# COMMUNITY DEVELOPMENT AGENCY
## LONG RANGE PLANNING

**2850 Fairlane Court, Placerville, CA 95667**
**Phone (530) 621-4650, Fax (530) 642-0508**


# Site Design Measures Manual
# For
# El Dorado County Post-Construction Storm Water Requirements


Effective Date: July 1, 2015



Submit By: El Dorado County
Community Development Agency – Long Range Planning Division
2850 Fairlane Court
Placerville, CA 95667
(530) 573-7906

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## Contents



## Attachments

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## 1.0 Introduction

Site Design Measures shall be implemented on all Small Projects and Single Family Homes that are not part of a larger plan of development and create and/or replace (including projects with no net increase in impervious footprint) between 2,500 square feet or more of impervious surface. Site Design Measures are intended to slow, treat, retain, and infiltrate storm water runoff to mimic the natural, pre-development hydrology of the site and manage volumes of runoff from small storms onsite.

Site design measures are NOT applicable to utility linear underground/overhead projects (LUPs).

Projects creating and/or replacing 5,000 square feet or more of impervious surface are considered Regulated Projects and are required to implement appropriately sized Site Design Measures based on the objective of achieving infiltration, evapotranspiration, and/or harvesting/reuse of the 85$^{th}$ percentile 24-hour storm runoff event. Regulated Projects and Hydromodification Projects do NOT include single family home projects that are not part of a larger plan of development.

All Project applicants shall refer to the Phase II MS4 Post-Construction Requirements Table located on the El Dorado County Storm Water Programs website to determine water quality standards: http://www.edcgov.us/Government/LongRangePlanning/StormWaterManagement/Storm_Water_Pollution_Prevention.aspx

## 2.0 Site Design Measures Definitions

Applicable projects shall implement at least one of the following Site Design Measures and direct surface water runoff to the selected measure(s) for the purpose of reducing project runoff:

1. Rooftop and Impervious Area Disconnection – Rerouting of rooftop drainage pipes to drain rainwater to rain barrels, cisterns, or permeable areas instead of the storm sewer.
2. Porous Pavement – Pavement that allows runoff to pass through it, thereby reducing the runoff from a site and surrounding areas and filtering pollutants.
3. Rain Barrels and Cisterns – System that collects and stores storm water runoff from a roof or other impervious surface.
4. Vegetated Swales – Vegetated swales are open, shallow channels with vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points.
5. Bioretention Facilities – Bioretention includes depressed planting areas that have the ability to receive flows from small drainage areas and allow storm water to be retained so it can infiltrate into soil. Bioretetion areas require a special soil mix and specially selected plants.
6. Green Roofs – A vegetative layer grown on a roof (roof garden).

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## 3.0 Step-by-Step Instructions

### Step 1: Form Completion

Complete all fields in the form, print, and include with your submittal.

| | | |
|---|---|---|
| 1. | Project Name/Number | |
| 2. | Application Submittal Date | |
| 3. | Project Location<br>[Street Address if available, or intersection and/or APN] | |
| 4. | Name of Owner or Developer | |
| 5. | Project Type and Description<br>[Examples: "Single Family Residence," "Parking Lot Addition," "Retail and Parking"] | |
| 6. | Total Project Site Area (acres) | |
| 7. | Total Pre-Project Impervious Surface Area (square feet) | |
| 8. | Total New or Replaced Impervious Surface Area (square feet)<br>[Sum of impervious areas that will be constructed as part of the project] | |
| 9. | Total Post-Project Impervious Surface Area (square feet)<br>[Row 7 + Row 8] | |
| 10. | Site Design Measure(s) Selected<br>(Check one or more) | ❑ 1. Rooftop and Impervious Area Disconnection<br>❑ 2. Porous Pavements<br>❑ 3. Cistern or Rain Barrels<br>❑ 4. Vegetated Swales<br>❑ 5. Biorentention Facilities<br>❑ 6. Green Roofs |

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## Step 2: Project Sketch

Include a project sketch or site plan in your submittal - On a site plan or sketch, show the below:

- The proposed impervious area (i.e., roof, portion of a roof, or paved area) that will drain to your Site Design Measure.
- Location(s) and type(s) of Site Design Measure(s) you have selected.

Provided below is an example:

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## Step 3: Site Design Measure Options

For each Site Design Measure option selected, complete the brief checklist to confirm your design and your submittal will meet minimum requirements. Print the selected checklist(s) and include with your submittal.

**Site Design Measure Options include:**

1. Rooftop and Impervious Area Disconnection
2. Porous Pavements
3. Cistern or Rain Barrels
4. Vegetated Swales
5. Bioretention Facilities
6. Green Roofs

*Note: The following is intended to assist the designer in preparation of a complete site specific design, and it is not to replace the independent judgment and analysis by a qualified designer.*

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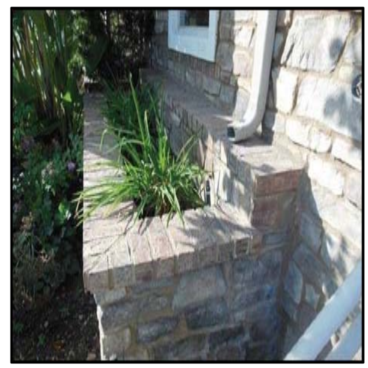
**<u>Option 1: Rooftop and Impervious Area Disconnection</u>**

This is the easiest option. Downspouts can route storm water to vegetated areas. The height of the structure makes it possible to route roof drainage some distance away from foundations and footings. Paved areas can be designed with or without curbs/curb cuts, to direct storm water runoff to surrounding vegetation.

On the site plan, show:

- ❑ Each impervious area from which runoff will be directed, and its square footage.
- ❑ The vegetated areas that will receive runoff, and the approximate square footage of each.
- ❑ If necessary, explain in notes on the plan how runoff will be routed from impervious surfaces to vegetated areas.



Directing a rooftop downspout to a vegetated area is an easy way to route drainage away from a structure and allow for infiltration. **Refer to Attachment A for additional design guidance.**

Confirm the following standard specifications are met:

- ❑ Tributary impervious square footage in no instance exceeds twice the square footage of the receiving pervious area.
- ❑ Roof areas collect runoff and route it to the receiving pervious area via gutters and downspouts.
- ❑ Paved areas are sloped so drainage is routed to the receiving pervious area.
- ❑ Runoff is dispersed across the vegetated area (for example, with a splash block) to avoid erosion and promote infiltration.
- ❑ Vegetated area has amended soils, vegetation, and irrigation as required to maintain soil stability and permeability.
- ❑ Any drain inlets within the vegetated area are at least 3 inches above surrounding grade.

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**Option 2: Porous Pavement**

This option can be easy to install and maintain, cost-effective, and can add aesthetic value to your project. Permeable pavements may include pervious concrete, pervious asphalt, porous pavers, crushed aggregate, open pavers with grass or plantings, open pavers with gravel, or solid pavers.

Show on your site plan:

- ❑ Location, type, and approximate square footage of pervious pavements.

Confirm the following standard specifications are met:

- ❑ No erodible areas drain on to permeable pavement.
- ❑ Subgrade compaction is minimal.
- ❑ Reservoir base course is of open-graded crushed stone. Base depth is adequate to retain rainfall (3 inches is adequate) and support design loads (more depth may be required).
- ❑ No subdrain is included or, if a subdrain is included, outlet elevation is a minimum of 3 inches above bottom of base course.
- ❑ Subgrade is uniform and slopes are not so steep that subgrade is prone to erosion.
- ❑ Rigid edge is provided to retain granular pavements and unit pavers.
- ❑ Solid unit pavers, if used, are set in sand or gravel with minimum 3/8 inch gaps between the pavers. Joints are filled with an open-graded aggregate free of fines.
- ❑ Permeable concrete or porous asphalt, if used, are installed by industry-certified professionals according to the vendor's recommendations.
- ❑ Selection and location of pavements incorporates Americans with Disabilities Act requirements (if applicable), site aesthetics, and uses.

Porous pavements allow runoff to pass through it, thereby reducing the runoff from a site and surrounding areas and filters pollutants. **Refer to Attachment B for additional guidance.**

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**Option 3: Cistern or Rain Barrels**

By installing cisterns or rain barrels, roof runoff is temporarily stored and then released for irrigation or infiltration between storms. Consideration must be given to selecting rain barrels that are vector proof and childproof. Additional approvals and/or permits may apply for larger systems.

Show on your site plan:

- ❑ Impervious areas tributary to each cistern or rain barrel.
- ❑ Location of each cistern or rain barrel.

Collect and store storm water runoff from a roof or other impervious surface for outdoor landscaping or non-potable water needs. **Refer to Attachment A for additional guidance.**

Confirm the following standard specifications are met:

- ❑ Rain barrels are sited at grade on a sound and level surface at or near gutter downspouts.
- ❑ Gutters tributary to rain barrels are screened with a leaf guard or maximum ½-inch to ¼-inch-minimum corrosion-resistant metallic hardware fabric.
- ❑ Water collected will be used for irrigation only.
- ❑ Openings are screened with a corrosion-resistant metallic fine mesh (1/16 inch or smaller) to prevent mosquito harborage.
- ❑ Large openings are secured to prevent entry by children.
- ❑ Rain barrels and gutters are to be cleaned annually.
- ❑ The local mosquito and vector control district is informed of the installation. The district will be provided additional information and/or rights of entry if they request.

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**Option 4: Vegetated Swales**

Vegetated swales are designed to treat storm water runoff through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils. Swales can be natural or manmade. They trap particulate pollutants (suspended solids and trace metals), promote infiltration, and reduce the flow velocity of storm water runoff. Vegetated swales can serve as part of a storm water drainage system and can replace curb and gutters.

A vegetated swale is a vegetated, open-channel management practice designed specifically to treat and attenuate (reduce) storm water runoff. The swale shown in the above photo is located at the El Dorado Hills Library and treats the library's parking lot and rooftop runoff.

Show on your site plan:

- ❑ Impervious areas tributary to the vegetated swale.
- ❑ Location and footprint of the vegetated swale.

