Bioretention Treatment Best Management Practice

Design Guidance

June 2021

California Department of Transportation
HQ Division of Design

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Caltrans Division of Design

Office of Hydraulics and Stormwater Design

P.O. Box 942874, Sacramento, CA 94274-0001

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AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society of Testing and Materials
BASMAA	Bay Area Stormwater Management Agencies Association
BEES	Basic Engineering Estimating System
BMP	Best Management Practice
CDA	contributing drainage area
CF	cubic feet
cfs	cubic feet per second
CRZ	Clear Recovery Zone (AASHTO Clear Zone)
CTM	California Test Methods
CY	cubic yards
DPPIA	Design Pollution Prevention Infiltration Area
FHWA	Federal Highway Administration
ft	foot/feet
ft/s	foot/feet per second
H:V	Horizontal:Vertical
HDM	Highway Design Manual
HEC	Hydraulic Engineering Circular
HRT	Hydraulic Residence Time
HSG	Hydrologic Soil Group
in	inch
in/hr	inches per hour
LID	Low Impact Development
max	maximum
min	minimum
MWELO	Model Water Efficient Landscape Ordinance
NPDES	National Pollutant Discharge Elimination System
nSSP	non-Standard Special Provision
OHSD	Headquarters Office of Hydraulics and Stormwater Design
PA/ED	Project Approval/Environmental Document
PDT	Project Development Team
PE	Project Engineer
PECE	Preliminary Engineer's Cost Estimate
PID	Project Initiation Document
PPCE	Project Planning Cost Estimate
PPDG	Project Planning and Design Guide
PS&E	Plans, Specifications, and Estimate
RWQCB	Regional Water Quality Control Board
sec	second
SQFT	square feet
SSP	Standard Special Provision
SWDR	Stormwater Data Report
TBMP	Treatment Best Management Practice
TDS	total dissolved solids
TRM	Turf Reinforcement Mat
USDA	United States Department of Agriculture
WQ	water quality
WQF	Water Quality Flow
WQV	Water Quality Volume

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Section 1
Introduction

This document provides guidance for Caltrans designers for incorporating Bioretention as a Treatment Best Management Practice (TBMP) into projects during the planning and design phases of Caltrans highways and facilities. Bioretention TBMP facilities are a low impact development (LID), vegetation and soil-based practice utilizing the chemical and biological properties of soil to reduce pollutants, as well as physical characteristics to attenuate stormwater flows. Bioretention TBMPs are vegetated surface water systems that filter water through vegetation and soil, or engineered media. Bioretention TBMPs are configured as a basin and can include facilities with an underdrain or without an underdrain. Facilities with an underdrain filter water prior to discharge via underdrain to the downstream conveyance system. Facilities without an underdrain are designed to infiltrate the full Water Quality Volume (WQV) into native soils. The primary functions of this document are to:

1. Describe a Bioretention TBMP
2. Provide design considerations and guidance
3. Review the required elements for implementing a Bioretention TBMP into Plans, Specifications, and Estimates (PS&E) packages

It is assumed that the need for post construction TBMPs has already been determined in accordance with the guidelines and procedures presented in the Project Planning and Design Guide (PPDG; Caltrans 2019a). It is also assumed Checklist T-1, Part 1 process has been followed and Bioretention is being considered, and that all the preliminary siting and design criteria have been satisfied.

The following guidance is provided based on a Caltrans pilot study, review of similar media approved by other agencies, and limited design experience of this non-standard treatment facility within the Caltrans right-of-way. Designers may utilize alternatives to the calculation methodologies presented in this guidance. Alternative calculations and design decisions must be documented in the project Stormwater Data Report (SWDR) and the Project File. The SWDR template can be found in the PPDG.

1.1 Design Responsibility

The Project Engineer (PE) is responsible for the design of Bioretention facility hydrology, hydraulics, grading, and traffic because they are part of the highway drainage system. The designer must consider the highway grading plans and the impacts stormwater infiltration may have on the roadway especially in consideration of the Clear Recovery Zone (CRZ). Coordinate with other functional experts to implement successful and functioning Bioretention TBMPs.

Refer to Chapter 800 of the Highway Design Manual (HDM), the Headquarters Office of Hydraulics and Stormwater Design (OHSD), and District Hydraulics for project drainage requirements. Contact District Landscape Architect for appropriate plant selection based on the physiographic region and the purpose of the TBMP. The hydraulic and landscape design should consider the soil composition and the need for lining the Bioretention TBMP based on water quality (WQ) and design flow velocities. Lining materials can range from erosion control blankets at lower velocities to rock slope protection at higher velocities. To achieve sustainability requirements, the Project Development Team (PDT) is encouraged to use native and climate appropriate vegetation that does not require irrigation and requires the least amount of maintenance.

1.2 Bioretention TBMPs

Bioretention TBMPs use vegetation and soil, or engineered media, to promote stormwater treatment through filtration and storage. Bioretention TBMPs utilize bermed or excavated areas to create a basin to capture runoff. They can be adjacent to impervious areas within parking lot landscaping, along roadsides, and in open spaces to allow stormwater runoff to flow into the TBMP either as sheet flow or as an end of pipe system that receives concentrated flows (e.g., from a culvert system or rock lined ditch). Bioretention TBMPs are used for treating stormwater runoff from project pavement areas (e.g., roadways, parking lots, maintenance facilities, etc.) that contain pollutants of concern. Infiltration (in facilities without a liner), filtration (in facilities with a liner), sedimentation, adsorption to soil particles, biochemical processes, and plant uptake are the primary means for pollutant removal of the WQV.

During a storm, runoff enters the Bioretention TBMP causing the water level in the basin to rise. During the rainfall, and for some time after it ends, the runoff infiltrates into the soil or engineered media through the invert area which is sized based upon the WQV, the permeability of the soil below the invert, and the time period selected for infiltration. It is preferred that events greater than the WQ Event be bypassed around the TBMP to preserve infiltration capacity, to prevent erosion or scour, and to minimize the size of the BMP. Flows greater than the WQ Event can be passed through the BMP, typically over a spillway through the confining berm or through an overflow riser, when necessary.

