For individuals with sensory disabilities, this document is available in alternate formats upon request. Please call or write to Storm Water Liaison, Caltrans Division of Environmental Analysis, P.O. Box 942874, MS-27, Sacramento, CA 94274-0001. (916) 653-8896 Voice, or dial 711 to use a relay service.
# Table of Contents

1. **INTRODUCTION** ................................................................................................................... 1
   1.1. OVERVIEW ............................................................................................................................ 1
   1.2. BIOFILTRATION STRIPS – A BRIEF DESCRIPTION .............................................................. 1

2. **BASIS OF BIOFILTRATION STRIP DESIGN** .............................................................................. 4
   2.1. DESIGN CRITERIA .................................................................................................................... 4
   2.2. RESTRICTIONS ...................................................................................................................... 5
   2.3. MINIMUM BIOFILTRATION STRIP LENGTH .......................................................................... 5

3. **GETTING STARTED** .................................................................................................................. 8
   3.1. PRELIMINARY DESIGN PARAMETERS .................................................................................. 8
   3.2. CALCULATIONS .................................................................................................................... 9

4. **BMP LAYOUT AND DESIGN** .................................................................................................... 12
   4.1. LAYOUT ............................................................................................................................... 12
   4.2. SITE SPECIFIC DESIGN ELEMENTS .................................................................................... 12

5. **PS&E PREPARATION** .............................................................................................................. 14
   5.1. PS&E DRAWINGS .................................................................................................................... 14
   5.2. SPECIFICATIONS .................................................................................................................. 15
   5.3. PROJECT COST ESTIMATES .................................................................................................. 16

6. **REFERENCES** .......................................................................................................................... 17

A **BIOFILTRATION GUIDANCE-VEGETATION** .............................................................................. 18
   A.1 OVERVIEW .............................................................................................................................. 18
   A.2 SOIL TESTING & INVESTIGATION ......................................................................................... 18
   A.3 SOIL AND PLANTING AREA PREPARATION .......................................................................... 19
   A.4 IRRIGATION STRATEGIES ....................................................................................................... 20
   A.5 PLANTING STRATEGIES ........................................................................................................... 20
   A.6 RESTRICTIONS FOR PLANT SELECTION ............................................................................... 22
   A.7 DRAINAGE FACILITIES .......................................................................................................... 22
   A.8 PLANT ESTABLISHMENT PERIOD (PEP) ................................................................................ 22
   A.9 DEFINITIONS: .......................................................................................................................... 23
   A.10 ADDITIONAL RESOURCES .................................................................................................... 23
Table of Contents

LIST OF TABLES

TABLE 2-1 BIOFILTRATION SWALE DESIGN CRITERIA ................................................................. 4

LIST OF FIGURES

FIGURE 1-1 SCHEMATIC OF BIOFILTRATION SWALE AND STRIP ............................................. 2
FIGURE 1-2 BIOFILTRATION STRIP (DISTRICT 7, I-605/SR-91) .................................................. 3
FIGURE 2-1 PERCENT OF RUNOFF INFILTRATED VS. DISTANCE FROM EDGE OF PAVEMENT ....... 7
FIGURE 2-2 TSS CONCENTRATION REDUCTION VS. DISTANCE EDGE OF PAVEMENT ............... 7

LIST OF ACRONYMS

BMP Best Management Practice
ft feet
DPP BMP Design Pollution Prevention BMP
HDM Highway Design Manual
HRT Hydraulic Residence Time
in inches
max maximum
min minimum
NPDES National Pollutant Discharge Elimination System
PS&E Plans, Specifications and Estimate
RWQCB Regional Water Quality Control Board
sec second
TSS total suspended solids
WQF Water Quality Flow
1. Introduction

1.1. Overview

This document provides guidance for Caltrans Project Engineers and District Landscape Architects for incorporating Biofiltration Strip Treatment Best Management Practices (BMPs) into projects during the planning and design phases of Caltrans highways and facilities. The primary functions of this document are to:

1) Assist with determining the applicability of a Biofiltration Strip (“BioStrip”);

2) Provide the design guidance;

3) Cover the required elements for implementing a Biofiltration Strip in a PS&E package (Plans, Specifications, and Estimates) for a given project;

4) In an Appendix (separate attachment), information is presented about vegetation in BioStrips.

The Project Engineer and the District Landscape Architect have different perspectives and responsibilities during the design of BioStrips. Guidance is provided to the Project Engineer in this document, while guidance to the Landscape Architect is provided in the Appendix (separate attachment); the latter guidance is considered the best available at this time, but the Headquarters Office of Roadside Management will develop and issue additional guidance as needed.

1.2. Biofiltration Strips – A Brief Description

Biofiltration Strips are one of several BMPs for treatment of stormwater runoff from project areas that are anticipated to produce pollutants of concern (e.g., roadways, parking lots, maintenance facilities, etc.). BioStrips are sloped vegetated land areas located adjacent to impervious areas, over which storm water runoff flows as sheet flow. Pollutants are removed by filtration through the vegetation, uptake by plant biomass, sedimentation, adsorption to soil particles, and infiltration through the soil.

BioStrips are effective at trapping litter, Total Suspended Solids (soil particles), and particulate metals (Caltrans, 2002).