Confirm the following standard specifications are met:

- ❑ Have all vegetated swales been designed in accordance with Treatment Control BMP 30 (TC-30 - Vegetated Swale) from the California Stormwater BMP Handbook, New Development and Redevelopment? **TC-30 is provided in Attachment C of this manual.**

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**Option 5: Bioretention Facilities**

An above-ground bioretention facility may be appropriate for projects with site constraints (i.e., slopes and the inability to install porous pavements). Bioretention facilities can treat runoff from impervious surfaces approximately 25 times their area (sizing factor of 4%). **Bioretention design guidance and a Plant List are provided in Attachment D**.

Show on your site plan:

- ❑ Impervious areas tributary to the bioretention facility.
- ❑ Location and footprint of bioretention facility.

Confirm the following standard specifications are met:

- ❑ Reservoir depth is 4"-6" minimum.
- ❑ 18" depth soil mix with minimum long-term infiltration rate of 5"/hour.
- ❑ Bioretention Soil shall be a mixture of fine sand/loam and compost, measured on the volume basis: 65% Sand, 20% Sandy Loam, and 15% Compost.
- ❑ Surface area of soil mix is a minimum 0.04 times the tributary impervious area.
- ❑ “Class 2 perm” drainage layer 12" deep.
- ❑ No filter fabric.
- ❑ Perforated pipe (PVC SDR 35 or approved equivalent) underdrain with outlet located flush or nearly flush with planter bottom.

Bioretention facilities look like regular landscaped areas but they are designed (engineered) to manage storm water runoff volumes and pollutants created by urbanization. Specifying the appropriate plants and soil for a bioretention system is critical to its performance.

- ❑ Connection with sufficient head to storm drain or discharge point. Flows from the underdrain and overflow must be directed in accordance with the County’s Drainage Manual.
- ❑ Underdrain has a clean-out port consisting of a vertical, rigid, non-perforated PVC pipe, connected to the underdrain via a sweep bend, with a minimum diameter of 4" and a watertight cap.
- ❑ Overflow outlet connected to a downstream storm drain or approved discharge point.
- ❑ Emergency spillage will be safely conveyed overland.
- ❑ Plantings are suitable to the climate, exposure, and a well-drained soil.
- ❑ Irrigation system with connection to water supply, on a separate zone.

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**Option 6: Green Roofs**

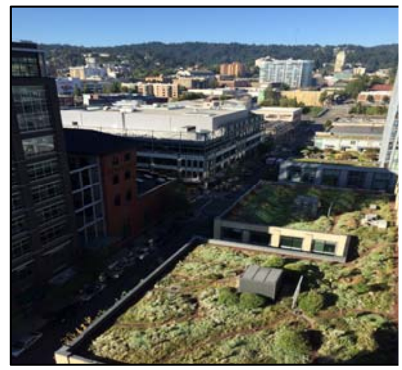
Green roofs are a Green Stormwater Infrastructure Best Management Practice that intercepts precipitation, thereby greatly reducing the contribution of rooftop runoff to stormwater. If properly maintained, green roofs provide other useful benefits such as reduced heat-island effect, reduced need for heating and cooling of a structure, and a longer lifespan when compared to a traditional roof. Green roofs must be designed by a qualified engineer.

Show on your site plan:

- ❑ Location and approximate square footage of the green roof.

Confirm the following standard specifications are met

- ❑ Has a professional engineer assessed the necessary load reserves and designed a roof structure to meet state and local codes?
- ❑ Are the approved engineered plans attached to your submittal?
- ❑ Is the irrigation needed for plant establishment and/or to sustain the green roof during extended dry periods, is the source from stored, recycled, reclaimed, or reused water?
- ❑ Is the roof slope less than 15% or does it have a grid to hold the substrate in place until it forms a thick vegetation mat?



In urban areas, green roofs can provide valuable open space where little exists. Green Roof design guidance can be found at: **http://www.lid-stormwater.net/greenroofs_home.htm**

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### Step 4: Submit Your Post Construction Storm Water Control Plan

Submit your Post Construction Storm Water Control Plan (with your selected site design measure worksheets completed above) with your Permit Application package for approval. If you have any questions, please consult with municipal staff by calling (530) 573-7906.

## 4.0 Useful Resources

The following online resources may be useful for design. Designs must meet the minimum standard specifications herein and shall be completed by a qualified designer.

- Environmental Protection Agency LID
  http://water.epa.gov/polwaste/green/
- Urban Design Tools LID
  http://www.lid-stormwater.net/
- Low Impact Development Center
  www.lowimpactdevelopment.org
- LID Urban Design Tools
  www.lid-stormwater.net
- California Stormwater Quality Association
  https://www.casqa.org/resources/california-lid-portal
- Interlocking Concrete Pavement Institute
  http://www.icpi.org/
- Concrete Promotion Council of Northern California.
  http://www.cpcnc.org/categories/membership/membership.html
- California Asphalt Pavement Association
  http://www.calapa.net/stormwater.html
- Start At the Source: Design Guidance Manual for Stormwater Quality.
  Bay Area Stormwater Management Agencies Association, 1999.
  http://www.cccleanwater.org/Publications/StartAtTheSource/Start_At_The_Source_Full.pdf
- State Water Resources Control Board's Storm Water Films
  http://www.swrcb.ca.gov/stormfilm/

# ATTACHMENT A

## Options 1 and 3 Rooftop Runoff Controls SD-11 CASQA Design Guidance

# Roof Runoff Controls SD-11

Rain Garden

## Design Objectives

- ☑ Maximize Infiltration
- ☑ Provide Retention
- ☑ Slow Runoff
- Minimize Impervious Land Coverage
- Prohibit Dumping of Improper Materials
- ☑ Contain Pollutants
- Collect and Convey

## Description

Various roof runoff controls are available to address stormwater that drains off rooftops. The objective is to reduce the total volume and rate of runoff from individual lots, and retain the pollutants on site that may be picked up from roofing materials and atmospheric deposition. Roof runoff controls consist of directing the roof runoff away from paved areas and mitigating flow to the storm drain system through one of several general approaches: cisterns or rain barrels; dry wells or infiltration trenches; pop-up emitters, and foundation planting. The first three approaches require the roof runoff to be contained in a gutter and downspout system. Foundation planting provides a vegetated strip under the drip line of the roof.

## Approach

Design of individual lots for single-family homes as well as lots for higher density residential and commercial structures should consider site design provisions for containing and infiltrating roof runoff or directing roof runoff to vegetative swales or buffer areas. Retained water can be reused for watering gardens, lawns, and trees. Benefits to the environment include reduced demand for potable water used for irrigation, improved stormwater quality, increased groundwater recharge, decreased runoff volume and peak flows, and decreased flooding potential.

## Suitable Applications

Appropriate applications include residential, commercial and industrial areas planned for development or redevelopment.

## Design Considerations

### *Designing New Installations*

*Cisterns or Rain Barrels*

One method of addressing roof runoff is to direct roof downspouts to cisterns or rain barrels. A cistern is an above ground storage vessel with either a manually operated valve or a permanently open outlet. Roof runoff is temporarily stored and then released for irrigation or infiltration between storms. The number of rain

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barrels needed is a function of the rooftop area. Some low impact developers recommend that every house have at least 2 rain barrels, with a minimum storage capacity of 1000 liters. Roof barrels serve several purposes including mitigating the first flush from the roof which has a high volume, amount of contaminants, and thermal load. Several types of rain barrels are commercially available. Consideration must be given to selecting rain barrels that are vector proof and childproof. In addition, some barrels are designed with a bypass valve that filters out grit and other contaminants and routes overflow to a soak-away pit or rain garden.

If the cistern has an operable valve, the valve can be closed to store stormwater for irrigation or infiltration between storms. This system requires continual monitoring by the resident or grounds crews, but provides greater flexibility in water storage and metering. If a cistern is provided with an operable valve and water is stored inside for long periods, the cistern must be covered to prevent mosquitoes from breeding.

A cistern system with a permanently open outlet can also provide for metering stormwater runoff. If the cistern outlet is significantly smaller than the size of the downspout inlet (say ¼ to ½ inch diameter), runoff will build up inside the cistern during storms, and will empty out slowly after peak intensities subside. This is a feasible way to mitigate the peak flow increases caused by rooftop impervious land coverage, especially for the frequent, small storms.

*Dry wells and Infiltration Trenches*

Roof downspouts can be directed to dry wells or infiltration trenches. A dry well is constructed by excavating a hole in the ground and filling it with an open graded aggregate, and allowing the water to fill the dry well and infiltrate after the storm event. An underground connection from the downspout conveys water into the dry well, allowing it to be stored in the voids. To minimize sedimentation from lateral soil movement, the sides and top of the stone storage matrix can be wrapped in a permeable filter fabric, though the bottom may remain open. A perforated observation pipe can be inserted vertically into the dry well to allow for inspection and maintenance.

In practice, dry wells receiving runoff from single roof downspouts have been successful over long periods because they contain very little sediment. They must be sized according to the amount of rooftop runoff received, but are typically 4 to 5 feet square, and 2 to 3 feet deep, with a minimum of 1-foot soil cover over the top (maximum depth of 10 feet).

To protect the foundation, dry wells must be set away from the building at least 10 feet. They must be installed in solids that accommodate infiltration. In poorly drained soils, dry wells have very limited feasibility.

Infiltration trenches function in a similar manner and would be particularly effective for larger roof areas. An infiltration trench is a long, narrow, rock-filled trench with no outlet that receives stormwater runoff. These are described under Treatment Controls.

*Pop-up Drainage Emitter*

Roof downspouts can be directed to an underground pipe that daylights some distance from the building foundation, releasing the roof runoff through a pop-up emitter. Similar to a pop-up irrigation head, the emitter only opens when there is flow from the roof. The emitter remains flush to the ground during dry periods, for ease of lawn or landscape maintenance.

*Foundation Planting*

Landscape planting can be provided around the base to allow increased opportunities for stormwater infiltration and protect the soil from erosion caused by concentrated sheet flow coming off the roof. Foundation plantings can reduce the physical impact of water on the soil and provide a subsurface matrix of roots that encourage infiltration. These plantings must be sturdy enough to tolerate the heavy runoff sheet flows, and periodic soil saturation.