The Bioretention TBMP is effective at removing suspended solids, metals, litter, and nutrients as noted in the PPDG. The TBMP effectiveness varies with the amount of infiltration and filtration provided by the soil media and surrounding native soils. When native soils have low infiltration potential (i.e., hydrologic soil group [HSG] C and D), consider using a perforated underdrain to collect the treated effluent from the subsurface layer. Some studies of bioretention with underdrains have observed export of nutrients, particularly inorganic nitrogen (nitrate and nitrite) and dissolved phosphorus. In some studies this is a short-lived phenomenon but other studies found it to be a long-term issue. Potential for pollutant export is partly a function of media composition; media design must minimize potential for export of nutrients, particularly where receiving waters are impaired for nutrients.

Typical Bioretention TBMP components include:

- Upstream bypass for events greater than the WQV
- Inflow distribution mechanisms (e.g. perimeter flow spreader or filter strips)
- Energy dissipation mechanism for concentrated inflows (e.g. splash blocks or riprap pad)
- Inlets designed to minimize blockage of inflows
- Surface ponding, shallow surface ponding for captured flows
- Side slope and basin bottom vegetation selected based on expected climate and ponding depth
- Non-floating mulch layer (optional)
- Media layer (planting mix or engineered media) capable of supporting vegetation growth
- Filter course layer to prevent the migration of media layer soils into the aggregate storage layer (optional)
- Subsurface drainage layer, can be designed to provide additional storage capacity (optional)
- Underdrain outlet pipe either near the bottom or at top of aggregate layer, at top provides better treatment of nitrates, nitrites and phosphorus.
- Overflow device configured as an overflow riser or a spillway (recommended for both inline and offline BMPs)
- Uncompacted native soils at the bottom of the facility preferred, use liner when required

Bioretention TBMPs may be configured in different shapes to meet right-of-way restrictions and to conform to the available space and topography. Consider ease of construction and maintenance in the basin design. Consult with Geotechnical Design, Hydraulics, and Traffic Safety if within the CRZ.

Figure 1-1 below shows an example section of a Bioretention TBMP.

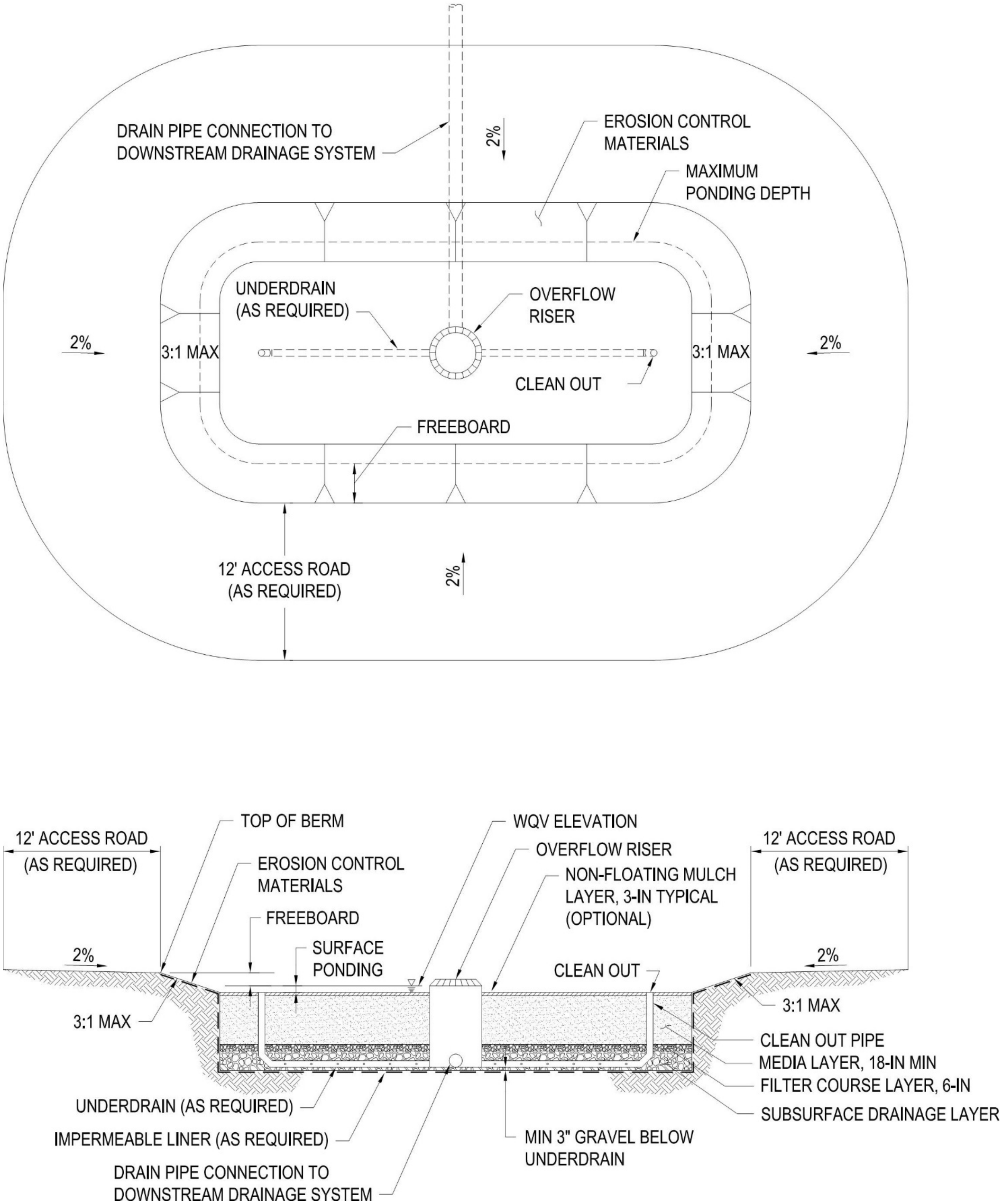

Figure 1-1. Schematic of a Bioretention TBMP

Section 2

Basis of Bioretention TBMP Design

Bioretention TBMPs may be considered at a specific location to enhance filtration or promote infiltration. Bioretention TBMPs can be considered upstream of other TBMPs as part of a treatment train for the remaining WQV. Bioretention TBMPs must meet certain preliminary design criteria to perform as an effective TBMP. The primary factors to be incorporated in the design are found in PPDG Table B-9.