The following list demonstrates some advantages of utilizing a BioStrip as a Treatment Control BMP.

1. When properly implemented, Biostrips are aesthetically pleasing. Due to the presence of its vegetation, the public views Biostrips as a “landscaped roadside”
which would make placement more acceptable than other Treatment BMPs using concrete vaults.

2. Biostrips were determined to be an effective Treatment BMP in reducing sediment and heavy metals, as described in the *BMP Retrofit Pilot Program Final Report* (Caltrans, 2004).

3. In that same report Biostrips were determined to be cost effective and, together with Bioswales, were among the least expensive Treatment BMP per volume of runoff treated.

4. Biostrips also are well suited to being part of a “treatment-train” system of BMPs and should be considered whenever siting other BMPs that could benefit from pretreatment, especially Bioswales, Infiltration Basins, Infiltration Trenches, and Wet Basins. When there are right of way restrictions there may be occasions to use a lined ditch at the downstream edge of a Biostrip. A lined ditch will reduce the width and possibly the slope of the ditch, if needed, and are typically less wide than a vegetated swale of equal hydraulic capacity. For instance if there is only 18 feet of roadside between the edge of pavement and the right of way fence, it may be better to have a 15 foot Biostrip and a 3 foot lined ditch instead of a 10 foot Biostrip and a 5 foot Bioswale.

A schematic of a BioStrip adjacent to a Biofiltration Swale is shown below.

![Figure 1-1 Schematic of Biofiltration Swale and Strip](image-url)
Figure 1-2 Biofiltration Strip (District 7, I-605/SR-91)
2. Basis Of Biofiltration Strip Design

2.1. DESIGN CRITERIA

To perform as an effective Treatment BMP, the Biofiltration Strip must meet certain design criteria:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min. Value</th>
<th>Max. Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate, cfs</td>
<td>For water quality treatment: WQF</td>
<td>None, except that the site must not be considered erodible during larger rainfall intensities</td>
</tr>
<tr>
<td>Side Slope Ratio</td>
<td>Must grade to drain, but no minimum limit; 4H:1V preferred (refer to HDM 304.1 for further discussion of slopes).</td>
<td>Slope must support required vegetation; see also see also Section 2.3</td>
</tr>
<tr>
<td>Tributary Area</td>
<td>No minimum length (length of flow path)</td>
<td>150 ft maximum, but consult District NPDES Coordinator if longer</td>
</tr>
<tr>
<td>Biofiltration Strip Length (Direction of Flow), ft</td>
<td>15 ft unless supported by RVTS; see also Section 2.3</td>
<td>100 ft</td>
</tr>
<tr>
<td>Biofiltration Strip Width (perpendicular to flow, usually parallel with traffic)</td>
<td>No minimum value established, but should be considered in the context of the overall location; use of very short widths is discouraged, but any width can be considered; agreement with District Maintenance is required</td>
<td></td>
</tr>
<tr>
<td>Manning's n value</td>
<td>During WQF: 0.20 (routinely mowed) to 0.30 but 0.24 (infrequently mowed) recommended. See Note 1</td>
<td></td>
</tr>
<tr>
<td>WQF Velocity, ( V_{WQF} )</td>
<td>No minimum value</td>
<td>1.0 fps, but seldom controls design</td>
</tr>
<tr>
<td>Flow Depth (WQF), ( d_{WQF} )</td>
<td>No minimum value</td>
<td>1.0 inch, but seldom controls design</td>
</tr>
<tr>
<td>Vegetative Coverage and Type;</td>
<td>70 % minimum coverage (see Note 2); Vegetative Type - See Appendix A (separate attachment)</td>
<td></td>
</tr>
<tr>
<td>Hydraulic Residence Time</td>
<td>No minimum required; the Biofiltration Strip Length controls</td>
<td></td>
</tr>
<tr>
<td>Hydraulic conductivity (permeability) of the soils</td>
<td>No value set, but it is acknowledged that a percentage of the treatment is made via infiltration. Consider conductivity only in the context of vegetation purposes.</td>
<td></td>
</tr>
</tbody>
</table>

1) Refer to HDM Table 816.6A. If the proposed grass type or its conditions are not known, use \( n = 0.24 \). If the grass is known refer to FHWA HEC 15, Design of Roadside Channels with Flexible Linings, (2nd ed., April 1988, Table 1 and Charts 5, 6, 7, and 8) or the 3rd ed, Sept. 2005, chapter 4.1. The use of 0.24 is adequate for almost all situations, as Manning’s Equation would be used to calculate the velocity and the depth, and these parameters seldom control the design. Soil amendments (such as compost material) may increase Manning’s n value; support use of any higher value in the Storm Water Data Report.

2) Vegetative cover is the percentage of soil surface in contact with plant stems and leaves including the area covered by leaves, stems, or other plant parts that extend no more than 12-inches above the ground surface.
2.2. Restrictions

Successful implementation and utilization of the BioStrip as a BMP will require proper siting by coordinating with District Hydraulics, District Maintenance, and District Landscape Architecture. A BioStrip should not be designed outside the values presented in Table 2-1 without consultation with the District NPDES Design Coordinator.