***Redeveloping Existing Installations***

Various jurisdictional stormwater management and mitigation plans (SUSMP, WQMP, etc.) define "redevelopment" in terms of amounts of additional impervious area, increases in gross floor area and/or exterior construction, and land disturbing activities with structural or impervious surfaces. The definition of " redevelopment" must be consulted to determine whether or not the requirements for new development apply to areas intended for redevelopment. If the definition applies, the steps outlined under "designing new installations" above should be followed.

## Supplemental Information

***Examples***

- City of Ottawa's Water Links Surface –Water Quality Protection Program
- City of Toronto Downspout Disconnection Program
- City of Boston, MA, Rain Barrel Demonstration Program

## Other Resources

Hager, Marty Catherine, Stormwater, "Low-Impact Development", January/February 2003. www.stormh2o.com

Low Impact Urban Design Tools, Low Impact Development Design Center, Beltsville, MD. www.lid-stormwater.net

Start at the Source, Bay Area Stormwater Management Agencies Association, 1999 Edition

**ATTACHMENT B**

**Option 2 Porous Pavement SD-20 CASQA Design Guidance**

# Pervious Pavements SD-20


### Design Objectives

- ☑ Maximize Infiltration
- ☑ Provide Retention
- ☑ Slow Runoff
- ☑ Minimize Impervious Land Coverage
- Prohibit Dumping of Improper Materials
- Contain Pollutants
- Collect and Convey

## Description

Pervious paving is used for light vehicle loading in parking areas. The term describes a system comprising a load-bearing, durable surface together with an underlying layered structure that temporarily stores water prior to infiltration or drainage to a controlled outlet. The surface can itself be porous such that water infiltrates across the entire surface of the material (e.g., grass and gravel surfaces, porous concrete and porous asphalt), or can be built up of impermeable blocks separated by spaces and joints, through which the water can drain. This latter system is termed 'permeable' paving. Advantages of pervious pavements is that they reduce runoff volume while providing treatment, and are unobtrusive resulting in a high level of acceptability.

## Approach

Attenuation of flow is provided by the storage within the underlying structure or sub base, together with appropriate flow controls. An underlying geotextile may permit groundwater recharge, thus contributing to the restoration of the natural water cycle. Alternatively, where infiltration is inappropriate (e.g., if the groundwater vulnerability is high, or the soil type is unsuitable), the surface can be constructed above an impermeable membrane. The system offers a valuable solution for drainage of spatially constrained urban areas.

Significant attenuation and improvement in water quality can be achieved by permeable pavements, whichever method is used. The surface and subsurface infrastructure can remove both the soluble and fine particulate pollutants that occur within urban runoff. Roof water can be piped into the storage area directly, adding areas from which the flow can be attenuated. Also, within lined systems, there is the opportunity for stored runoff to be piped out for reuse.

## Suitable Applications

Residential, commercial and industrial applications are possible. The use of permeable pavement may be restricted in cold regions, arid regions or regions with high wind erosion. There are some specific disadvantages associated with permeable pavement, which are as follows:

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- Permeable pavement can become clogged if improperly installed or maintained. However, this is countered by the ease with which small areas of paving can be cleaned or replaced when blocked or damaged.
- Their application should be limited to highways with low traffic volumes, axle loads and speeds (less than 30 mph limit), car parking areas and other lightly trafficked or non-trafficked areas. Permeable surfaces are currently not considered suitable for adoptable roads due to the risks associated with failure on high speed roads, the safety implications of ponding, and disruption arising from reconstruction.
- When using un-lined, infiltration systems, there is some risk of contaminating groundwater, depending on soil conditions and aquifer susceptibility. However, this risk is likely to be small because the areas drained tend to have inherently low pollutant loadings.
- The use of permeable pavement is restricted to gentle slopes.
- Porous block paving has a higher risk of abrasion and damage than solid blocks.

## Design Considerations

### *Designing New Installations*

If the grades, subsoils, drainage characteristics, and groundwater conditions are suitable, permeable paving may be substituted for conventional pavement on parking areas, cul de sacs and other areas with light traffic. Slopes should be flat or very gentle. Scottish experience has shown that permeable paving systems can be installed in a wide range of ground conditions, and the flow attenuation performance is excellent even when the systems are lined.

The suitability of a pervious system at a particular pavement site will, however, depend on the loading criteria required of the pavement.

Where the system is to be used for infiltrating drainage waters into the ground, the vulnerability of local groundwater sources to pollution from the site should be low, and the seasonal high water table should be at least 4 feet below the surface.

Ideally, the pervious surface should be horizontal in order to intercept local rainfall at source. On sloping sites, pervious surfaces may be terraced to accommodate differences in levels.

*Design Guidelines*

The design of each layer of the pavement must be determined by the likely traffic loadings and their required operational life. To provide satisfactory performance, the following criteria should be considered:

- The subgrade should be able to sustain traffic loading without excessive deformation.
- The granular capping and sub-base layers should give sufficient load-bearing to provide an adequate construction platform and base for the overlying pavement layers.
- The pavement materials should not crack of suffer excessive rutting under the influence of traffic. This is controlled by the horizontal tensile stress at the base of these layers.

There is no current structural design method specifically for pervious pavements. Allowances should be considered the following factors in the design and specification of materials:

- Pervious pavements use materials with high permeability and void space. All the current UK pavement design methods are based on the use of conventional materials that are dense and relatively impermeable. The stiffness of the materials must therefore be assessed.
- Water is present within the construction and can soften and weaken materials, and this must be allowed for.
- Existing design methods assume full friction between layers. Any geotextiles or geomembranes must be carefully specified to minimize loss of friction between layers.
- Porous asphalt loses adhesion and becomes brittle as air passes through the voids. Its durability is therefore lower than conventional materials.

The single sized grading of materials used means that care should be taken to ensure that loss of finer particles between unbound layers does not occur.

Positioning a geotextile near the surface of the pervious construction should enable pollutants to be trapped and retained close to the surface of the construction. This has both advantages and disadvantages. The main disadvantage is that the filtering of sediments and their associated pollutants at this level may hamper percolation of waters and can eventually lead to surface ponding. One advantage is that even if eventual maintenance is required to reinstate infiltration, only a limited amount of the construction needs to be disturbed, since the sub-base below the geotextile is protected. In addition, the pollutant concentration at a high level in the structure allows for its release over time. It is slowly transported in the stormwater to lower levels where chemical and biological processes may be operating to retain or degrade pollutants.

The design should ensure that sufficient void space exists for the storage of sediments to limit the period between remedial works.

- Pervious pavements require a single size grading to give open voids. The choice of materials is therefore a compromise between stiffness, permeability and storage capacity.
- Because the sub-base and capping will be in contact with water for a large part of the time, the strength and durability of the aggregate particles when saturated and subjected to wetting and drying should be assessed.
- A uniformly graded single size material cannot be compacted and is liable to move when construction traffic passes over it. This effect can be reduced by the use of angular crushed rock material with a high surface friction.

In pollution control terms, these layers represent the site of long term chemical and biological pollutant retention and degradation processes. The construction materials should be selected, in addition to their structural strength properties, for their ability to sustain such processes. In general, this means that materials should create neutral or slightly alkaline conditions and they should provide favorable sites for colonization by microbial populations.

*Construction/Inspection Considerations*

- Permeable surfaces can be laid without cross-falls or longitudinal gradients.
- The blocks should be lain level
- They should not be used for storage of site materials, unless the surface is well protected from deposition of silt and other spillages.
- The pavement should be constructed in a single operation, as one of the last items to be built, on a development site. Landscape development should be completed before pavement construction to avoid contamination by silt or soil from this source.
- Surfaces draining to the pavement should be stabilized before construction of the pavement.
- Inappropriate construction equipment should be kept away from the pavement to prevent damage to the surface, sub-base or sub-grade.

*Maintenance Requirements*

The maintenance requirements of a pervious surface should be reviewed at the time of design and should be clearly specified. Maintenance is required to prevent clogging of the pervious surface. The factors to be considered when defining maintenance requirements must include:

- Type of use
- Ownership
- Level of trafficking
- The local environment and any contributing catchments

Studies in the UK have shown satisfactory operation of porous pavement systems without maintenance for over 10 years and recent work by Imbe et al. at 9th ICUD, Portland, 2002 describes systems operating for over 20 years without maintenance. However, performance under such regimes could not be guaranteed, Table 1 shows typical recommended maintenance regimes:

| Table 1 Typical Recommended Maintenance Regimes | |
|---|---|
| **Activity** | **Schedule** |
| ▪ Minimize use of salt or grit for de-icing<br>▪ Keep landscaped areas well maintained<br>▪ Prevent soil being washed onto pavement | Ongoing |
| ▪ Vacuum clean surface using commercially available sweeping machines at the following times:<br>- End of winter (April)<br>- Mid-summer (July / August)<br>- After Autumn leaf-fall (November) | 2/3 x per year |
| ▪ Inspect outlets | Annual |
| ▪ If routine cleaning does not restore infiltration rates, then reconstruction of part of the whole of a pervious surface may be required.<br>▪ The surface area affected by hydraulic failure should be lifted for inspection of the internal materials to identify the location and extent of the blockage.<br>▪ Surface materials should be lifted and replaced after brush cleaning. Geotextiles may need complete replacement.<br>▪ Sub-surface layers may need cleaning and replacing.<br>▪ Removed silts may need to be disposed of as controlled waste. | As needed (infrequent)<br>Maximum 15-20 years |

Permeable pavements are up to 25 % cheaper (or at least no more expensive than the traditional forms of pavement construction), when all construction and drainage costs are taken into account. (Accepting that the porous asphalt itself is a more expensive surfacing, the extra cost of which is offset by the savings in underground pipework etc.) (Niemczynowicz, et al., 1987)

Table 1 gives US cost estimates for capital and maintenance costs of porous pavements (Landphair et al., 2000)

### *Redeveloping Existing Installations*

Various jurisdictional stormwater management and mitigation plans (SUSMP, WQMP, etc.) define "redevelopment" in terms of amounts of additional impervious area, increases in gross floor area and/or exterior construction, and land disturbing activities with structural or impervious surfaces. The definition of " redevelopment" must be consulted to determine whether or not the requirements for new development apply to areas intended for redevelopment. If the definition applies, the steps outlined under "designing new installations" above should be followed.