2.1 Appropriate Applications and Siting

Bioretention TBMPs may be considered whenever safety criteria are met and where flow velocities can be mitigated to prevent scour. If infiltration is not allowed, a liner and underdrain will be required. The site should have sufficient area for pretreatment BMPs (e.g., Biofiltration Strips, Biofiltration Swales) upstream of the basin. The Regional Water Quality Control Board (RWQCB) having jurisdiction may impose additional requirements for water protection purposes; consult with District/Regional NPDES Coordinator.

During design of infiltrative Bioretention TBMPs, include an assessment of whether infiltration would exacerbate existing groundwater accretion problems. Groundwater accretion has been implicated in certain areas as a contributing factor to impairment by salt and other salt-associated dissolved constituents, such as boron, selenium, sulfate, and chloride. If stormwater infiltration is determined to increase the risk of groundwater accretion and seepage of high total dissolved solids (TDS) water from down gradient areas, infiltration may not be appropriate. At these sites, Bioretention TBMPs may still be feasible if a liner and an underdrain is included.

Additional design criteria applicable to the siting of Bioretention TBMPs are:

- If Bioretention TBMP is to be located closer than: i) 1,000 ft from any municipal water supply well; ii) 100 ft from any private well, septic tank, or drain field; and iii) 200 ft from a Holocene fault zone, a liner is required.
- A liner must be included if in close proximity to a Recharge Facility due to difficulty in cleaning in the event of a spill; consult with the District/Regional NPDES Coordinator and the most recent District Work Plan.
- Bioretention TBMPs should not be used in fill sites, or on cut slopes steeper than 15 percent (3.7H:1V) unless the location is approved in a geotechnical report. A liner and/or subsurface drainage may be required.

- A liner is required if within 10 ft down gradient or 100 ft up gradient of building or other structure foundations.
- Coordinate with the District Hazardous Waste Coordinator and District/Regional NPDES Coordinator if Bioretention TBMPs are proposed at locations having contaminated soils or are above contaminated groundwater plumes, to discuss feasibility and design options in these locations. A liner may be required.
- If the site has groundwater within 5 ft of the Bioretention TBMP invert, consult with RWQCB to determine if a liner is required.
- If site investigation indicates that the infiltration rate is significantly greater than 2.5 inches/hr, adequate groundwater information must be available or contact the District/Regional NPDES Coordinator to determine if consultation with the RWQCB is needed before approving the site for bioretention without a liner and subsurface drainage. A liner and subsurface drainage may be required.
- Bioretention TBMPs should be placed offline. Even when placed offline, the Bioretention TBMPs must be configured with an overflow release device. (See Section 4.2)

2.2 Preliminary Design Criteria

Bioretention TBMPs must meet certain preliminary design criteria to perform as an effective TBMP. The primary factors to be incorporated in the design are found in the PPDG Table B-9. Additional general design guidelines for Bioretention TBMPs are as follows:

- Contributing tributary area is ≤ 5 acres (≤ 1 acre preferred).
- Optimal surface ponding depth is ≤ 6 in when k=1 in/hr and ≤ 12 in when k=5 in/hr; depth can vary by site and the designer can modify the design for specific criteria and still have an effective bioretention basin.
- A minimum freeboard of 1 in is provided for offline facilities and minimum 12 in for inline facilities.
- Design slopes to be as flat as possible. If a project includes new slopes steeper than 2:1 (h:v), then a Geotechnical Design Report should be prepared. Projects including slopes between 4:1 and 2:1 (h:v) should be coordinated with Division of Engineering Services (DES) Geotechnical Design unit.
- Finish grade of the facility should be ≤ 2%. In long bioretention facilities where the potential for internal erosion and channelization exists, the use of check dams is recommended.
- Media layer is a minimum 18 in deep and meets the Bioretention Soil Media Specifications in Section 2.4
- Subsurface drainage layer is typically 12 in deep. When an underdrain is required, the pipe should be installed 3-6 in above the bottom of the subsurface

drainage layer, this may vary depending on the pollutant of concern for receiving water and site conditions.

- Provide access to the overflow spillway and around the entire perimeter of the Bioretention TBMP when possible.
- Contributing drainage area should be stabilized and pretreated whenever possible to prevent sediment discharge to the Bioretention TBMP.
- Inlets to the Bioretention TBMP should be designed to minimize blockage of inflows into the TBMP, usually resulting from accumulation of sediment. Overside drains should be at least 12 inches wide, have a 4-6 inch reveal (drop), an apron (to prevent blockage from vegetation), and energy dissipation as needed.
- Inflow velocities are limited to 3 ft/sec or less or use energy dissipation methods for concentrated inflows.
- A low flow channel or other energy dissipator can be used to prevent erosion within the Bioretention TBMP.
- Overflow device is used to safely convey runoff in excess of TBMP capacity to a downstream storm drain system or discharge point.
- Liners are used when required to protect water quality as described above.
- Basin shape/configuration should result in as natural an appearance as possible.

2.3 Site Soils and Infiltration

The design of a Bioretention TBMP is dependent on the infiltration characteristics of the native soils where the TBMP will be placed. The HSG classification can be used as an initial parameter to identify the infiltration characteristics of native soils. Soils within HSG A are characterized as having higher infiltration rates; Bioretention TBMPs placed within these soils will likely not require an underdrain. Soils within HSG B and C are characterized as having moderate infiltration rates. An underdrain system may be required if soil testing and design calculations show that the infiltration rate of the native soil does not allow for the desired TBMP drawdown time. Soils within HSG D are characterized as having low infiltration rates. An underdrain system will likely be required for Bioretention TBMPs constructed within HSG D.

Soil testing to determine the infiltration rate of native site soils should be completed as part of the Geotechnical request. The tests that should be considered by the PE are included in Tables 2-1 and 2-2 below. If testing shows that the site soils have low infiltration, account for low infiltration rates in the TBMP design, in developing the soil media composition, and the use of an underdrain. Consult with Geotechnical support on available test methods for your project.