Additional restrictions applicable to the use of the BioStrip BMP Detail Drawings are as follows:

- Biostrips in arid regions will require installation of a temporary (or permanent) irrigation system to ensure 70 percent vegetative coverage, and/or must be planted with vegetation that will go dormant outside of the rainy season; consult with the District Landscape Architect to verify that water is available for irrigation. Also assess feasibility. Refer to Section 2.4.2.1 of the PPDG.

- Consult with District Design NPDES Coordinator if Biostrips are proposed at locations having contaminated soils or above contaminated groundwater plumes.

- Slopes should be designed as flat as possible. For new construction, widening, or where slopes are otherwise being modified, embankment (fill) slopes should be 1:4 or flatter (Refer to HDM 304.1 for further discussion of slopes).

- BioStrips are not generally subject to setback restrictions as an Infiltration Device is; however, if unusual geotechnical conditions exist, or if a BioStrip is proposed above a retaining wall and the soils are known to be especially erodible or permeable, consult with Geotechnical Design.

- Nearby fill slopes should be observed for signs that the embankment soils are highly erodible, and the District Landscape Architect should be consulted about soil amendments, use of fiber rolls, or other methods to reduce the potential erosion.

2.3. Minimum Biofiltration Strip Length

Treatment is obtained by BioStrips through filtration through the vegetation, uptake by plant biomass, sedimentation, adsorption to soil particles, and infiltration through the soil. Of these mechanisms, probably the two most important are sedimentation and infiltration. The relative proportion of total treatment done by the sedimentation and infiltration can vary by site, but in terms of total pollutant load reduction (as opposed to concentration reductions) the role played by infiltration can be much more than 50% (see Reference 4, especially Figures 5 and 6). Using TSS (total suspended solids) as the key pollutant for
this discussion indicated a reduction in the TSS concentration of 50% or more can occur after as little as 12 feet of travel for a variety of side slope ratios, including slopes as steep as 2H:1V. As mentioned, the concentration reduction does not fully indicate the significant reduction in loading that occurred due to the large volume of runoff infiltrated. Based on the data presented, the minimum recommended slope length for BioStrips is 15 ft for any side slope ratio as long as the site supports the required 70 percent vegetation coverage without rills or gullies; a reduced minimum length can be considered as a design exception if supported by the RVTS study with respect to: side slope ratio, percentage vegetation coverage, and soil type.

These findings about infiltration and reduction in concentration of TSS, because they are critical to understanding the recommended minimum length criteria, have been plotted on the following page to better illustrate these findings.
Figure 2-1 Percent of Runoff Infiltrated Vs. Distance from Edge of Pavement

Figure 2-2 TSS Concentration Reduction Vs. Distance Edge of Pavement

1 Figures 2-1 and 2-2 based on data presented in Reference 4. Figure 2-1 presents data from seven of the eight monitored sites, ignoring only Moreno Valley (which did not meet the minimum vegetation coverage percentage). Figure 2-2 presents data from six of the eight monitored sites (ignoring Yorba Linda, where gopher activity was high, Moreno Valley, which did not meet the minimum vegetation coverage percentage, and including only the first monitoring location at San Onofre, where gopher activity was low). For both: 100% value at the edge of pavement represents runoff directly from the road surface.
3. Getting Started

Before selecting, sizing, and laying out the Biofiltration Strip, existing site conditions are evaluated to obtain and assess the necessary design parameters that will be used to determine if a BioStrip is applicable. **In general, verification of the depth of flow or velocity is not needed if the Design Criteria is used.** However, these calculations may be needed for other purposes, and are briefly discussed in this section. Since these calculations will seldom be needed for Caltrans’ designs, no Design Example is provided in this document.

1. The Water Quality Flow rate (WQF)
2. Tributary Area Length (in the direction of flow)
3. Length of BioStrip in the direction of flow.
4. Surface slope of BioStrip in the direction of flow

### 3.1. PRELIMINARY DESIGN PARAMETERS

#### 3.1.1. Rainfall Intensities and WQF

**A. WQF**

Design Flow: The flow used for designing BioStrips is the Water Quality Flow (WQF). The WQF may be found in the PPDG, Section 2.4.2.2, or by referring to the Basin Sizer program that has been created for Caltrans use. The Basin Sizer program, an explanation of the methodologies incorporated into the program, and a description of how to use Basin Sizer can be found at the following online link:

http://stormwater.water-programs.com/BasinSizer/Basinsizer.htm

The flow for designing BioStrips should be made using the WQF intensity, the tributary area, and the appropriate runoff coefficient, multiplied using the Rational Formula.

\[
Q_{\text{WQF}} = C \times I \times A \quad \text{See Footnote 2}
\]

where

\[
\begin{align*}
Q_{\text{WQF}} & \quad = \text{Water Quality Flow rate (cfs)} \\
C & \quad = \text{runoff coefficient} \\
I & \quad = \text{WQF rainfall intensity (in/hr)} \\
A & \quad = \text{tributary area to the BioStrip (acres)}
\end{align*}
\]

---

2 In metric units: \( Q_{\text{WQF}} = 0.28 C \times I \times A \) where \( Q_{\text{WQF}} \) is m\(^3\)/sec, \( C \) as above, intensity \( I \) as mm/hr, and area \( A \) as square kilometers.
B. Flow in the BioStrip during the Design Event: $Q_{25}$

The BioStrip must handle the peak drainage from the roadway. However, calculations using this intensity are not usually made, in part since there is no need for an ‘overflow’ device from this type of Treatment BMP.