## Additional Information

*Cost Considerations*

Permeable pavements are up to 25 % cheaper (or at least no more expensive than the traditional forms of pavement construction), when all construction and drainage costs are taken into account. (Accepting that the porous asphalt itself is a more expensive surfacing, the extra cost of which is offset by the savings in underground pipework etc.) (Niemczynowicz, et al., 1987)

Table 2 gives US cost estimates for capital and maintenance costs of porous pavements (Landphair et al., 2000)

**Table 2 Engineer's Estimate for Porous Pavement**

| Porous Pavement | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Units | Price | Cycles/ Year | Quant. 1 Acre WS | Total | Quant. 2 Acre WS | Total | Quant. 3 Acre WS | Total | Quant. 4 Acre WS | Total | Quant. 5 Acre WS | Total |
| Grading | SY | $2.00 | | 604 | $1,208 | 1209 | $2,418 | 1812 | $3,624 | 2419 | $4,838 | 3020 | $6,040 |
| Paving | SY | $19.00 | | 212 | $4,028 | 424 | $8,056 | 636 | $12,084 | 848 | $16,112 | 1060 | $20,140 |
| Excavation | CY | $3.60 | | 201 | $724 | 403 | $1,451 | 604 | $2,174 | 806 | $2,902 | 1008 | $3,629 |
| Filter Fabric | SY | $1.15 | | 700 | $805 | 1400 | $1,610 | 2000 | $2,300 | 2800 | $3,220 | 3600 | $4,140 |
| Stone Fill | CY | $16.00 | | 201 | $3,216 | 403 | $6,448 | 604 | $9,664 | 806 | $12,896 | 1008 | $16,128 |
| Sand | CY | $7.00 | | 100 | $700 | 200 | $1,400 | 300 | $2,100 | 400 | $2,800 | 500 | $3,500 |
| Sight Well | EA | $300.00 | | 2 | $600 | 3 | $900 | 4 | $1,200 | 7 | $2,100 | 7 | $2,100 |
| Seeding | LF | $0.05 | | 644 | $32 | 1288 | $64 | 1932 | $97 | 2576 | $129 | 3220 | $161 |
| Check Dam | CY | $35.00 | | 0 | $0 | 0 | $0 | 0 | $0 | 0 | $0 | 0 | $0 |
| Total Construction Costs | | | | | $10,105 | | $19,929 | | $29,619 | | $40,158 | | $49,798 |
| Construction Costs Amortized for 20 Years | | | | | $505 | | $996 | | $1,481 | | $2,008 | | $2,490 |
| Annual Maintenance Expense | | | | | | | | | | | | | |
| Item | Units | Price | Cycles/ Year | Quant. 1 Acre WS | Total | Quant. 2 Acre WS | Total | Quant. 3 Acre WS | Total | Quant. 4 Acre WS | Total | Quant. 5 Acre WS | Total |
| Sweeping | AC | $250.00 | 6 | 1 | $1,500 | 2 | $3,000 | 3 | $4,500 | 4 | $6,000 | 5 | $7,500 |
| Washing | AC | $250.00 | 6 | 1 | $1,500 | 2 | $3,000 | 3 | $4,500 | 4 | $6,000 | 5 | $7,500 |
| Inspection | MH | $20.00 | 5 | 5 | $100 | 5 | $100 | 5 | $100 | 5 | $100 | 5 | $100 |
| Deep Clean | AC | $450.00 | 0.5 | 1 | $225 | 2 | $450 | 3 | $675 | 3.9 | $878 | 5 | $1,125 |
| Total Annual Maintenance Expense | | | | | $3,960 | | $7,792 | | $11,651 | | $15,483 | | $19,370 |

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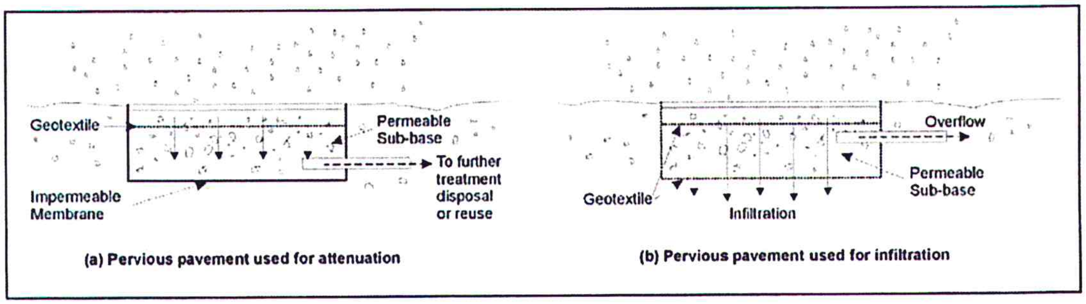


**Schematics of a Pervious Pavement System**

# ATTACHMENT C

## Option 4 Vegetated Swale TC-30 CASQA Design Guidance

## Design Considerations

- Tributary Area
- Area Required
- Slope
- Water Availability

## Description

Vegetated swales are open, shallow channels with vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. They are designed to treat runoff through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils. Swales can be natural or manmade. They trap particulate pollutants (suspended solids and trace metals), promote infiltration, and reduce the flow velocity of stormwater runoff. Vegetated swales can serve as part of a stormwater drainage system and can replace curbs, gutters and storm sewer systems.

## California Experience

Caltrans constructed and monitored six vegetated swales in southern California. These swales were generally effective in reducing the volume and mass of pollutants in runoff. Even in the areas where the annual rainfall was only about 10 inches/yr, the vegetation did not require additional irrigation. One factor that strongly affected performance was the presence of large numbers of gophers at most of the sites. The gophers created earthen mounds, destroyed vegetation, and generally reduced the effectiveness of the controls for TSS reduction.

## Advantages

- If properly designed, vegetated, and operated, swales can serve as an aesthetic, potentially inexpensive urban development or roadway drainage conveyance measure with significant collateral water quality benefits.

## Targeted Constituents

| | Constituent | Removal |
|---|---|---|
| ☑ | Sediment | ▲ |
| ☑ | Nutrients | ● |
| ☑ | Trash | ● |
| ☑ | Metals | ▲ |
| ☑ | Bacteria | ● |
| ☑ | Oil and Grease | ▲ |
| ☑ | Organics | ▲ |

Legend *(Removal Effectiveness)*

● Low ■ High

▲ Medium

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- Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible.

## Limitations

- Can be difficult to avoid channelization.
- May not be appropriate for industrial sites or locations where spills may occur
- Grassed swales cannot treat a very large drainage area. Large areas may be divided and treated using multiple swales.
- A thick vegetative cover is needed for these practices to function properly.
- They are impractical in areas with steep topography.
- They are not effective and may even erode when flow velocities are high, if the grass cover is not properly maintained.
- In some places, their use is restricted by law: many local municipalities require curb and gutter systems in residential areas.
- Swales are mores susceptible to failure if not properly maintained than other treatment BMPs.

## Design and Sizing Guidelines

- Flow rate based design determined by local requirements or sized so that 85% of the annual runoff volume is discharged at less than the design rainfall intensity.
- Swale should be designed so that the water level does not exceed 2/3rds the height of the grass or 4 inches, which ever is less, at the design treatment rate.
- Longitudinal slopes should not exceed 2.5%
- Trapezoidal channels are normally recommended but other configurations, such as parabolic, can also provide substantial water quality improvement and may be easier to mow than designs with sharp breaks in slope.
- Swales constructed in cut are preferred, or in fill areas that are far enough from an adjacent slope to minimize the potential for gopher damage. Do not use side slopes constructed of fill, which are prone to structural damage by gophers and other burrowing animals.
- A diverse selection of low growing, plants that thrive under the specific site, climatic, and watering conditions should be specified. Vegetation whose growing season corresponds to the wet season are preferred. Drought tolerant vegetation should be considered especially for swales that are not part of a regularly irrigated landscaped area.
- The width of the swale should be determined using Manning's Equation using a value of 0.25 for Manning's n.

### *Construction/Inspection Considerations*

- Include directions in the specifications for use of appropriate fertilizer and soil amendments based on soil properties determined through testing and compared to the needs of the vegetation requirements.
- Install swales at the time of the year when there is a reasonable chance of successful establishment without irrigation; however, it is recognized that rainfall in a given year may not be sufficient and temporary irrigation may be used.
- If sod tiles must be used, they should be placed so that there are no gaps between the tiles; stagger the ends of the tiles to prevent the formation of channels along the swale or strip.
- Use a roller on the sod to ensure that no air pockets form between the sod and the soil.
- Where seeds are used, erosion controls will be necessary to protect seeds for at least 75 days after the first rainfall of the season.

## Performance

The literature suggests that vegetated swales represent a practical and potentially effective technique for controlling urban runoff quality. While limited quantitative performance data exists for vegetated swales, it is known that check dams, slight slopes, permeable soils, dense grass cover, increased contact time, and small storm events all contribute to successful pollutant removal by the swale system. Factors decreasing the effectiveness of swales include compacted soils, short runoff contact time, large storm events, frozen ground, short grass heights, steep slopes, and high runoff velocities and discharge rates.

Conventional vegetated swale designs have achieved mixed results in removing particulate pollutants. A study performed by the Nationwide Urban Runoff Program (NURP) monitored three grass swales in the Washington, D.C., area and found no significant improvement in urban runoff quality for the pollutants analyzed. However, the weak performance of these swales was attributed to the high flow velocities in the swales, soil compaction, steep slopes, and short grass height.

Another project in Durham, NC, monitored the performance of a carefully designed artificial swale that received runoff from a commercial parking lot. The project tracked 11 storms and concluded that particulate concentrations of heavy metals (Cu, Pb, Zn, and Cd) were reduced by approximately 50 percent. However, the swale proved largely ineffective for removing soluble nutrients.