For more detailed guidance for determining the feasibility of infiltration, consult Infiltration Basin Design Guidance Section 3 (Caltrans 2020b).

Table 2-1. Infiltration and Soil Properties Testing Table for Input into Caltrans Infiltration Tool	
Parameter	Test method(s)
Infiltration Rate, in/hr	CTM 750 (modified for shallow depth) ASTM D5126 (Single-Ring/Infiltrometer) ASTM D3385-09 (Double-ring/Infiltrometer) ASTM D8152-18 (Modified Philip Dunne/Infiltrometer) CTM 220
Bulk Density, Dry Density, Water Content	ASTM D7263-09 ASTM D1557 CTM 216 - compaction behavior
Specific Gravity	CTM 209 - specific gravity of the soil ASTM D1557 ASTM D854
Void Ratio	ASTM D1556

Table 2-2. Other Possible Soil Tests	
Parameter	Test method(s)
Hydraulic Conductivity, Saturated	ASTM D5856
Soil Classification	AASHTO M145 ASTM D2487
Particle Size Distribution	CTM 202 - sieve analysis CTM 203 - hydrometer
Remolded Moisture Curve	ASTM D698 ASTM D1557

2.4 Soil Media

Soil media is the defining characteristic of Bioretention TBMPs that provides an increase in storage and treatment of the WQV. Soil media used for bioretention is typically comprised of a mixture of sand, compost, and topsoil and may also include a mixture of other organic or non-organic material. OHSD developed an approved non-Standard Special Provision (nSSP) for bioretention soil media that has been used for Bioretention TBMPs (Caltrans 2016). The PE also has the option to design soil media to meet specific project needs.

Soil media depth will typically range from 18 to 24 in. The media depth should be designed based on the native infiltration rate of the site soils and infiltration calculations (e.g. using Caltrans Infiltration Tool (Caltrans 2019e) or an approved modeling program). Bioretention soil should have a permeability rate of at least 1 in/hr; 3 in/hr is preferred. The component ratio by volume, should consist of 4 parts sand, 2 parts compost and 1 part topsoil when the OHSD nSSP is used. Additional design, construction, and maintenance considerations are included in the nSSP and must be reviewed, and modified as needed, by the PE.

2.4.1 Bioretention Soil Media Mix Composition

In designing the bioretention soil media, the PE must consider the pollutant removal effectiveness of the media and receiving water limitations. Media composition should be specified to provide treatment processes that address the anticipated pollutants of concern while providing appropriate hydraulic properties. The bioretention soil media design can use varied sand, compost, and topsoil ratios or other components to maximize pollutant removal efficiency and plant sustainability.

Alternative media components may be considered to address specific pollutants of concern. Media components may be incorporated into the soil media or added as a polishing layer below the bioretention soil media. Materials shall also be selected to minimize potential leaching of any pollutants at levels of concern.

2.5 Subsurface Drainage

Bioretention TBMPs with a subsurface drainage system are typically used in areas where the infiltration potential of native soils is limited, especially in HSG C and D soils, or where infiltration is prohibited. Where infiltration is prohibited, an impermeable liner would be required. The subsurface drainage layer generally includes a permeable material, typically 12 to 24 in thick, with an underdrain set 3-6 in above the bottom of the layer. The underdrain must comply with Section 68 of the Standard Specifications and D102 of the Standard Plans and should be designed to gravity flow to the downstream system.

Saturated storage within the permeable material layer can be added in TBMPs without a liner by raising the underdrain further above the bottom of the subsurface drainage layer. The stored volume should infiltrate within a 36-hour drawdown time but can vary.

Filter fabric should not be used to separate the media layer and the subsurface drainage layer due to clogging concerns. Rather, consider the use of a filter course layer. A filter course layer is 6 in deep and consists of Class 2 permeable material (Standard Specification Section 68-2.02F(2), Type A) placed at the top of the subsurface drainage layer to limit migration of fines.

Where underdrain is used for Bioretention TBMPs, cleanouts are typically placed at the upstream end, the downstream end, and at regular intervals based on TBMP length. Typical underdrain cleanout details are shown in D102 of the Standard Plans. Cleanout locations must allow maintenance access and should be coordinated with District Maintenance.

2.6 Safety Considerations

Bioretention TBMPs should be located using the safe roadside environment CRZ standards as discussed in Topic 309 "Clearances" of the HDM, and in the AASHTO Roadside Design Guide(AASHTO 4th edition 2011). Traffic safety is an important part of highway drainage facility design. When placed within the CRZ, the Bioretention TBMP must be compacted to at least 90 percent to provide a traversable section for errant traffic leaving the traveled way within the CRZ (HDM Topics 304, 309, and 861.4).

Coordinate with other functional experts such as District Traffic Operations, District Maintenance, District Hydraulics, Geotechnical Design, and Traffic Safety, as applicable. Discuss the proposed TBMP location with the District Traffic Operations unit even when placed outside of the CRZ.

2.7 Maintenance

Discuss proposed Bioretention TBMP location and access with the District Maintenance Stormwater Coordinator, as maintenance and regular inspections are critical to these devices. Maintenance would typically include: mowing or weeding, erosion and scour repairs, and removal of sediment, trash, and/or vegetation at inlets to ensure flows are properly entering the TBMP. Repairs of surface erosion or shearing may be required and it may be necessary to reevaluate functional performance. District Maintenance should concur with the proposed TBMP location and configuration, as part of the SWDR review.