3.2. CALCULATIONS

3.2.1. WQF Depth, Velocity, and Travel Time Using Manning’s Equation

A. Depth

The design flow depth is calculated using a re-arranged version of Manning’s equation (assumes the depth of flow is nominal with respect to the width of flow). The flow for designing BioStrips should be made using the WQF intensity, the tributary area, and the appropriate runoff coefficient, multiplied using the Rational Formula.

$$Q_{WQF} = \frac{1}{n} \times A \times R^{2/3} \times S^{1/2}$$

where

- $Q_{WQF}$ = flow at defined event (cfs)
- $n$ = Manning’s coefficient; recommend using “$n$” = 0.24 for $Q_{WQF}$
- $A$ = Cross-sectional area of the flow in the channel, unit width (ft)
- $R$ = Hydraulic Radius = “$A$” / Wetted Perimeter (“$P$”)
- $S$ = longitudinal slope (ft/ft)

Since the area $A$ will equal the depth times the unit width, and since the wetted perimeter will also equal depth, the formula can be re-written as:

$$Q_{WQF} = \left(\frac{1}{n}\right) \times d^{5/3} \times S^{1/2}$$

And re-arranging to solve for depth:

$$d = \left[\left(\frac{Q_{WQF} \times n}{S^{1/2}}\right)\right]^{3/5}$$

where

- $d$ = Flow depth during the WQF event (ft) and all other terms as above.

The flow depth should not exceed 1 inch (Design Criteria); if it does, a reduced WQF intensity could be negotiated with the RWQCB (see PPDG Section 2.4.2.2), an increased slope could be made (although this will increase the velocity, so it is not the ideal adjustment), or the area could be considered as a Vegetated Surface Design Pollution.
Prevention (DPP) BMP. Note: Flow depth will not control the design if the Design Criteria are otherwise followed.

B. Design Velocity

Using the depth and $Q_{WQF}$ calculated in the steps above, velocity equals:

$$V_{WQF} = \frac{Q_{WQF}}{d}$$

where

$V_{WQF} = \text{Velocity during the WQF event (fps)}$

d = \text{Design Flow Depth (ft)}$

If the design flow velocity exceeds 1.0 ft/s, a BioStrip cannot be used, unless the slope can be made flatter. Note: velocity during WQF events will not control the design if the Design Criteria are otherwise followed.

C. Hydraulic Residence Time

While there is no minimum travel time (termed the Hydraulic Residence Time [HRT]) required within the BioStrip, it may need to be calculated for other reasons. This calculation would be made after the proposed BioStrip was analyzed using Manning’s Equation, as discussed above. The velocity associated with the $Q_{WQF}$ is determined, and the HRT calculated using the proposed length of the BioStrip:

$$HRT = \frac{L}{60 \times V_{WQF}}$$

where

$L = \text{proposed length of the BioStrip (ft)}$

$HRT = \text{Hydraulic Residence Time (minutes)}$

$V_{WQF} = \text{velocity at } Q_{WQF} (\text{ft/sec})$

60 = conversion from seconds to minutes
3.2.2. Travel Time Using the Kinematic Wave Equation

An alternative formula is sometimes used to calculate the travel time, using the Kinematic Wave Equation presented in *HDM* Topic 816.6, Time of Concentration ($T_c$) and Travel Time ($T_t$), copied below:

$$T_t = \left[0.93 \times L^{3/5} \times n^{3/5} / (i^{2/5} \times S^{3/10})\right]$$  See Footnote 3

where

- $T_t$ = travel time [HRT] (minutes)
- $L$ = proposed length of the BioStrip (ft)
- $n$ = Manning’s coefficient; recommend using “n” = 0.24 for QWF
- $i$ = WQF rainfall intensity (in/hr)
- $S$ = longitudinal slope (ft/ft)

One advantage of this formula is that it allows the HRT to be calculated directly, without first calculating the unit width QWF. Note that this formula will calculate a longer travel time than will Manning’s Equation for the shorter lengths that are typical for BioStrips, as there are different assumptions made for each of these empirical equations. If the calculation for the Hydraulic Residence Time is done at the request or to meet the requirements of an outside agency, it is recommended that this equation be used, unless otherwise directed by that agency.

---

3 Using metric units: $T_t = \left[6.92 \times L^{3/5} \times n^{3/5} / (i^{2/5} \times S^{3/10})\right]$, with all terms the same, except that $L$ is in meters, and intensity $i$ is in mm/hr.
4. BMP Layout and Design

4.1. Layout

4.1.1. Location
BioStrips are probably the least expensive Treatment BMPs for an area that has already been determined to be suitable resistant to erosion without hardening. BioStrips can be a stand-alone device, or the first BMP encountered in a “treatment train”. They perform well upstream of other Treatment BMPs that benefit from pretreatment such as Infiltration Devices, Detention Devices, and Wet Basins.