The effectiveness of vegetated swales can be enhanced by adding check dams at approximately 17 meter (50 foot) increments along their length (See Figure 1). These dams maximize the retention time within the swale, decrease flow velocities, and promote particulate settling. Finally, the incorporation of vegetated filter strips parallel to the top of the channel banks can help to treat sheet flows entering the swale.

Only 9 studies have been conducted on all grassed channels designed for water quality (Table 1). The data suggest relatively high removal rates for some pollutants, but negative removals for some bacteria, and fair performance for phosphorus.

**Table 1 Grassed swale pollutant removal efficiency data**

| Study | TSS | TP | TN | $NO_3$ | Metals | Bacteria | Type |
|---|---|---|---|---|---|---|---|
| | Removal Efficiencies (% Removal) | | | | | | |
| Caltrans 2002 | 77 | 8 | 67 | 66 | 83-90 | -33 | dry swales |
| Goldberg 1993 | 67.8 | 4.5 | - | 31.4 | 42–62 | -100 | grassed channel |
| Seattle Metro and Washington Department of Ecology 1992 | 60 | 45 | - | -25 | 2–16 | -25 | grassed channel |
| Seattle Metro and Washington Department of Ecology, 1992 | 83 | 29 | - | -25 | 46–73 | -25 | grassed channel |
| Wang et al., 1981 | 80 | - | - | - | 70–80 | - | dry swale |
| Dorman et al., 1989 | 98 | 18 | - | 45 | 37–81 | - | dry swale |
| Harper, 1988 | 87 | 83 | 84 | 80 | 88–90 | - | dry swale |
| Kercher et al., 1983 | 99 | 99 | 99 | 99 | 99 | - | dry swale |
| Harper, 1988. | 81 | 17 | 40 | 52 | 37–69 | - | wet swale |
| Koon, 1995 | 67 | 39 | - | 9 | -35 to 6 | - | wet swale |

While it is difficult to distinguish between different designs based on the small amount of available data, grassed channels generally have poorer removal rates than wet and dry swales, although some swales appear to export soluble phosphorus (Harper, 1988; Koon, 1995). It is not clear why swales export bacteria. One explanation is that bacteria thrive in the warm swale soils.

### Siting Criteria

The suitability of a swale at a site will depend on land use, size of the area serviced, soil type, slope, imperviousness of the contributing watershed, and dimensions and slope of the swale system (Schueler et al., 1992). In general, swales can be used to serve areas of less than 10 acres, with slopes no greater than 5 %. Use of natural topographic lows is encouraged and natural drainage courses should be regarded as significant local resources to be kept in use (Young et al., 1996).

#### *Selection Criteria (NCTCOG, 1993)*

- Comparable performance to wet basins
- Limited to treating a few acres
- Availability of water during dry periods to maintain vegetation
- Sufficient available land area

Research in the Austin area indicates that vegetated controls are effective at removing pollutants even when dormant. Therefore, irrigation is not required to maintain growth during dry periods, but may be necessary only to prevent the vegetation from dying.

The topography of the site should permit the design of a channel with appropriate slope and cross-sectional area. Site topography may also dictate a need for additional structural controls. Recommendations for longitudinal slopes range between 2 and 6 percent. Flatter slopes can be used, if sufficient to provide adequate conveyance. Steep slopes increase flow velocity, decrease detention time, and may require energy dissipating and grade check. Steep slopes also can be managed using a series of check dams to terrace the swale and reduce the slope to within acceptable limits. The use of check dams with swales also promotes infiltration.

### Additional Design Guidelines

Most of the design guidelines adopted for swale design specify a minimum hydraulic residence time of 9 minutes. This criterion is based on the results of a single study conducted in Seattle, Washington (Seattle Metro and Washington Department of Ecology, 1992), and is not well supported. Analysis of the data collected in that study indicates that pollutant removal at a residence time of 5 minutes was not significantly different, although there is more variability in that data. Therefore, additional research in the design criteria for swales is needed. Substantial pollutant removal has also been observed for vegetated controls designed solely for conveyance (Barrett et al, 1998); consequently, some flexibility in the design is warranted.

Many design guidelines recommend that grass be frequently mowed to maintain dense coverage near the ground surface. Recent research (Colwell et al., 2000) has shown mowing frequency or grass height has little or no effect on pollutant removal.

#### *Summary of Design Recommendations*

1) The swale should have a length that provides a minimum hydraulic residence time of at least 10 minutes. The maximum bottom width should not exceed 10 feet unless a dividing berm is provided. The depth of flow should not exceed 2/3rds the height of the grass at the peak of the water quality design storm intensity. The channel slope should not exceed 2.5%.

2) A design grass height of 6 inches is recommended.

3) Regardless of the recommended detention time, the swale should be not less than 100 feet in length.

4) The width of the swale should be determined using Manning's Equation, at the peak of the design storm, using a Manning's n of 0.25.

5) The swale can be sized as both a treatment facility for the design storm and as a conveyance system to pass the peak hydraulic flows of the 100-year storm if it is located "on-line." The side slopes should be no steeper than 3:1 (H:V).

6) Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible. If flow is to be introduced through curb cuts, place pavement slightly above the elevation of the vegetated areas. Curb cuts should be at least 12 inches wide to prevent clogging.

7) Swales must be vegetated in order to provide adequate treatment of runoff. It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing, water-resistant grasses. If possible, divert runoff (other than necessary irrigation) during the period of vegetation

establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.

### Maintenance

The useful life of a vegetated swale system is directly proportional to its maintenance frequency. If properly designed and regularly maintained, vegetated swales can last indefinitely. The maintenance objectives for vegetated swale systems include keeping up the hydraulic and removal efficiency of the channel and maintaining a dense, healthy grass cover.

Maintenance activities should include periodic mowing (with grass never cut shorter than the design flow depth), weed control, watering during drought conditions, reseeding of bare areas, and clearing of debris and blockages. Cuttings should be removed from the channel and disposed in a local composting facility. Accumulated sediment should also be removed manually to avoid concentrated flows in the swale. The application of fertilizers and pesticides should be minimal.

Another aspect of a good maintenance plan is repairing damaged areas within a channel. For example, if the channel develops ruts or holes, it should be repaired utilizing a suitable soil that is properly tamped and seeded. The grass cover should be thick; if it is not, reseed as necessary. Any standing water removed during the maintenance operation must be disposed to a sanitary sewer at an approved discharge location. Residuals (e.g., silt, grass cuttings) must be disposed in accordance with local or State requirements. Maintenance of grassed swales mostly involves maintenance of the grass or wetland plant cover. Typical maintenance activities are summarized below:

- Inspect swales at least twice annually for erosion, damage to vegetation, and sediment and debris accumulation preferably at the end of the wet season to schedule summer maintenance and before major fall runoff to be sure the swale is ready for winter. However, additional inspection after periods of heavy runoff is desirable. The swale should be checked for debris and litter, and areas of sediment accumulation.

- Grass height and mowing frequency may not have a large impact on pollutant removal. Consequently, mowing may only be necessary once or twice a year for safety or aesthetics or to suppress weeds and woody vegetation.

- Trash tends to accumulate in swale areas, particularly along highways. The need for litter removal is determined through periodic inspection, but litter should always be removed prior to mowing.

- Sediment accumulating near culverts and in channels should be removed when it builds up to 75 mm (3 in.) at any spot, or covers vegetation.

- Regularly inspect swales for pools of standing water. Swales can become a nuisance due to mosquito breeding in standing water if obstructions develop (e.g. debris accumulation, invasive vegetation) and/or if proper drainage slopes are not implemented and maintained.

## Cost

### *Construction Cost*

Little data is available to estimate the difference in cost between various swale designs. One study (SWRPC, 1991) estimated the construction cost of grassed channels at approximately \$0.25 per $ft^2$. This price does not include design costs or contingencies. Brown and Schueler (1997) estimate these costs at approximately 32 percent of construction costs for most stormwater management practices. For swales, however, these costs would probably be significantly higher since the construction costs are so low compared with other practices. A more realistic estimate would be a total cost of approximately \$0.50 per $ft^2$, which compares favorably with other stormwater management practices.

**Table 2 Swale Cost Estimate (SEWRPC, 1991)**

| Component | Unit | Extent | Unit Cost | | | Total Cost | | |
|---|---|---|---|---|---|---|---|---|
| | | | Low | Moderate | High | Low | Moderate | High |
| Mobilization / Demobilization-Light | Swale | 1 | $107 | $274 | $441 | $107 | $274 | $441 |
| Site Preparation | | | | | | | | |
| Clearing[b]............... | Acre | 0.5 | $2,200 | $3,800 | $5,400 | $1,100 | $1,900 | $2,700 |
| Grubbing[c]............. | Acre | 0.25 | $3,800 | $5,200 | $6,600 | $950 | $1,300 | $1,650 |
| General Excavation[d]........... | $Yd^3$ | 372 | $2.10 | $3.70 | $5.30 | $781 | $1,376 | $1,972 |
| Level and Till[e]....... | $Yd^2$ | 1,210 | $0.20 | $0.35 | $0.50 | $242 | $424 | $605 |
| Sites Development | | | | | | | | |
| Salvaged Topsoil Seed, and Mulch[f].. | $Yd^2$ | 1,210 | $0.40 | $1.00 | $1.60 | $484 | $1,210 | $1,936 |
| Sod[g]..................... | $Yd^2$ | 1,210 | $1.20 | $2.40 | $3.60 | $1,452 | $2,904 | $4,356 |
| **Subtotal** | -- | -- | -- | -- | -- | $5,116 | $9,388 | $13,660 |
| Contingencies | Swale | 1 | 25% | 25% | 25% | $1,279 | $2,347 | $3,415 |
| **Total** | -- | -- | -- | -- | -- | $6,395 | $11,735 | $17,075 |

Source: (SEWRPC, 1991)

Note: Mobilization/demobilization refers to the organization and planning involved in establishing a vegetative swale.