2.8 Vegetation in Bioretention TBMPs

The presence of vegetation is believed to serve a number of important functions in Bioretention TBMPs including:

- Root action creates or maintains soil macro-pores, reduces soil density, and maintains or restores permeability, thereby reducing the risk/frequency of clogging
- Nutrient uptake into plants helps provide long term nutrient retention (although plant material needs to be removed periodically to result in permanent retention)
- Some plant roots may exude chemicals that inactivate pathogens and/or may form symbiotic relationships with fungus that are beneficial for water quality

Vegetation in Bioretention TBMPs at the invert and side slopes is encouraged, both for performance and aesthetic reasons. The use of diverse and locally appropriate species is recommended. For additional information about plant species suited to the conditions within the Bioretention TBMP on a location-specific basis within the various ecological subregions of California, consult:

- District Landscape Architecture
- The Biofiltration Strip Design Guidance (Caltrans 2020c) and Biofiltration Swale Design Guidance (Caltrans 2020d)
- Ecological Subregions of California Section and Subsection Descriptions, USDA, Forest Service, USDA, Natural Resources Conservation Service, published May 1998 (online at: http://www.fs.fed.us/r5/projects/ecoregions/) (USDA 1998)
- Calflora Database (online at: http://www.calflora.org)
- Calscape native grass database (online at: https://calscape.org/loc-California/cat-Grasses/ord-popular)
- BASMAA's Post-Construction Manual Appendix F Bioretention Facility Plant Matrix (online at: http://basmaa.org/)
- Contra Costa County's Stormwater C.3 Guidebook Appendix B (online at: https://www.cccleanwater.org/)
- Santa Clara Valley Urban Runoff Pollution Prevention Program's C.3 Stormwater Handbook Appendix D Plant List (online at: https://www.sccgov.org/sites/cwp/Documents/SCVURPPP_C.3_Technical_Guidance_Handbook_2016_Chapters.pdf)
- San Mateo Countywide Water Pollution Prevention Program's Green Infrastructure Design Guide "Choosing and Placing Appropriate Plant Material" (online at: https://www.flowstobay.org/wp-content/uploads/2020/03/GIDG-2nd-Edition-2020-03kh-RED.pdf)
- San Diego Low Impact Development Design Manual Appendix E. Plant List (online at: https://www.sandiego.gov/sites/default/files/lidmanual.pdf)

Caltrans Water Conservation Requirements: Limit planting to native and non-native plants appropriate for the project micro-climate so no water beyond natural rainfall is required for healthy plant survival after the plant establishment period. Trees are not recommended within bioretention basins due to the reduced soil water availability in bioretention soil media and reduced soil depth and volume (BASMAA 2016b). Limit supplemental water provided by irrigation to non-potable, unless not practical.

When irrigation is required, the District Landscape Architect will comply with the California Department of Water Resources Model Water Efficient Landscape Ordinance (MWELO). Guidance on water conservation and the MWELO is available at: http://www.dot.ca.gov/design/lap/landscape-design/irrigation/irrigation-mwelo.html

2.9 Restrictions/Coordination

Successful implementation of the Bioretention TBMP requires proper siting by the PDT with coordination of the District/Regional Design Stormwater Coordinator, District Hydraulics, District Maintenance, District Traffic Operations, District Landscape Architecture, Geotechnical Design, and Traffic Safety, as applicable per site design. Bioretention TBMP design decisions and coordination must be documented in the SWDR.

Section 3

Getting Started

Evaluate site conditions to obtain and assess the design parameters that will be used to determine if a Bioretention TBMP is suitable based on the Feasibility Criteria described in Section 2. When native infiltration is feasible and the basin is unlined, Bioretention TBMPs require an extensive geotechnical investigation, see the Infiltration Basins Design Guidance for more information (Caltrans 2020b). This section provides the calculations that are used to verify BMP feasibility and to determine the portion of WQV treated by the BMP. If the Bioretention TBMP is configured inline, also verify that the BMP can convey the Design Storm flows.

3.1 Contributing Drainage Area and WQV

The WQV generated by the TBMP contributing drainage area (CDA) is calculated using the Small Storm Hydrology Method (PPDG Section 5.3). The Caltrans Infiltration Tool version IT4 can also be used when this TBMP is modeled as an infiltration basin (Caltrans 2019e). An explanation of CDA delineation and WQV calculation and example can be found in Section 3 of the DPPIA Design Guidance (Caltrans 2021).

3.2 Minimum Surface Area

The portion of WQV that exceeds the storage capacity of the media layer will pond above the soil layer until it can be infiltrated over a desired drawdown time. When the TBMP is unlined, the WQV infiltrated though native soils should be determined and used to refine the TBMP size. The following calculation method is used to size the TBMP footprint area necessary to treat the required WQV (Claytor and Schueler 1996):

$A_f = WQV\ (d_f\ /\ [k\ (h_f + d_f)\ t_f])$

Where:

A_f = Minimum surface area of the bioretention ponding area (ft^2)

WQV = Water Quality Volume (ft^3)

d_f = Media layer depth (ft)

k = Coefficient of permeability for bioretention soil media (infiltration rate), (ft/day)

h_f = Average water depth above the soil media layer (ponding depth) (ft); $h_f = ½ * h_{max}$

t_f = Design drain time for WQV (days)

The design factors used to calculate the surface area of the Bioretention TBMP should be based on site conditions and allowable design parameters accepted by the District/Regional Design Stormwater Coordinator. Typical ranges for the bioretention soil media characteristics are detailed in Section 2.4 and listed in Table 3-1. The values in Table 3-1 are based on optimal design from pilots, variations in these values can be considered by the designer based on site conditions, as long as the BMP pollutant removal function is considered in the change.

Table 3-1. Bioretention TBMP Design Criteria

Design Parameter	Optimal Value
Soil media composition	sand, compost, and topsoil
Composition Ratio	4 parts sand, 2 parts compost and 1 part topsoil, or regionally appropriate mix
Coefficient of permeability for soil media	1 in/hr min, 3 in/hr preferred
Depth of media layer	18-24 in
Placement depth of soil media	8-12 in lifts
Compaction of soil media	80% relative compaction, when allowable
Filter course layer	6 in Class 2 Permeable Material
Depth of subsurface drainage layer	12-24 in of Class 2 Permeable Material
Underdrain pipe diameter	6 in min, perforations at bottom
Design drain time for WQV	48-72 hr preferred, 96 hr max
Maximum Ponding Depth	6-12 in
Recommended Freeboard	1 in (offline), 12 in (inline)

3.3 Design Storm Event

When placed in an inline configuration (see Section 4.2), the BMP must safely pass flows that are larger than the WQ Event, typically through an overflow device. The TBMP bypass must be designed to convey peak drainage from the roadway in accordance with HDM Topic 831. This event is called the Design Storm[1]. Continue to use the runoff coefficients in HDM Topic 819.2 and the total TBMP CDA for drainage design and flood flows. The permissible velocity and permissible shear stress of the lining vegetated or non-vegetated, for upstream and downstream conveyance systems, during the Design Storm must be evaluated when flows are expected to concentrate, see HDM Chapter 860 and Table 865.2.