Narrow shoulders and conflicts with sound walls and other structures suggest that there will not be abundant opportunities for retrofit with BioStrips on existing freeways in the most highly urbanized areas.

One location that should receive special consideration is runoff at each end of a bridge structure discussed in more detail in Section 4.2.2.

4.1.2. Maintenance
BioStrips need sufficient space for maintenance and inspections along the roadways. There should be enough space for maintenance vehicles and all equipment necessary for cleaning, repair, or inspection. District Maintenance should concur that the proposed BioStrip location have adequate space and access for maintenance and inspection of the device. Refer to Caltrans Standard Plan H9, “Maintenance Vehicle Pullout” for a typical detail.

4.2. Site Specific Design Elements

4.2.1. Use of Level Spreaders
The BMP Retrofit Report discussed the use of flow spreading, and due to various difficulties, that report recommended against the use of concrete level spreaders to distribute runoff.

4.2.2. Concentrated runoff at the end of a bridge
Runoff at the end of a bridge will usually be in the form of concentrated flow, rather than sheet flow. Since the use of level spreaders is discouraged, this runoff should be considered for capture in a drainage inlet, from which it ideally would be brought to the base of the embankment and directed into a Biofiltration Swale. The remaining portion of the bridge approach would then be allowed to convey runoff as sheet flow onto BioStrips. In any event, runoff from the end of a bridge should not be allowed to cause erosion.
4.2.3. Use of Curbs and Dikes within the roadway cross section

Curbs are used when needed to improve channelization, delineation, or improving traffic flow and safety, and their use will likely not be waived due to water quality issues. However, dikes are used when deemed needed for drainage control, and can be considered in the context both of water quality and highway drainage. Use of dikes should be discouraged as much as possible on embankment sections that would otherwise meet BioStrip criteria, with agreement by District Hydraulics and Maintenance required. A further discussion about the use of curbs and dikes will be found under HDM Topic 303 - Curbs, Dikes, and Side Gutters.
5. PS&E Preparation

This section provides guidance for incorporating BioStrips into the PS&E package, discusses the typical specifications, and presents information about estimating the construction costs.

5.1. PS&E Drawings

BioStrip Treatment BMPs do not have standard drawings for the device as a complete feature, but there are several sheets that should be placed in the PS&E package. The PS&E drawings for most projects having BioStrips will include:

- **Layout(s):** Show location(s) of BioStrips. This will aid in the recognition within and outside the Department that BioStrips were placed within the project limits.

- **Contour Grading(s):** As BioStrips are primarily earthwork features they may be shown on Contour Grading sheets. Any other associated grading surrounding the BioStrip should be shown on these sheet(s).

- **Construction Details:** There will not typically be any construction details associated with BioStrips, but if there are, these sheets may be used to show these items. Final grade should maintain sheet flow across BioStrips. To avoid mulch and plant material from blocking the sheet flow across the BioStrip, a construction detail showing the final grade including mulch may be required.

- **Landscape Plans:** These sheets, and the Contour Grading sheets, will be the primary sheets used to show the placement of the landscape contract items of work for BioStrips.

- **Other Sheets:** Drainage Plans, Water Pollution Control, Erosion Control Plans, Construction Staging, Utility Plans, Irrigation Plans, and other sheets should be considered as appropriate for the construction of BioStrips on a project-specific basis.

If BioStrips will be constructed at multiple locations, a “Locations of Construction” table should be considered. This table could present the stationing and other location information. WQF could also be considered. This table may be incorporated into an existing drawing if there is room (such as a Title, Layout or Construction Detail), or may be developed as a separate drawing if necessary.

While every effort has been made to provide accurate information here, the Project Engineer is responsible for incorporating all design aspects of BioStrips into the PS&E in accordance with the requirements of Section 5 of the Department’s *Plans, Specifications And Estimates Guide*. 
5.2. SPECIFICATIONS
Contract specifications for BioStrip Treatment BMP projects will include Standard Specifications, Standard Special Provisions (SSPs), and non-Standard Special Provisions (nSSPs). Where indicated below specific nSSPs have been developed by the HQ Office of Storm Water Management.

The special provisions for the various items of work directly needed to construct the BioStrip could be organized under the blanket heading of ‘BioStrip’ with some or all of these items listed as subheadings, and payment would be made for by ‘each’ BioStrip, or separate listings could be made for each contract item of work, with separate measurement and payment. The Project Engineer and the District Office Engineer should consider which method would better serve the particular project.

Listed below are SSPs that would typically be used for a project that constructs a BioStrip Treatment BMP; the Project Engineer should consider the construction of BioStrips in the context of the entire project to determine if other SSPs may be required.

- Order of Work\(^5\) (SSP 05-010)
- Water Pollution Control (SSP 07-340 or 07-345)
- Clearing and Grubbing (SSPs 16-050, or 16-060, or 16-070)
- Earthwork (SSP 19-010; and/or Miscellaneous Earthwork Clauses, SSP 19-040; and/or Measurement And Payment (Earthwork), SSP 19-590)
- Erosion Control (Erosion Control (Type C), SSP 20-030; or Erosion Control (Type D), SSP 20-040)
- Temporary Irrigation (as Plant Establishment Work, SSP 20-550)
- Highway Planting (SSP 20-350)
- Slope Protection (SSP 72-010)

5.2.2. Non-Standard Special Provisions
Typical placement of BioStrips will not require any nSSPs. However, the Project Engineer and the District Landscape Architect must ensure that non-Standard Special Provisions, if needed, have been developed based on site-specific requirements. HQ Landscape will most likely be the approval group for any Biostrip nSSPs developed.

