinforcement mat should be installed to prevent scour.
	Diversion structure can direct flows to bioretention area. Diversion structure design is discussed in Common Design Elements.	Set at the specified ponding depth and capped with an appropriate nonclogging grate.	Set at specified ponding depth, or slightly greater if used in conjunction with a vertical riser.
		Sized to safely convey flows greater than the water quality design storm.	Can be designed as a weir to allow for varied outlet flows.

Table A.1-9. Bioretention outlet/bypass recommendations by implementation areas

IMP Siting	Recommended Outlet Type
Landscaped parking lot islands	Offline or Online
Common landscaped areas	Offline or Online
In parks and along open space edges	Offline or Online
In rights-of-way along roads	Offline

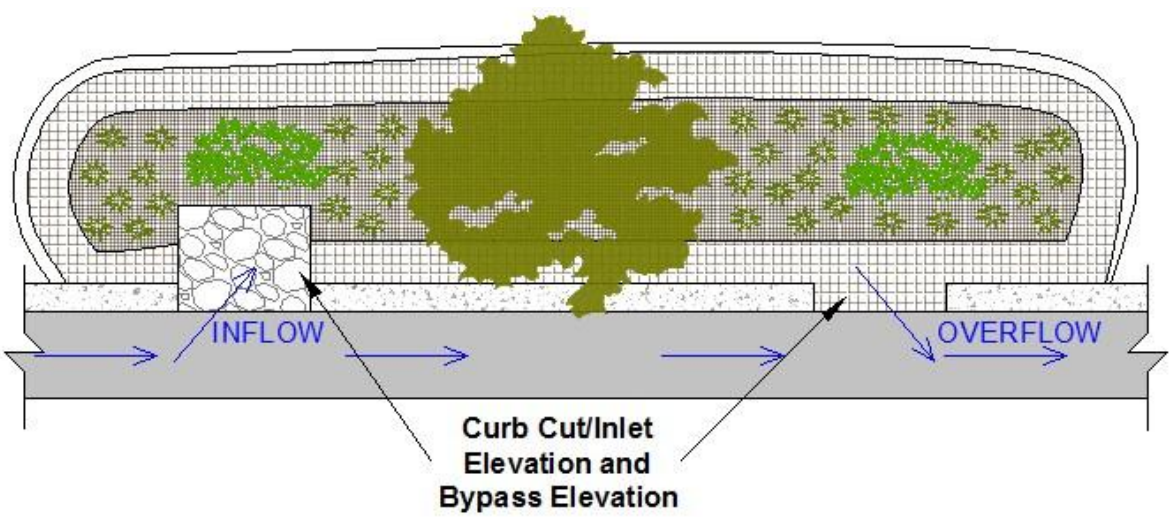

Figure A.1-11. Offline bioretention area where system fills to capacity and excess flow bypasses along curbline at inlet.

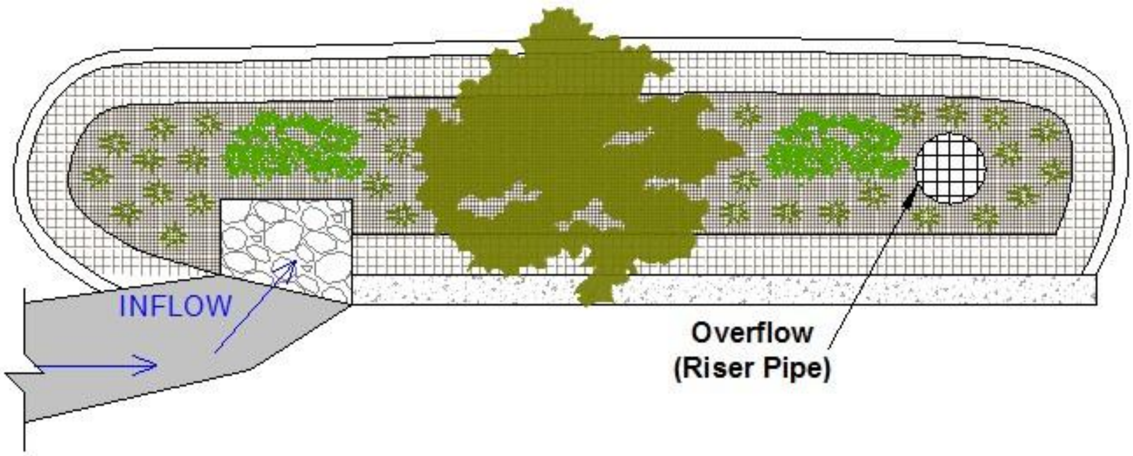

Figure A.1-12. Online bioretention area with a vertical riser overflow and a variable flow outlet structure.

Figure A.1-13. Flow spreaders (illustrated as a stabilized earthen berm in this photograph) can be used to regulate ponding depths in small, online bioretention areas.