In addition, when using an inline configuration a minimum freeboard of 12 inches should be provided between the surface water elevation during the overflow event and the lowest elevation of the confinement in order to provide assurance of the physical integrity of the TBMP and downstream facilities. Downstream conveyance design is beyond the scope of this document.

3.4 Alternative TBMP Sizing

Alternative calculations may be generated by the PE for a specific project to refine the TBMP size. One alternative is to use the California Stormwater Quality Association (CASQA) TC-40 methodology for sizing media filter bed areas (CASQA 2003). The TC-40 includes the following rule-of-thumb for sizing the filter area (A_f):

If the filter is preceded by a sedimentation basin that releases the WQV to the filter over 24-hours, then the minimum average surface area is:

$A_f = WQV/18$

If no pretreatment is provided, then the minimum average surface area is:

$A_f = WQV/10$

Additionally, the calculations in this guidance assume instantaneous runoff to the TBMP (i.e., 'slug-flow') which does not consider active treatment during the event, leading to conservative sizing designs. A sizing alternative to account for timing of runoff is to perform rainfall-runoff and unsteady-flow routing computations for the TBMP. When the runoff is distributed over the duration of an event, early-event runoff can be treated and released before the peak runoff arrives. Using these calculations, the TBMP does not need to be sized to store the entire runoff volume at once (i.e., 'slug-flow'), leading to smaller designs. By accounting for active treatment occurring during the event, an increase in the treated WQV can be expected. Details of this methodology and findings are discussed in the Review of Design Guidance for Sizing Media Filters for Stormwater Quality Treatment (Caltrans 2019d).

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[1] For convenience in this document, the Design Storm flow is referred to as the 25-year storm event. However, other recurrence intervals may have been used for the roadway drainage design, as described in HDM Chapter 830, Transportation Facility Drainage; confer with District Hydraulics.

Additionally, when an infiltrative BMP is installed in a Type A or Type B soil the BMP footprint can be reduced while treating the same WQV. The following figure shows an example of how accounting for active treatment and native soil type using the Caltrans Infiltration Tool IT4 tool impacts BMP size. The example shows that in a Type A soil a BMP can be 60% smaller than if it were installed in Type C or Type D soils.

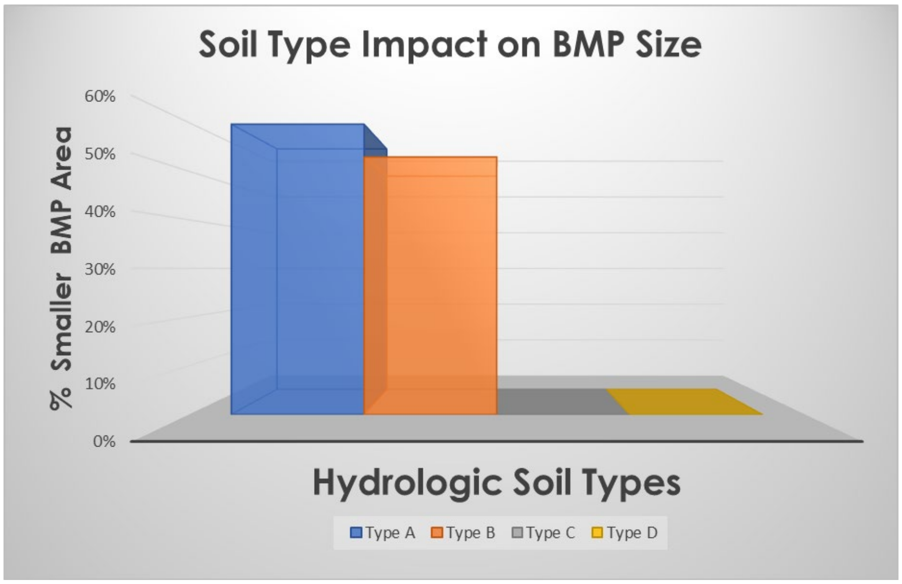

Figure 3-1. BMP Size Reduction Based on Soil Type

Alternative calculations may be used by the PE for a specific project and must be developed in consultation with the District/Regional Design Stormwater Coordinator and documented in the SWDR. Consult with Division of Environmental Analysis and OHSD for design approval or to determine if a Special Design or pilot is required.

Section 4

TBMP Layout and Design

This section includes considerations for layout and specific design elements of a Bioretention TBMP.

4.1 Location

A Bioretention TBMP can be used as a stand-alone device or can be placed in series with other TBMPs. To avoid clogging, they should be placed downstream of other TBMPs that reduce sediment loading, and not considered for use as a pretreatment device for high-sediment runoff. Bioretention TBMP used downstream of a pretreatment device is an example of a treatment train.

4.2 Inline vs. Offline Placement

A Bioretention TBMP can be placed in an inline or offline configuration. Inline systems can easily be overwhelmed by sediment, trash, or aggregate and some can be very hard or nearly impossible to clean if loaded with material. Maintainable pretreatment and diversions for flows greater than the WQ event should be implemented to reduce the risk of clogging or failure of this TBMP.

When a Bioretention TBMP is placed in an inline configuration it must include a means to convey events greater than the WQ Event through the device. Additionally, the Bioretention TBMP must be able to convey the runoff generated during the Design Storm event to a downstream conveyance without objectionable backwater effects to upstream facilities. An overflow device should be designed to convey the runoff in excess of the BMP capacity in accordance with Section 4.4.