\(^4\) Standard Specifications will not be included but merely referenced in the contract’s special provisions.
\(^5\) The Order of Work should indicate that no runoff from construction should be allowed to flow into the BioStrip until all upstream areas contributing runoff are stabilized.
5.3. Project Cost Estimates

Project Cost Estimates (PCEs) are required at every phase of the project, as discussed below. Section 7 of the Ready-to-List and Construction Contract Award Guide (RTL Guide) should be consulted for more details on preparing construction cost estimates.

5.3.1. PID and PA/ED Phases

At the PID phase of the project, the construction cost could be estimated based on the findings of the BMP Retrofit Pilot Program Final Report, which was at $21/ft³ of WQV treated, exclusive of right of way.6

To determine an initial cost estimate using this value simply use the following equation:

\[
\text{Initial construction cost} = (\$21/\text{ft}^3 \times \text{run-up factor}) \times \text{tributary area} \times 0.75/12
\]

This estimate will need to be modified as the project progresses. If some design is conducted during the PA/ED phase of the project, it is possible that a more refined estimate could be made using the methods in Section 5.3.2. A cost escalation should be added for projects that are anticipated to advertise more than a year after the date of the estimate.

5.3.2. PS&E Phase

As the design process proceeds into the PS&E phase, unit quantities would be available, and the associated unit costs need to be obtained, as accurate costs are critical. When developing costs based on unit quantities, the cost estimates should be based upon the Department’s Contract Cost Data Book or recent, similar projects in the District, as appropriate. The Project Engineer should use SSPs and nSSPs from Sections 5.2.1 and 5.2.2 of this document, as well as those added on a project-specific basis, to develop a list of items for which item costs should be developed. The Project Engineer should carefully check that all items of work are accounted for either as pay or non-pay items.

---

6 In 1999 dollars; contact District Office Engineer for appropriate run-up factors based on local experience. Note that costs were given in units more appropriate for a volume-based Treatment BMP, for comparison purposes within that report. The formula shown has been modified slightly to account for the otherwise incorrect units, and should only be used for estimating purposes in these phases of the project.
6. References


A Biofiltration Guidance-Vegetation

A.1 Overview
This Appendix provides design guidance for the vegetative cover component of Biofiltration BMPs (i.e., bioswales and biostrips). For Biofiltration BMPs, District Landscape Architecture is responsible for selecting vegetation, and developing the appropriate plans, specifications, details, and estimates for contract documents. Incorporation of other improvements such as soil amendment and irrigation may be required to satisfy site conditions. For Biofiltration BMPs to be effective, it is necessary to establish a healthy, sustainable vegetative cover.

The District Landscape Architect or delegated representative is to verify that specific project requirements, necessary to provide vegetative cover for the Biofiltration BMPs, are documented in the Storm Water Data Report (SWDR) and prepared for PS&E.

A.2 Soil Testing & Investigation
It is important to identify roadside soil characteristics of a site to determine its erosion potential, infiltration qualities, and ability to establish vegetative cover.

When analyzing soils information for Biofiltration BMPs the soils test should report the following:

- USDA-NRCS particle size distribution (soil texture) – ASTM D6913-04e1
- Organic matter percentage – ASTM D2974-07a
- Infiltration rate –ASTM D3385-03
- pH
- Salinity
- Sodium (Na)
- Boron (B)
- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)

1) Information on soils should be requested as part of the geotechnical investigation. Soils characteristics such as USDA Soil Group, USDA-NRCS particle distribution (soil texture), organic matter percentage, and infiltration rate should be requested. If the Geotechnical Report has been completed without soils information, or if no Geotech Report is prepared for the project, then the Landscape Architect should collect soil samples and submit them to a soils testing lab for processing.
2) If soils information cannot be obtained for the project site, then soils information from a reference site should be evaluated. To be valid, the reference site must have characteristics similar to the project site such as slope aspect (north-facing, etc.) topography (cut or fill slopes), climate, geology, and existing vegetation.

A.3 Soil and Planting Area Preparation

Roadway construction that requires excavation or embankment work typically results in soils unable to support desirable vegetation. Grading operations, including compaction, produce soils of pulverized parent material with inverted soil horizons that lack nutrients, organic matter, rooting depth, and pore space. When these site conditions are anticipated, an assessment should be made by District Landscape Architecture to determine the level of treatment necessary to support vegetation. Coordination with the project engineer is recommended to ensure harvesting of suitable roadside soils within the project limits is considered.