[a] Swale has a bottom width of 1.0 foot, a top width of 10 feet with 1:3 side slopes, and a 1,000-foot length.

[b] Area cleared = (top width + 10 feet) x swale length.

[c] Area grubbed = (top width x swale length).

[d] Volume excavated = (0.67 x top width x swale depth) x swale length (parabolic cross-section).

[e] Area tilled = $\left(\text{top width} + \frac{8(\text{swale depth}^2)}{3(\text{top width})}\right)$ x swale length (parabolic cross-section).

[f] Area seeded = area cleared x 0.5.

[g] Area sodded = area cleared x 0.5.

**Table 3 Estimated Maintenance Costs (SEWRPC, 1991)**

| Component | Unit Cost | Swale Size (Depth and Top Width): 1.5 Foot Depth, One-Foot Bottom Width, 10-Foot Top Width | Swale Size (Depth and Top Width): 3-Foot Depth, 3-Foot Bottom Width, 21-Foot Top Width | Comment |
|---|---|---|---|---|
| Lawn Mowing | $0.85 / 1,000 $ft^2$/ mowing | $0.14 / linear foot | $0.21 / linear foot | Lawn maintenance area=(top width + 10 feet) x length. Mow eight times per year |
| General Lawn Care | $9.00 / 1,000 $ft^2$/ year | $0.18 / linear foot | $0.28 / linear foot | Lawn maintenance area = (top width + 10 feet) x length |
| Swale Debris and Litter Removal | $0.10 / linear foot / year | $0.10 / linear foot | $0.10 / linear foot | – |
| Grass Reseeding with Mulch and Fertilizer | $0.30 / $yd^2$ | $0.01 / linear foot | $0.01 / linear foot | Area revegetated equals 1% of lawn maintenance area per year |
| Program Administration and Swale Inspection | $0.15 / linear foot / year, plus $25 / inspection | $0.15 / linear foot | $0.15 / linear foot | Inspect four times per year |
| **Total** | -- | **$0.58 / linear foot** | **$ 0.75 / linear foot** | – |

***Maintenance Cost***

Caltrans (2002) estimated the expected annual maintenance cost for a swale with a tributary area of approximately 2 ha at approximately $2,700. Since almost all maintenance consists of mowing, the cost is fundamentally a function of the mowing frequency. Unit costs developed by SEWRPC are shown in Table 3. In many cases vegetated channels would be used to convey runoff and would require periodic mowing as well, so there may be little additional cost for the water quality component. Since essentially all the activities are related to vegetation management, no special training is required for maintenance personnel.

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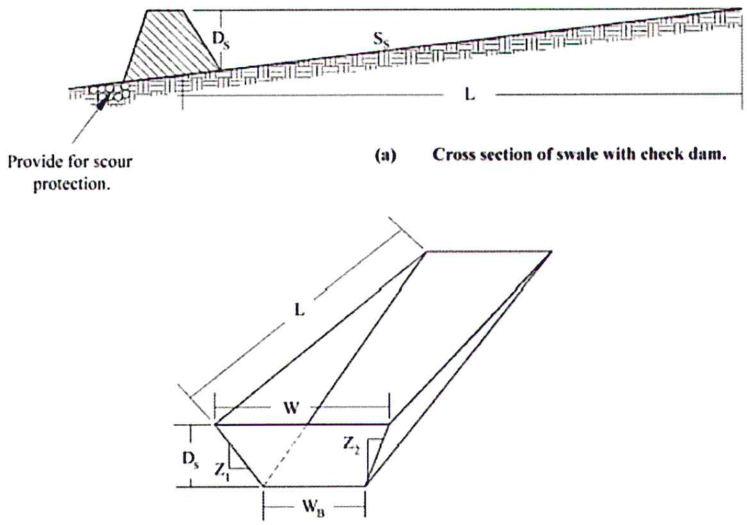



(a) Cross section of swale with check dam.

(b) Dimensional view of swale impoundment area.

**Notation:**

L = Length of swale impoundment area per check dam (ft)
$D_S$ = Depth of check dam (ft)
$S_S$ = Bottom slpe of swale (ft/ft)
W = Top width of check dam (ft)
$W_B$ = Bottom width of check dam (ft)
$Z_{1\&2}$ = Ratio of horizontal to vertical change in swale side slope (ft/ft)

# ATTACHMENT D

## Option 5 Bioretention Design Guidance and Plant List

(d) **Site Design Measures**

The Permittee shall implement Site Design Measures (as defined in Section E.12.b. Site Design Measures and Section E.12.e(ii)(a) Site Assessment), site layout and design measures, based on the objective of achieving infiltration, evapotranspiration and/or harvesting/reuse of the 85th percentile 24-hour storm runoff event. Site design measures shall be used to reduce the amount of runoff, to the extent technically feasible, for which retention and runoff is required . Any remaining runoff from impervious DMAs may then be directed to one or more bioretention facilities as specified in Section E.12.e.(ii)(f), below.

(e) **Source Controls**

The Permittee shall implement Source Controls as defined in Section E.12.d. Source Control Measures.

(f) **Storm Water Treatment Measures and Baseline Hydromodification Management Measures**

After implementation of Site Design Measures, remaining runoff from impervious DMAs must be directed to one or more facilities designed to infiltrate, evapotranspire, and/or bioretain the amount of runoff specified in Section E.12.e(ii)(c) Numeric Sizing Criteria for Storm Water Retention and Treatment. The facilities must be demonstrated to be at least as effective as a bioretention system with the following design parameters:

1) Maximum surface loading rate of 5 inches per hour, based on the flow rates calculated. A sizing factor of 4% of tributary impervious area may be used.
2) Minimum surface reservoir volume equal to surface area times a depth of 6 inches.
3) Minimum planting medium depth of 18 inches. The planting medium must sustain a minimum infiltration rate of 5 inches per hour throughout the life of the project and must maximize runoff retention and pollutant removal. A mixture of sand (60%-70%) meeting the specifications of American Society for Testing and Materials (ASTM) C33 and compost (30%-40%) may be used.
4) Subsurface drainage/storage (gravel) layer with an area equal to the surface area and having a minimum depth of 12 inches.
5) Underdrain with discharge elevation at top of gravel layer.
6) No compaction of soils beneath the facility, or ripping/loosening of soils if compacted.
7) No liners or other barriers interfering with infiltration.
8) Appropriate plant palette for the specified soil mix and maximum available water use.

(g) **Alternative Designs —** Facilities, or a combination of facilities, of a different design than in Section E.12.e.(ii)(f) may be permitted if all of the following measures of equivalent effectiveness are demonstrated:

1) Equal or greater amount of runoff infiltrated or evapotranspired;
2) Equal or lower pollutant concentrations in runoff that is discharged after biotreatment;
3) Equal or greater protection against shock loadings and spills;
4) Equal or greater accessibility and ease of inspection and maintenance.

(h) **Allowed Variations for Special Site Conditions** - The bioretention system design parameters in Section E.12.e.(ii)(f) may be adjusted for the following special site conditions:

1) Facilities located within 10 feet of structures or other potential geotechnical hazards established by the geotechnical expert for the project may incorporate an impervious cutoff wall between the bioretention facility and the structure or other geotechnical hazard.
2) Facilities with documented high concentrations of pollutants in underlying soil or groundwater, facilities located where infiltration could contribute to a geotechnical hazard, and facilities located on elevated plazas or other structures may incorporate an impervious liner and may locate the underdrain discharge at the bottom of the subsurface drainage/storage layer (this configuration is commonly known as a "flow-through planter").
3) Facilities located in areas of high groundwater, highly infiltrative soils or where connection of underdrain to a surface drain or to a subsurface storm drain are infeasible, may omit the underdrain.
4) Facilities serving high-risk areas such as fueling stations, truck stops, auto repairs, and heavy industrial sites may be required to provide additional treatment to address pollutants of concern unless these high-risk areas are isolated from storm water runoff or bioretention areas with little chance of spill migration.

(i) **Exceptions to Requirements for Bioretention Facilities** - Contingent on a demonstration that use of bioretention or a facility of equivalent effectiveness is infeasible, other types of biotreatment or media filters (such as tree-box-type biofilters or in-vault media filters) may be used for the following categories of Regulated Projects:

1) Projects creating or replacing an acre or less of impervious area, and located in a designated pedestrian-oriented commercial district (i.e., smart growth projects), and having at least 85% of the entire project site covered by permanent structures;
2) Facilities receiving runoff solely from existing (pre-project) impervious areas;and
3) Historic sites, structures or landscapes that cannot alter their original configuration in order to maintain their historic integrity.

By the second year of the effective date of the permit, each Permittee shall adopt or reference appropriate performance criteria for such biotreatment and media filters.

Central California Coast
**Technical Assistance Memo (TAM)**

# LID Plant Guidance for Bioretention

## Low Impact Development

**This Technical Assistance Memo (TAM) provides plant guidance for bioretention stormwater control measures.** Bioretention systems are low impact development (LID) features that use a combination of soil, plants, and other design elements to slow, treat, retain, and infiltrate stormwater runoff to mimic the natural, pre-development hydrology of a site.

While bioretention systems may look like regular landscaped areas, they are designed (engineered) to manage stormwater runoff volumes and pollutants created by urbanization. Specifying the appropriate plants and soil for a bioretention system is critical to its performance and community acceptance.

## Which Bioretention Facility Type?

There are two basic bioretention design types: planter and slope-sided. The flat-bottom planter type has a level soil surface, which allows stormwater to pond across the entire area. All plants in the planter type of bioretention must be able to tolerate stormwater inundation (Figure 1, Zone A). In comparison, the slope-sided type has two landscape conditions: the area that functions for stormwater management (Figure 2, Zone A) and the area above the ponding level. Similar to the planter type, plants in Zone A of a slope-sided bioretention type must be able to survive periodic ponding conditions. Plants in Zone B, however, are not located in the stormwater management area and the plants/trees can be selected from conventional plant palettes. For each project, it is important that the landscape designer understand where the delineation between Zone A and Zone Be occurs in order to develop a proper plant design.