A Bioretention TBMP is placed in an offline configuration when an alternative route for runoff in excess of the WQV is provided. The excess volume is diverted around the TBMP to avoid exposing the treatment facility to events larger than the WQ Event. Offline placement also provides better treatment by collecting first-flush runoff. A flow diversion structure typically consists of a flow splitter, weir, orifice, or pipe to bypass excess runoff (Caltrans 2020f). Even in an offline configuration, an overflow device should be included in the BMP design in accordance with Section 4.4.

4.3 Pretreatment of Runoff

Runoff entering a Bioretention TBMP should be pretreated to minimize the build-up of sediments and trash in the device, which will impair performance. Pretreatment is used to extend the maintenance interval on the system and reduce the life cycle cost.

Stormwater runoff that is directed to a Bioretention TBMP would usually be in a concentrated flow regime. Place a sediment TBMP immediately upstream of the Bioretention inlet and provide maintenance access.

Pretreatment of runoff for oil and grease is recommended for large parking lots, commercial sites, and industrial sites when a significant potential exists for discharge of contaminants to groundwater or surface water (e.g., spills, high concentrations of oil/grease). Consideration of trash capture in these areas is also advisable due to the increased potential for generation of litter.

4.4 Overflow Release

An overflow device should be provided for all Bioretention TBMPs and must be provided for inline placement. When placed inline, the Bioretention TBMP must safely pass events that exceed the WQV through the TBMP. The release elevation of the overflow device should be set to the water surface elevation of the WQV. Typically, the device would be configured as an overflow riser or a spillway to convey the larger storm events.

Overflow risers are vertical pipes that act as sharp-crested weirs designed to pass flows in excess of the WQV. Riser pipe diameter should be sized to accommodate the design storm. Details of overflow risers can be found in Section 8 of the Supplemental Details Design Guidance (Caltrans 2020e).

Overflow spillways are broad-crested weirs intended to control the location where the flows would overtop the basin perimeter to avoid structural damage to the embankment and to direct the flows into the downstream conveyance system or other discharge point. Spillway length should be sized to accommodate the design storm. Details and design parameters of overflow spillways can be found in Section 5 of the Supplemental Details Design Guidance (Caltrans 2020e).

The overflow device should meet the design criteria and be accompanied with downstream conveyance engineered to handle the Design Storm flow (see Section 3.3). In addition, freeboard between the water surface elevation during the overflow event and the lowest elevation of the confinement should be considered to avoid pressurized conditions and to provide assurance of the physical integrity of the Infiltration Gallery and downstream facilities.

4.5 Upstream Effects

While Bioretention TBMPs are placed for water quality purposes, they must also operate safely and effectively as part of the overall highway drainage system. Hydraulic design issues must be carefully evaluated during the design process. The TBMP placement and design must consider the design of the roadway drainage system. The Design Storm must be determined and the associated hydraulic grade lines calculated to ensure that placement of the device does not impede the effective drainage of the roadway. Additional discussion of those analyses are beyond the scope of this document and should be coordinated with District Hydraulics.

4.6 Potential Downstream Impacts

Potential downstream impacts must be considered. Placement of this or any other TBMP must not cause objectionable headwater or violate requirements of Chapter 800 of the HDM. Specific consideration of the overall placement within a particular drainage system is beyond the scope of this document and should be coordinated with District Hydraulics.

4.7 Litter and Trash Considerations

Caltrans has developed a Statewide Trash Implementation Plan (Plan; Caltrans 2019c) to prevent the discharge of trash to surface waters through stormwater discharges. The Plan identifies statewide Significant Trash Generating Areas (STGAs) requiring consideration of full trash capture BMPs.

Full trash capture should be included in the design of a Bioretention TBMP within a watershed where any of the following exists:

1. A Total Maximum Daily Load (TMDL) restriction for trash
2. Discharges to a 303(d) listed waterway for trash
3. Has been identified as an STGA
4. Required by a Regional Basin Plan

The Bioretention TBMP is a Caltrans approved treatment device that can be certified as a multi benefit full trash capture BMP. The full-capture volume is calculated using the 1-year, 1-hour storm event depth. Refer to the Multi Benefit Treatment BMP Trash Full Capture Requirements Design Guide (Caltrans 2018) for specifics on design details.

Additionally, the PE may include a pretreatment device to capture the gross solids (e.g., paper, plastics, glass) and naturally occurring debris that may be conveyed by stormwater to the Bioretention TBMP. The device should be designed to remove all litter and solids 5 mm and larger. This pretreatment can be provided by the Caltrans approved Gross Solids Removal Devices (GSRDs) TBMP or other devices that meet the requirements for full trash capture.

Use of other devices requires a detailed design by the PE and must be coordinated with the District/Regional Design Stormwater Coordinator, District Hydraulics, Traffic Safety, District Maintenance Stormwater Coordinator, and OHSD, as appropriate. Consult with OHSD for design approval or to determine if a Special Design is required. Pilot BMPs may be considered with OHSD and DEA approval. Design decisions and coordination on the trash device must be documented in the SWDR

Section 5

PS&E Preparation

This section provides guidance for incorporating Bioretention TBMPs into the PS&E package, discusses the typical specifications that may be required, and presents information about estimating construction costs.

While every effort has been made to provide accurate information here, the PE is responsible for incorporating all design aspects of Bioretention TBMPs into the PS&E in accordance with the requirements of Section 2 of the Construction Contract Development Guide (Caltrans 2019c).

5.1 PS&E Drawings

Bioretention TBMPs do not have standard drawings for the device as a complete feature. The PE is responsible for incorporating all design aspects of the Bioretention TBMP into the PS&E drawings in accordance with the procedures typically followed when developing a PS&E package.

The PS&E drawings for most projects having Bioretention TBMPs may include:

- Layout(s): Show location(s) of the Bioretention TBMPs. This will aid in recognizing, both within and outside Caltrans, that Bioretention TBMPs were placed within the project limits.
- Drainage Plan(s), Profiles, Details, and Quantities:
  - Drainage Plan sheets should show each Bioretention TBMP in plan view, along with other existing (or proposed) drainage conveyance devices that direct the runoff into the device and overflow from the device.
  - Drainage Profile sheets should show the Bioretention TBMP in profile within the drainage conveyance system. These sheets should also call out the specific Bioretention TBMP inlet and outlet flow line (surface) elevations and invert elevation.
  - Drainage Detail sheets should show any detailing needed for the construction of the Bioretention TBMP. Inflow and outflow detailing should be shown including the overflow release device (e.g., spillway through the confining berm or through a CMP riser).
  - Drainage Quantity sheets should include all pay and non-pay items associated with the construction of the Bioretention TBMPs, except for those items that will be placed on the Summary of Quantities sheets.