Compost and organic slow release fertilizers provide a better method to provide nutrients for desirable plant species than conventional commercial fertilizer. Because commercial fertilizers provide nutrients that are readily available, the germination and growth of invasive weeds is encouraged rather than desirable slower growing species. Incorporating compost and applying organic slow-release fertilizer releases nutrients gradually, thereby promoting the germination and establishment of perennial grasses and woody shrubs. In addition to providing long-term nutritional benefits as a soil amendment, compost can be applied as a 1” to 2” mulch layer on biostrips to prevent the germination of most invasive annual weed species. When a compost mulch layer is specified, apply the seed on top of the compost to ensure that desirable seed species will germinate.

The following should be considered when preparing soil for biofiltration BMPs:

1) The soils in areas designated for biofiltration should be ripped and cultivated to a minimum depth of 12-inches to relieve surface compaction. For slopes steeper than 4:1(H:V), coordinate with the geotechnical engineer and District NPDES Coordinator. Deeper ripping may provide long term treatment benefits by increasing infiltration and water holding capacity, especially where soils are shallow.

2) Compost can be used to boost soil nitrogen and organic matter percentage if a soils report indicates a deficiency for these. A minimum of 1100 lb total N/acre distributed throughout the top 12 inches of soil is the end goal. For poor soils, compost should be incorporated at a minimum rate of 400 cuyd/acre to a minimum depth of 12-inches to help restore soil organics, rooting depth, porosity and nutrients (carbon and nitrogen). Compost should be specified as per SSP 20-056, “Compost, Incorporate”.

3) Harvest topsoil from areas to be graded. Compost use may not be required if topsoil has an acceptable level of organic matter. Designate topsoil harvest and stockpile locations on the plans. Plant harvested topsoil with a temporary
vegetative cover of appropriate native species to maintain microbial soil health. Include details for re-application and placement of topsoil. Coordination with the project engineer is recommended in ensuring staging requirements and environmental issues are considered.

4) Where invasive weeds are pervasive, specify that weed seeds be germinated and resulting weeds killed or include mulch for weed control. Germination of an existing seed bank is a very effective method for controlling weeds. Planting by hydroseeding or other methods should be done after one or more weed germination cycles. Weed germination is only practical when temporary irrigation is employed. A 1”-2” layer of compost mulch is also an effective method to prevent germination and competition from annual weeds. Keep mulch clear of flow lines for bioswales.

5) Incorporate amended soil as part of slope construction when specifying Mechanically Stabilized Embankments (MSE) for steep embankments. Placing amended soil at the proposed slope face can be done as part of placing each geotextile reinforced lift. An open weave erosion control blanket should be used to contain the material at the slope face by using a “wrap-back” method. The slope can be hydroseeded upon completion of the MSE.

A.4 Irrigation Strategies
California’s diverse microclimates make establishing vegetation difficult and sometimes impossible without supplemental irrigation. Harsh site conditions often limit the ability of the plantings to survive and thrive to the extent necessary for successful treatment. Under these conditions, irrigation should be provided when connecting to a water source is practicable.

The following criteria should be considered when designing biofiltration BMPs:

1) If vegetative cover goals (minimum 70%) are not achievable under normal rainfall, a temporary irrigation system will be required until plants are established.

2) If establishment of vegetative cover is required prior to normal rainfall, or the anticipated contract schedule necessitates germination prior to winter, then the use of a temporary irrigation system to establish the vegetation prior to the rainy season is recommended.

3) If the proposed biofiltration BMP is adjacent to or within an irrigated landscape then utilization of the existing water service for permanent irrigation is recommended to ensure design compatibility with existing highway planting.

A.5 Planting Strategies
The following criteria should be used as a general measure of successful Biofiltration BMP installation:

1) Within the first year, a minimum of 70 percent vegetative cover is achieved.
2) The Biofiltration BMP does not exhibit rills, gullies, or visible erosion that is contributing to the export of sediment.

3) Biofiltration BMPs located within a landscaped urban interchange should be designed to complement the adjacent existing highway planting.

California’s diverse microclimates require equally diverse strategies for successfully establishing vegetation. The following planting strategies have been successfully used for roadside revegetation and should be considered for biofiltration BMPs where appropriate:

1) Provide temporary cover until the desired percent cover of vegetation is achieved. For challenging sites, it may take more than one growing season to establish adequate vegetative cover. This is especially true for shrubs and woody perennials on harsh sites. Temporary cover is usually provided through the use of short-term, degradable erosion control products such as rolled erosion control products (RECPs), wood chips and compost, straw, and hydromulches. These products vary in how long they will last. For example, straw can be expected to last through a single rainy season while a high quality coconut fiber erosion control blanket will usually function for 3 years.

2) Strive for cost effective solutions. In most cases, the temporary cover product with the greatest longevity will also be the most expensive. While plant performance, slope steepness, slope inclination, slope aspect, and soil characteristics must be considered, avoid over-design. Specify materials as warranted by specific project conditions. For example, a cost-effective project design may use straw and hydroseed on areas of good soil and gentle slopes, reserving compost and coir netting for steep, cut slopes.

3) Specify drought tolerant grasses, with a goal to use as many appropriate local native species as possible. Species that become dormant during the dry season are acceptable as long as biofiltration performance is not affected. In Southern California, it is preferable to select plant species that are not dormant during the winter and spring (wet season).