A.1.1.7.1.1 Designing for Hydromodification

Bioretention facilities can be designed for hydromodification flow control by modifying the standard bioretention facility design criteria detailed in the County SUSMP. Specifically, hydromodification flow control can be provided by increasing both the surface area sizing factor and subsurface gravel storage layer as compared to the standard bioretention facility design, and also by modifying the facility underdrain design. To provide hydromodification flow control, the surface area sizing factor will increase as compared to the standard sizing factor based on the project location (rain gage), pre-project soil type, and pre-project land slope. Table 4-8 of the County SUSMP provides required hydromodification flow control sizing factors. The sizing factors that Table 4-8 lists provide for both hydromodification flow control and water quality treatment control. Additional design changes include the extension of the subsurface gravel storage layer to a depth of 30 inches below the bottom of the amended soil mix layer to provide additional storage as compared to the standard design, in which only a thin layer of gravel is required for protection of the underdrain. Whereas the underdrain in the standard design is unobstructed, hydromodification flow control is provided by inserting an orifice plate in the underdrain and sizing the orifice to match the hydromodification low-flow threshold. Both the soil mix layer depth (18 inches) and the surface ponding depth (10 inches) are the same for both the standard bioretention design and the hydromodification flow control design. See the Hydromodification Management Plan in the County SUSMP for a more detailed discussion.

Instead of increasing the SUSMP surface area and media depth, bioretention areas can be designed for peak flow mitigation by providing additional ponding storage and altering the discharge rate by modifying the outlet structure as shown in Figure A.1-14. If additional ponding is provided, the maximum ponding depth must not exceed 18 inches. The design should also allow for the maximum ponding drain-down time of 24 hours. Orifices that can be clogged by debris should be protected with a trash rack, a hood, or by installing a downturned pipe.

Outlet structures designed for peak flow mitigation in Camp Pendleton, California (left), where a graduated riser pipe regulates drawdown of the detention volume, and (right) at Southwest Middle School in Gastonia, North Carolina, where orifices allow controlled dewatering of the detention volume—the water quality treatment volume is retained below the orifice elevation.

Figure A.1-14. Bioretention outlet structures designed for peak flow mitigation.

Discharge of the detention volume through orifices and weirs can be calculated using the following equations:

Orifice: $Q = C_d A\sqrt{2gH}$
Weir: $Q = CLH^{3/2}$

where

Q = discharge (ft/s^2)
C_d = coefficient of discharge (0.6 for sharp openings, 0.8 for pipe openings)
A = cross-sectional area of orifice
g = acceleration due to gravity (32.2 ft/s^2)
H = head of water acting on the structure (height of water over the centerline of the orifice or height of water over the crest of the weir)
C = discharge coefficient (3.33 for broad-crested weir, 3.0 for sharp-crested weir)
L = total length of weir (perpendicular to flow)

Additional storage to meet the Hydromodification Management Plan requirements can be provided by incorporating an IWS as discussed in section A.1.1.2.3 and a deeper storage layer beneath the soil media as shown in Figure A.1-15.