- Planting Plans/Erosion Control Plans: These sheets are used to show vegetative portion of the BMP if needed. Planting quantities (e.g., hydroseed) for each Bioretention TBMP should be provided.
- Temporary Water Pollution Control Plans: These sheets are used to show the temporary BMPs used to establish the Bioretention TBMPs and compliance with the Construction General Permit.

5.2 Specifications

Contract specifications for Bioretention TBMP projects will include a combination of Standard Specifications, Standard Special Provisions (SSPs), and non-Standard Special Provisions (nSSPs). In some cases, specific nSSPs have been developed by OHSD.

The special provisions for the various items of work directly needed to construct the Bioretention TBMP could be organized under an umbrella 'Bioretention TBMP' nSSP with the required items listed as subheadings. Payment would be made by volume for each Bioretention TBMP.

Optionally, separate listings could be made for each contract item of work, with separate measurements and payments. The PE and the District Office Engineer should consider which method would better serve the project.

5.2.1 Standard Specifications

Standard Specifications may be used for a Bioretention TBMP in conjunction with Bioretention TBMP nSSP from OHSD. Consider the construction of the Bioretention TBMP in the context of the entire project to determine what Standard Specifications are applicable. Within the Standard Specifications, these are the sections that may be applicable:

13 Water Pollution Control

17 General (Earthwork and Landscape)

19 Earthwork

20 Landscape

21 Erosion Control

26 Aggregate Base

68 Subsurface Drains

70 Miscellaneous Drainage Facilities

71 Existing Drainage Facilities

72 Slope Protection

96 Geosynthetics

5.2.2 Standard Special Provisions

SSPs can be used for a project that constructs a Bioretention TBMP. Consider the construction of Bioretention TBMPs in the context of the entire project to determine if SSPs are required or if they can enhance the overall design as part of the Bioretention TBMP.

5.2.3 Non-Standard Special Provisions

A Bioretention TBMP nSSP can be obtained from OHSD. Use of the Bioretention TBMP nSSP is recommended so the costs and location of the TBMP can be captured and tracked for compliance with the NPDES permit.

5.3 Project Cost Estimates

Project Cost Estimates are required at every phase of the project – Project Initiation Document (PID), Project Approval/Environmental Document (PA/ED), and PS&E. The Caltrans Division of Design, Office of Project Support has developed the following website to assist in the development of cost estimates:

http://www.dot.ca.gov/design/pjs/index.html

This website includes links to Chapter 20 Project Development Cost Estimates of the Project Development Procedures Manual and Caltrans Cost Estimating Guidelines. In addition to Chapter 20, this website includes other useful cost estimating information on project cost escalation, contingency and supplemental work, and cost estimating templates for the planning and design phases of the project. These templates may be used to track estimates relating to costs for incorporating TBMPs.

5.3.1 PID and PA/ED Phases

A preliminary cost estimate, Project Planning Cost Estimate (PPCE), is required as an attachment of the SWDR during the PID phase of the project. A refined version of the PPCE is developed in the PA/ED phase. For details on what needs to be included in PPCE, refer to Section 6.4.9 and Appendix F of the PPDG. 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

Preliminary Engineer's Cost Estimates (PECE) are initiated at the beginning of PS&E and are updated until the completion of PS&E phase of the project. PECEs focus on the construction costs of the project and the stormwater TBMPs and are inputs to the Basic Engineering Estimating System (BEES). Verify the quantities for inclusion in the project cost estimate to determine appropriate unit prices for each. Develop all necessary earthwork quantities for each specific Bioretention TBMP location and determine limits of excavation and backfill. Sample quantity sheet can be provided by OHSD.

5.4 Developing Bioretention TBMP Cost Estimates

Develop a quantity-based cost estimate. As the design process proceeds, the project cost estimate should be updated as new data becomes available. Identify the contract items required to construct the Bioretention TBMP. A challenging aspect of developing a cost estimate is determining the TBMP limits of work. Only costs for work exclusively used to construct the TBMP should be included in the estimate.

It may not be necessary to include costs for items that support the TBMP. For example, utility relocation, maintenance vehicle pullouts, traffic safety items, drainage systems, or other site design elements that are required for the project even if the TBMP was not needed. Include the costs for these items when they are exclusively required for the TBMP.

Table 5-1 includes typical contract items that may be included in the cost estimate if they are required exclusively for Bioretention TBMPs. Table 5-1 is not a complete list and must be modified on a project specific basis to accommodate all aspects of design.

Table 5-1. Example Bioretention TBMP Estimate

Contract Item	Type	Unit	Quantity	Price	Amount
Clearing and Grubbing		LS			
Excavation		CY			
Soil Media		CY			
Rock Slope Protection		CY			
Permeable Material		CY			
Perforated Pipe Underdrain		LF			
Erosion Control Seeding (e.g., Hydroseed, Dry Seed, Hydromulch)		SQFT			
TRM		SQFT			
Rolled Erosion Control Product (Blanket)		SQFT			

When developing costs based on unit quantities, the unit costs should be based upon the most recent Caltrans Contract Cost Data Book or District 8 Cost Data Base for current similar projects in the District:

https://sv08data.dot.ca.gov/contractcost/

Use the project specifications, SSPs, and nSSPs to develop a list of items for which unit costs should be supplied. Carefully check that all items of work are accounted for either as pay or non-pay items.

Watch for the costs associated with soil media for each specific Bioretention TBMP location, as that item of work can have the most variable costs for this TBMP. Estimate the total cost of each Bioretention TBMP used on the project for tracking TBMP costs at PS&E. Document all TBMP costs in the project SWDR at PS&E. Some Bioretention TBMP features may be required for drainage or other project features and should not be double counted. Cost items will vary by project.

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Section 6

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