4) Combine hydroseeding and direct planting. Some plant species favor particular planting methods, so special provisions may need to be made if these species are to be used. Many plant species can be applied by hydroseeding. Other plants are better established as liner, container, or plug plant material and can be installed in previously seeded areas, following germination. This method can be effective for bioswales when the upland zone on the banks is hydroseeded and the hydrophilic zone in the bed is planted with sedge, grass, and rush liners.

5) Specify erosion control blankets or other RECPs in areas that will receive concentrated flow. Although hydroseeding may be appropriate for planting portions of bioswales, it should not be used in locations that will receive concentrated runoff. Liner, container or plug plant material is a better choice in these areas.
A.6 Restrictions for Plant Selection
Nearly half of the bulk solids collected in the structural treatment BMPs consists of plant litter such as leaves and twigs. However, trees and shrubs provide both functional and aesthetic benefits to highway roadsides. To limit maintenance requirements of downstream treatment BMPs and especially basins and trash BMPs such as Gross Solid Removal Devices (GSRDs), trees and shrubs selected for banks of biofiltration swales should not contribute large amounts of plant litter (e.g., bark, leaves, flowers or seeds) to the BMP.

A.7 Drainage Facilities
Accommodations for drainage facilities upstream and downstream from biofiltration BMPs should be considered as follows:

1) Provide a concrete apron large enough to prevent overgrowth and reduce clogging:
   a) around drainage inlets located in bioswales,
   b) at culvert inlet and outlets such as flared end sections.
   This enhances performance and facilitates inspection and maintenance. Ensure apron design meets engineering standards as per Highway Design Manual.

2) Include armoring or other forms of scour protection such as the use of rock or turf reinforcement at the transitions from piped or other hard surface conveyance to vegetated areas.

3) Avoid standing water or rock placement on poorly draining soils in order to prevent vector (mosquito) breeding.

A.8 Plant Establishment Period (PEP)
PEP ensures project success by maintaining plants during a period when mortality rates tend to be high. This is true for Highway Planting, as well as for revegetation planting that includes grasses and forbs, and especially native grasses.

The following should be considered when requiring PEP for biofiltration BMPs:

1) Biofiltration BMPs that are graded, constructed and planted as part of a roadway construction contract should have a 1-year PEP. Depending upon the type of construction and order of work, the PEP may run concurrently with other work.

2) Work to be performed during the PEP should include the following when applicable for the project:
   a) Weed control and removing inappropriate plant species (as field identified by a qualified specialist),
   b) Watering plants as necessary,
   c) Mowing and other vegetation management,
   d) Repairing rills, gullies, and other damage caused by erosion and scour,
   e) Reseeding bare or repaired areas,
   f) Replacing liner, container, or plug planting,
Appendix A

Biofiltration Guidance-Vegetation

g) Monitoring and repairing irrigation system (permanent or temporary),
h) Removing accumulated sediment and debris, and
i) Removing temporary irrigation system at end of PEP.

3) The following activities may be performed during the PEP and done as extra work:
   a) Additional planting,
   b) Additional irrigation, and
   c) Monitoring plant growth and establishment.

4) Ideally, a 3-year contract to perform plant establishment work should follow immediately after completion of the roadway contract that installed the Biofiltration BMPs. If practical, the follow-up contract may include the Biofiltration BMPs of several construction projects in proximity of each other.

A.9 Definitions:

1) **Vegetative Cover:** (This definition is paraphrased from the draft NPDES Construction General Permit) Actively growing plant matter that is uniform, self-sustaining (perennial) and in contact with the soil. Live perennial vegetation may include grasses, grass like species, forbs, and some broad leaf species that are ground covers, low shrubs, or a combination. The area shall have a minimum vegetative cover of 70% within the first growing season. The remaining 30% shall be covered by fallen plant litter, standing dead plant material, or mulch.

2) **Temporary Cover:** Temporary cover consist of erosion control materials that provide short-term, interim protection of disturbed soil areas. Temporary cover products include erosion control blankets and other RECPs, straw, composts and mulches, and hydromulches. These products are generally composed of biodegradable and photodegradable materials with variable longevity.

A.10 Additional Resources

See locations below for additional information regarding planting methods and strategies for slope stabilization:

- Several studies on biofiltration BMPs, erosion control, and revegetation can be found on the Caltrans Department of Environmental Analysis webpage at: http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/index.htm.

- The Caltrans Revised Universal Soil Loss Equation (RUSLE2) and the Erosion Prediction Procedure (EPP) provide a software tool and guidance for predicting surface erosion and selecting BMPs. The EPP appendixes include information on collecting and processing soil samples. (Under development)
• The Erosion Control Technology Council (ECTC) is a non-profit organization dedicated to developing performance standards, uniform testing procedures, and guidance on the application and installation of rolled erosion control products (RECPs). Information for selection and installation of RECPs based upon longevity, slope inclination, C-factor, and shear strength is given for various classes of products. Access their webpage at: http://www.ectc.org/.

• The Soil Resource Evaluation (SRE) provides a stepwise process for regeneration and re-vegetation of drastically disturbed soils. Information on plant rooting depth, plant available water, soil nutrient levels, etc. can be found here. This information can be found on the HQ Landscape Architecture Program webpage at: http://www.dot.ca.gov/hq/LandArch/research/index.htm.