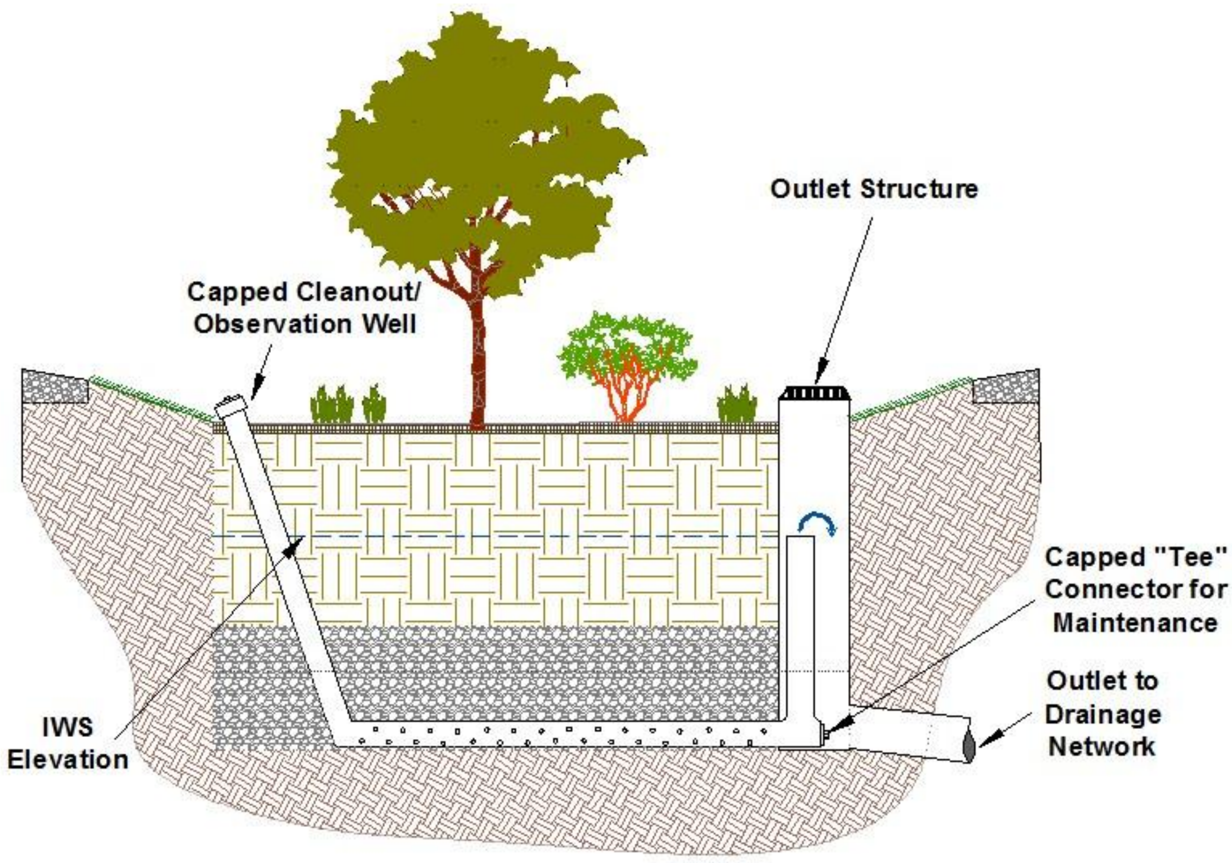

Figure A.1-15. IWS with additional storage below the soil media layer.

A.1.1.8 Step 8. Select Mulch and Vegetation

Both mulch and vegetation are critical design components of bioretention areas from hydrologic, water quality, and aesthetic perspectives. Much of the biological activity in bioretention areas occurs in the mulch and root zone. The following subsections provide specifications for mulch and vegetation.

A.1.1.8.1 Mulch

Mulch should meet the following criteria:

- Dimensional, chipped hardwood material, similar to that shown in Figure A.1-16, is preferred for its permeability of both water and air. Well-aged, triple-shredded hardwood material can also be used if dimensional, chipped hardwood material is unavailable. (*Well-aged mulch* is defined as mulch that has been stockpiled or stored for at least 12 months.)
- Must be free of weed seeds, soil, roots, and other material that is not hardwood material.
- Adequate mulch must be available for spreading to a depth of 2 to 4 inches thick, with 3 inches preferred. (Thicker applications can inhibit proper oxygen and carbon dioxide cycling between the soil and atmosphere.)

Note that grass clippings, pine nuggets, or pure bark should **NOT** be used as mulch.

Figure A.1-16. Triple-shredded hardwood mulch.

A.1.1.8.2 Vegetation

Appropriate vegetation will have the following characteristics:

- Plant materials must tolerate summer drought and extreme heat, ponding fluctuations, and saturated soil conditions for 12 to 48 hours.
- At least three of each tree, shrub, and herbaceous groundcover species should be incorporated to protect against facility failure caused by disease and insect infestations of a single species.
- Vegetation with deep and extensive root systems is more tolerant of extreme hydroperiods and can effectively transpire large volumes of soil water. Planting deep-rooting vegetation directly above buried underdrains should be avoided (although interference of plant roots with underdrains is not a common maintenance issue).
- Using native plant species or hardy cultivars that are not invasive and do not require chemical inputs is recommended to the maximum extent practicable. Only native noninvasive species should be selected for areas designated as natural open space.
- Shade trees should be free of branches below the following heights:

Caliper (inches)	Height (feet)
0.5 to 2.5	5
3	6

- Tree height and placement should consider overhead utilities.
- If large trees are to be planted in deep-fill media, care should be taken to prevent windthrow. Stakes and guy lines might be required to stabilize the trees during establishment.
- If turfgrass is preferred, sod that was not grown in clay soils should be selected (or washed “bare root” sod should be specified).
- Appendix E provides a full list of native plants appropriate for bioretention areas in the San Diego region.

Many options exist for vegetation arrangement and will most likely depend on the landscaping of the area around the bioretention facility. Size-limited landscaping could be required for bioretention areas in the right-of-way to maintain the required sight distances. Considerations should be given to water depth, bioretention configuration, desired aesthetic appearance, and potential multi-use benefits.

A.1.1.9 Step 9. Design for Multi-Use Benefits

In addition to enhancing biodiversity and beautifying the urban environment with native vegetation, the following components can be incorporated into bioretention to promote multi-use benefits:

- Simple signage or information kiosks can educate the public on the benefits of watershed protection measures or provide a guide for native plant and wildlife identification.
- Bird and butterfly feeders can be used to attract wildlife to the bioretention area.