Source: Kevin Robert Perry

**Slope-sided:** This facility type has a lower area that ponds and conventional landscape on the side-slopes. Only plants in the functional, ponding area (Zone A) must be tolerant of periodic inundation.

Source: Cannon

**Flat-bottom Planter:** This design type has a flat surface with consistent depth of ponding across the structure. The entire area functions for stormwater management and all plants in this facility must be tolerant of periodic inundation (Zone A).

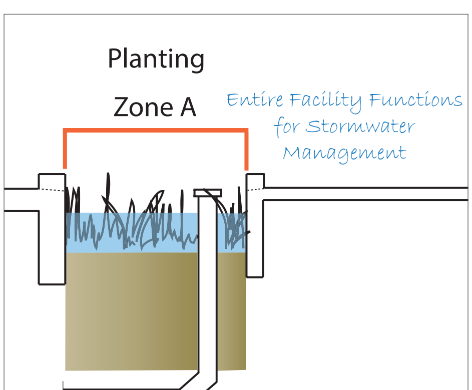



Figure 1

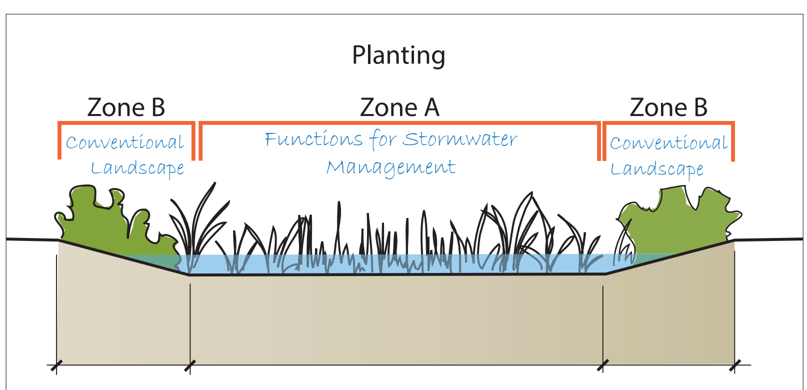



Figure 2

# Choosing the Plants

With the bioretention facility type known and ponding areas identified, the plants can be selected. A list of plants appropriate for Zone A conditions (periodic ponding) is available on the Central Coast Low Impact Development Initiative (LIDI) website.

The LIDI Bioretention plant list was developed using the following criteria:

- Tolerant of varied moisture conditions (wet and dry)
- Tolerant of varied soil types and growing conditions
- Low maintenance requirements
- Not invasive weeds
- Do not have aggressive/invasive root systems
- Exhibit an attractive appearance.

**centralcoastlidi.org/plants**

The bioretention plants provided on the LIDI website represent a basic bioretention plant palette. When selecting plants, the landscape designer should determine whether a plant species is appropriate for the site considering proximity to cars, pedestrians, height limits, and anticipated levels of maintenance. Drought tolerant native plants are strongly encouraged to support water conservation, provide wildlife habitat, and for their ability to survive in local climate conditions.

While plant selection for Zone B areas is at the discretion of the landscape designer, selection should take into account the sandy, free draining bioretention soil mix and the potentially erosive conditions where stormwater enters the facility.

Source: Las Pilitas Nursery

**Plant Selection and Maintenance:** Anticipating the level of maintenance a facility will receive informs plant selection and may improve long-term system function. Where irrigation levels and maintenance are expected to be low, select a tough plant palette using species with similar requirements. For example, on a road-side bioretention swale that will receive little or no irrigation and minimal maintenance after establishment, a planting of *Juncus patens*, *Achillea millefolium* and *Muhlenbergia rigens* could survive on rainfall once established. These tough plants, which look best when given supplemental water and cut back annually, will also tolerate mowing.

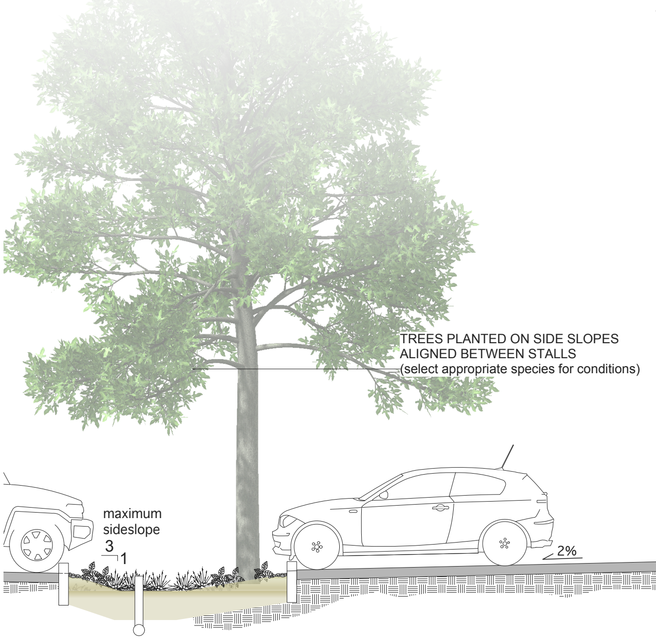
### About Plant Substitutions

Selection of different plant species may be appropriate based on the specific project objectives. However, the designer must ensure that plants selected for the Zone A location of a bioretention facility can tolerate periodic stormwater inundation. During construction, designers and/or construction managers should carefully review substitution requests. In the case of substitutions sought due to supplier availability, the contractor may need to broaden their search to locate a different supplier.

Source: William Cullina

**Bioretention Workhorse:** *Juncus* is a genus of plants, commonly known as rushes. They are found across the globe and frequently on bioretention plant lists because of their tolerance for inundation. Some *Juncus* perform better than others in arid environments. *Juncus patens* is an easy to grow California native rush. It tolerates poor drainage, flooding, drought, and shade. A strong bioretention performer, it is more drought tolerant than the commonly available *Juncus effusus*. Additional *Juncus* cultivars and varieties may also be available at nurseries. Ask growers which *Juncus* will perform well with both seasonal inundation and drought.

# Trees in Bioretention Areas




Trees provide additional aesthetic and performance benefits. Following these guidelines will maximize their success in bioretention areas:

- Provide sufficient facility width (a rule of thumb is 8' min.)
- Trees should be located at least five feet from facility inlets to avoid erosion of soils around the root ball
- Select trees that will tolerate seasonally wet soils and potential ponding
- Typically, locate trees on side-slopes; not at the bottom of Zone A
- Some trees may tolerate periodic shallow ponding, especially if native soils are highly infiltrative
- Do not specify trees with invasive roots
- Securely stake trees planted in bioretention areas

# Soils for Bioretention

Specifying the correct soils for bioretention areas is critical in order to achieve stormwater objectives and plant health. Soils must balance three primary design objectives:

- High enough infiltration rates to meet surface water draw down requirements
- Infiltration rates that are not so high that they preclude pollutant removal function of soils
- Soil composition that supports plant establishment and long-term health

**Bioretention Soil Mix:** Construction documents for any LID project should include a bioretention soil specification that defines the ratio of materials in the mix (approximately 35% aged compost to 65% concrete sand), and the gradation, quality analysis, and other requirements for the materials. Specifications should also include guidelines for blending and placement of the bioretention soil mix.

# Plant Installation

Landscape installation for bioretention areas is similar to that of traditional landscapes with a few added considerations:

- Conditions differ greatly between the ponding area (Zone A) and side-slopes (Zone B); plant installation must accurately follow landscape plans. After planting, an inspection should ensure correct placement.
- Plants should not block stormwater flows at inlets. The mature, full-size of plants should be estimated to determine proper setback from inlets, with adjustments made after installation, if plants are too close.
- A two-inch layer of compost may be applied to retain moisture, prevent erosion, and suppress weed growth. Use the same compost from the bioretention soil mix specification and avoid bark mulches that can float during storm events.
- Landscape installers should be aware to avoid compaction of the soil with machinery, or never working wet soils.

# Plant Establishment and Care

Like traditional landscapes, bioretention planting areas require care and ongoing maintenance for optimal health. Due to their functional nature as stormwater management facilities the following guidelines should be followed:

**Irrigation** is typically needed for two to three years following installation. After that period, native plants will need little to no supplemental irrigation to survive, however they may enter a dormant stage and appear dried up until rejuvenated by rains or supplemental irrigation. Because bioretention soils are formulated to infiltrate, irrigation application rates must be properly designed to avoid overwatering, and for systems with an underdrain prevent potential discharges through the underdrain.

**Compost Mulch** (1" - 2") may be reapplied to bioretention areas annually, or as the mulch layer breaks down. Use compost mulch (the same compost used in the bioretention soil mix) and avoid bark mulches that can float during storm events. Do not apply mulch just prior to the rainy season.

**Fertilizer** should not be used in bioretention areas. Instead, a compost top dressing or application of compost tea can be used to introduce nutrients and beneficial microorganisms to the soil.

**Synthetic herbicides and pesticides** should **not be used** in bioretention areas because of their potential toxicity risk to aquatic organisms. There are a variety of natural methods and products that can be used to control weeds and pests.

**Weeds** compete with plants for nutrients, water, and sunlight. They should be regularly removed, with their roots, by hand pulling or with manual pincer-type weeding tools. Care should be given to avoid unnecessary compaction of soils while weeding.

**Replace plants that die** due to unsuitable plant conditions, disease, underwatering, or other unforeseen issues. Dead and dying plants must be removed and replaced to avoid spreading disease, establishment of weeds in bare areas, and reduced LID function. Before replacing with the same species, determine if another species may be better suited to the conditions.

**Check tree staking**, especially in high wind areas. Trees in bioretention areas may be more easily impacted by storms because of side-slope and saturated soil conditions. They should be inspected once or twice a year and following storm events to ensure they maintain a vertical, upright position during establishment. Stakes should be removed once they are no longer needed to encourage self supporting root systems (between one and two years).

# Plant Nurseries

Check with your local nursery for availability of plants on the LIDI Bioretention plant list. Additionally, LIDI's Bioretention Vendor List, while it may not be inclusive of all suppliers, provides contact information for Central Coast nurseries that stock plants from the Bioretention plant list.