- Sculptures and other art can be installed in the bioretention area, and outlet structures can be painted in lively colors.
- Ornamental plants can be cultivated along the perimeter and in the bed of bioretention areas. (Invasive plants should be avoided.)
- Larger bioretention areas can be equipped with pedestrian cross-paths or benches for wildlife viewing.
- Bioretention areas can function as irrigation beds for stormwater captured by other IMPs, such as rainwater harvesting or the reservoir layer of permeable pavement.
- Vegetation with canopy cover can provide shade, localized cooling, and noise dissipation.
- Volunteer groups can be organized to perform basic maintenance as an opportunity to raise public awareness.

A.1.2 Critical Construction Considerations

Construction technique and sequencing are critical to bioretention cell performance. Failure of improperly constructed systems can be easily avoided by effectively communicating with the contractor and by inspecting the system during key steps. In addition to the general construction considerations provided in Chapter 4, emphasizing the following points will help ensure successful installation of bioretention cells:

- Minimize and mitigate compaction by scarifying subsoil surface.
- Inspect soil media before placement.
- Verify that average ponding depth is provided.

A.1.3 Operations and Maintenance

Bioretention areas require regular plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. Table A.1-10 provides a detailed list of maintenance activities.

Table A.1-10. Inspection and maintenance tasks

Task	Frequency	Indicator maintenance is needed	Maintenance notes
Catchment inspection	Weekly or biweekly with routine property maintenance	Excessive sediment, trash, or debris accumulation on the surface of bioretention	Permanently stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas might need to be re-graded.
Inlet inspection	Weekly or biweekly with routine property maintenance	Internal erosion or excessive sediment, trash, and debris accumulation	Check for sediment accumulation to ensure that flow into the bioretention is as designed. Remove any accumulated sediment.
Trash and leaf litter removal	Weekly or biweekly with routine property maintenance	Accumulation of litter and leafy debris within bioretention area	Litter and leaves should be removed to reduce the risk of outlet clogging, reduce nutrient inputs to the bioretention area, and to improve facility aesthetics.
Pruning	One to two times per year	Overgrown vegetation that interferes with access, lines of sight, or safety	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	two to twelve times per year	Overgrown vegetation that interferes with access, lines of sight, or safety	Frequency depends on location and desired aesthetic appeal.
Mulch removal and replacement	One time every 2 to 3 years	2/3 of mulch has decomposed	Mulch accumulation reduces available surface water storage volume. Removal of decomposed mulch also increases surface infiltration rate of fill soil. Remove decomposed fraction and top off with fresh mulch to a total depth of 3 inches
Temporary watering	One time every 2 to 3 days for first 1 to 2 months, sporadically after established	Until established and during severe droughts	Watering after the initial year might be required.
Fertilization	One time initially	Upon planting	One-time spot fertilization for first year of vegetation.
Remove and replace dead plants	One time per year	Dead plants	Within the first year, 10 percent of plants can die. Survival rates increase with time.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Erosion at outlet	Remove any accumulated mulch or sediment. Ensure IMP maintains a drain-down time of less than 72 hours.
Miscellaneous upkeep	Twelve times per year	Tasks include trash collection, plant health, spot weeding, removing invasive species, and removing mulch from the overflow device.	

A.1.4 References

Brown, R.A., Skaggs, R.W., and Hunt, W.F. In press. Calibration and validation of DRAINMOD to model bioretention hydrology. *Journal of Hydrology*.

Clark, S.E., and R. Pitt. 2009. Storm-water filter media pollutant retention under aerobic versus anaerobic conditions. *Journal of Environmental Engineering* 135(5):367–371.

County of San Diego. 2012. *County of San Diego SUSMP: Standard Urban Stormwater Mitigation Plan Requirements for Development Applications*. http://www.sdcounty.ca.gov/dpw/watersheds/susmp/susmppdf/susmp_manual_2012.pdf.

Davis, A.P. 2007. Field performance of bioretention: Water quality. *Environmental Engineering Science* 24(8):1048–1063.

Heasom, W.R. Traver, and A. Welker. 2006. Hydrologic modeling of a bioinfiltration best management practice. *Journal of the American Water Resources Association* 42(5):1329–1347.

Hunt, W.F., and W.G. Lord. 2006. *Bioretention Performance, Design, Construction, and Maintenance*. North Carolina Cooperative Extension, Raleigh, NC.

Hunt, W.F., A.P. Davis, and R.G. Traver. 2012. Meeting hydrologic and water quality goals through targeted bioretention design. *Journal of Environmental Engineering* 138(6):698–707.

Kim, H., E.A. Seagren, and A.P. Davis. 2003. Engineered bioretention for removal of nitrate from stormwater runoff. *Water Environment Research* 75(4):355–367.