Source: Las Pilitas Nursery

For additional technical resources:

**www.centralcoastlidi.org**

For questions or to contact the
Central Coast Low Impact Development Initiative:

**info@centralcoastlidi.org**

Central Coast Water Board

central coast LIDI

UC Davis LID Initiative

LEGAL DISCLAIMER: This Technical Assistance Memo (TAM) is intended as guidance only and should not be used as a substitute for site specific design and engineering. Applicants are responsible for compliance with all code and rule requirements, whether or not described in this TAM.

Bioretention Plant List
Plants for Zone A: Periodic inundation, area ponds following storm events (6" to 12" depth for 24 - 48 hours) and compost amended sand soil.

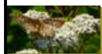
| Scientific & Common Name | Height / Width | Light Preferences | | | Water Tolerances | | CA Native | Sunset Climate Zones[1] | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | Sun | Part | Shade | Drought | Inundation | | | |
| **GRASS / GRASSLIKE** | | | | | | | | | |
| *Carex barbarae*<br>Santa Barbara Sedge/ Basket Sedge | 1-2' / 1'-2' | X | X | X | | X | X | 4 - 9, 14 - 23 | Attracts butterflies, deer resistant, good for erosion control, can spread agressively and should be sited carefully. |
| *Carex divulsa*<br>Berkeley Sedge | 1' / spreading | X | X | X | X | X | | all, but 1A- 3A | Attractive blue-grey leaves. Can be mowed 4 in high to keep clean look. |
| *Carex flacca*<br>Blue Sedge | 1' / spreading | X | X | | X | X | | 3A - 9, 14 - 23 | Attractive blue-grey leaves. Can be mowed 4 in high to keep clean look. |
| *Carex pansa*<br>California Meadow Sedge | 6-10" / spreading | X | X | | | X | X | 7-9, 11-24 | Used as a lawn substitute, can be left long or mowed, tolerates drought, once established. |
| *Carex praegracilis*<br>California Field Sedge | 1' / spreading | X | X | | | X | X | all, but 1A -3A | Mounding, drought deciduous during summer months. |
| *Carex spissa*<br>San Diego sedge | 3 - 4' / 2 - 3' | X | X | | X | X | X | all, but 1A-3A | Can handle foot traffic and is deer resistant. |
| *Chondropetalum tectorum*<br>Small Cape Rush | 2 - 3' / 3 - 4' | X | X | X | X | X | | all, but 1A-3A and 7 | Needs very little maintenance. If trimmed too much plant will loose visual integrity. |
| *Leymus condensatus* 'Canyon Prince'<br>Canyon Prince Wild Rye | 3'/3' | X | X | | | X | X | all, but 1A-3A | Tolerant of drought, poor soils, part shade and seasonal wet. Spreads by rhizomes, so nice planted in masses. Cut back annually in spring before new growth emerges. |
| *Juncus effusus*<br>Common Rush | 2 - 3' / clumping | X | X | | | X | X | all | Easy to grow & very reliable. Needs more water than *Juncus patens* . |
| *Juncus patens* 'Elk Blue'<br>Elk Blue California Gray Rush | 2' / clumping | X | X | | X | X | X | all | Very little maintenance, handles dry summers and wet winters. |
| *Muhlenbergia rigens*<br>Deer Grass | 2 - 3' / 3 - 6' | X | X | | X | X | X | all, but 1A-3A | Can handle no watering, will stay green year round with watering, trim annually. |
| *Scirpus cernus*<br>Low Bulrush | 1' / spreading | X | X | | | X | | 7 - 24 | Grow individually or in mass, cut back once a year, very attractive. |

1 Refers to Sunset Western Garden Book Zones. The Central Coast includes the following Climate Zones: 1A, 2A, 3A, 7, 9, 14-24 www.sunset.com/garden/climate-zones/

central coast LIDI
LOW IMPACT DEVELOPMENT INITIATIVE

Bioretention Plant List

Plants for Zone A: Periodic inundation, area ponds following storm events (6" to 12" depth for 24 - 48 hours) and compost amended sand soil.

| Scientific & Common Name | Height / Width | Light Preferences | | | Water Tolerances | | CA Native | Sunset Climate Zones[1] | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | Sun | Part | Shade | Drought | Inundation | | | |
|  PERENNIALS | | | | | | | | | |
| *Achillea millefolium californica* Yarrow | 1 - 3' / 2' | X | X | | X | X | X | all | Tolerates regular to no watering, foot traffic, attracts butterflies, stress deciduous. |
| *Anemopsis californica* Yerba Mansa | 1 - 2'/ spreading | X | X | | | X | X | all, but 1A-3A | Mat forming ground cover, interesting white flowers, prune back in late summer, likes moist conditions. |
| *Bidens laevis* Joaquin Sunflower | 2 - 3' / 1 - 2' | X | | | | X | X | all but 1A | Attracts beneficial insects, stress deciduous in summer, likes water but will survive drought if pruned back. |
| *Calliandra eriophylla* Fairy Duster | 1 - 3' / 1 - 3' | X | | | X | | X | 10 - 24 | Attractive pink flowers , drought tolerant once established, semi-evergreen, attracts pollinators, controls erosion. |
| *Epipactis gigantea* Stream Orchid | 1 - 2' / 2 - 3' | X | X | | | X | X | all | Interesting muted pink and yellow flowers, drought stress deciduous. |
| *Eschscholzia californica* California Poppy | 1 - 3 ' / 1 - 3" | X | | | X | X | X | all | Can handle periodic inundation, cut back yearly to prevent it from becoming weedy. |
| *Fragaria chiloensis* Beach Strawberry | 4-8" / spreading | X | X | | X | X | X | all, but 1A-3A | Vigorous, fast-growing perennial groundcover, tolerates light foot traffic. |
| *Iris douglasiana* Douglas Iris | 1 - 2' / spreading | X | X | | | X | X | all, but 1A-3A | Needs moisture or shade inland, does well on coast, evergreen leaves, attractive lanvendar-blue flowers in Spring. |
| *Iva hayesiana* San Diego Marsh Elder | 1-3' / 5' | X | X | | | X | X | all, but 1A-3A | Adaptable, low-maintenance shrub, controls erosion, shear or mow it back to the crown about every five years to rejuvinate. |
| *Lilium pardalinum* Leopard Lily | 3 - 8' / 6" | X | X | | | X | X | 2-7, 14-17 | Attractive red-orange spotted blossoms in spring, needs regular water, will get large in moist, partial shade conditions. |
| *Lobelia cardinalis* Cardinal Flower | 2 - 3' / 2' | X | X | X | | X | X | 1-7, 14-17 | A bog plant, attracts hummingbirds, showy scarlet flowers. |
| *Mimulus cardinalis* Scarlet Monkey Flower | 1 - 3' / 1 - 3' | X | X | X | | X | X | all but 1A | Year round red color with regular water, attracts hummingbirds, reseeds itself & should not be used for small spaces. |
| *Mimulus guttatus* Seep Monkey Flower | 1 - 3' / 1 - 3' | X | X | | | X | X | all but 1A | Yellow flowers are abundant in spring-summer, attracts butterflies, will die back in drought and come back following year. |

1 Refers to Sunset Western Garden Book Zones. The Central Coast includes the following Climate Zones: 1A, 2A, 3A, 7, 9, 14-24 www.sunset.com/garden/climate-zones/

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LOW IMPACT DEVELOPMENT INITIATIVE

Bioretention Plant List

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| Scientific & Common Name | Height / Width | Light Preferences | | | Water Tolerances | | CA Native | Sunset Climate Zones[1] | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | Sun | Part | Shade | Drought | Inundation | | | |
|  **PERENNIALS (cont.)** | | | | | | | | | |
| *Rudbeckia californica* California Coneflower | 2 - 5' / 1 - 2' | | X | | X | X | X | all | Yellow showy flowers late summer and fall, cut back in winter, can get large under ideal conditions and may require pruning. |
| *Salvia spathacea* Hummingbird Sage | 1 - 3' / spreading | | X | X | X | X | X | all, but 1A-3A | Very attractive foliage and flowers, fragrant, attracts hummingbirds, deer resistant, likes to grow in understory of trees. |
| *Salvia uliginosa* Bog Sage | 4-6' /3-4' | X | | | X | X | | 6-9,14-24 | Cut back to ground in winter, spreads by rhizomes. |
| *Satureja mimuloides* Monkeyflower Savory | 1-3' / 1-3' | X | X | | X | X | X | 4-9, 16-24, 26 | Deciduous perennial with orange flowers that attract hummingbirds. |
| *Sisyrinchium bellum* Blue-Eyed Grass * | 6" - 1' / 6" - 1 | X | | | X | X | X | all, but 1A-3A | Low maintenance, summer dormant, spring bloomer. Can irrigate to prolong flowering. |
| *Solidago californica* California Goldenrod ** | 1 - 3' / 2 - 3' | X | X | X | X | X | X | all, but 24 | Attractive yellow flowers in summer and fall, attracts pollinators, dormant in winter, cut back to ground. |
| *Zephyranthes candida* Rain Lily | 1' / 1' | X | X | | | X | | 4-9, 12-24 | A hardy bulb with rush-like foliage and small white flowers in late summer/fall. |
|  **SHRUBS/SUBSHRUBS** | | | | | | | | | |
| *Baccharis pilularis* Coyote Brush (Dwarf) | wide variation | X | | | X | X | X | all, but 1A-3A | Adaptable evergreen shrub, provides quick cover and bank stabilization, tolerant of coastal conditions, alkaline soil, sand, clay and seasonal wet, dwarf (low growing) varieties available. |

*Sisyrinchium californium (Yellow-eyed Grass) may also be used

**Cascade Creek Cultivar may also be used

1 Refers to Sunset Western Garden Book Zones. The Central Coast includes the following Climate Zones: 1A, 2A, 3A, 7, 9, 14-24 www.sunset.com/garden/climate-zones/

central coast LIDI LOW IMPACT DEVELOPMENT INITIATIVE