Riverside County
Santa Margarita River Watershed Region
Design Handbook
for
Low Impact Development
Best Management Practices

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Revised June 2018

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TABLE OF CONTENTS

APPENDICES

Riverside County - Santa Margarita River Watershed Region

Design Handbook for Low Impact Development Best Management Practices

1.0 Introduction

What is Low Impact Development?

According to the State Water Resources Control Board, Low Impact Development (LID) is:

> *… a sustainable practice that benefits water supply and contributes to water quality protection. Unlike traditional storm water management, which collects and conveys storm water runoff through storm drains, pipes, or other conveyances to a centralized storm water facility, LID takes a different approach by using site design and storm water management to maintain the site's pre-development runoff rates and volumes. The goal of LID is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to the source of rainfall.*[1]

When implemented correctly on a site, LID provides two primary benefits: 1) The post-construction site hydrology will more closely mimic the pre-development hydrology, thus reducing the downstream erosion that may occur due to increased runoff from impervious surfaces; and 2) Pollutants in runoff from the site will be significantly reduced.

Additionally, the California Stormwater Quality Association (CASQA) LID Manual[2] identifies that a properly and effectively designed site will incorporate two forms of LID: LID Principles and LID BMPs. Whereas LID Principles focus on planning and designing a site in a manner that minimizes the causes, or drivers, of project impacts (sometimes referred to as site design), this Handbook discusses LID BMPs which are implemented to help mitigate any impacts that are otherwise unavoidable.

Notes on terminology: This Handbook uses the term "LID Principles" or "Site Design" to refer to BMPs described in Provision E.3.a(3) of the Regional MS4 Permit (note the Permit calls these BMPs "Low Impact Development"). This Handbook uses the terms "LID BMPs" and "Treatment

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[1] State Water Resources Control Board, *Low Impact Development – Sustainable Storm Water Management*, 2010; http://www.waterboards.ca.gov/water_issues/programs/low_impact_development/index.shtml

[2] California Stormwater Quality Association, *Low Impact Development Manual for Southern California: Technical Guidance and Site Planning Strategies*, April 2010

Control BMPs" are used to refer to classes of Structural Stormwater Pollutant Control BMPs described in Provision E.3.c(1) of the Regional MS4 Permit.

About this Handbook

This Handbook supplements the Water Quality Management Plan (WQMP) for the Santa Margarita River Watershed Region (SMR) of Riverside County by providing guidance for the planning, design and maintenance of Low Impact Development (LID) BMPs (i.e. Permit Provision E.3.c(1))which may be used to mitigate the water quality impacts of development within the SMR Watershed.

This Handbook contains detailed information and designs for twelve (12) LID BMPs that are designed to encourage replication of the site's natural hydrologic processes. This includes maximizing direct or incidental infiltration and evapotranspiration, and using vegetation and other biological processes to filter and absorb pollutants. For each BMP, pertinent information is provided such as the maximum tributary drainage area, siting considerations, design procedures, and maintenance requirements. This Handbook also includes detailed guidance for infiltration testing, and basin considerations. It should be noted that project specific engineering analysis may be used to over-ride certain requirements described in this manual, as approved by the reviewing agency to ensure water quality is protected to the maximum extent practicable.

Selecting appropriate LID BMPs

LID BMPs are an effective, naturally-based form of stormwater pollutant treatment BMPs. Before selecting any particular BMPs for a site, refer to the 2018 SMR WQMP to determine LID options and requirements. The WQMP specifies particular types of LID or Treatment Control BMPs that can or must be considered for use on the project. Considerations for BMP selection include whether or not the LID BMP will maximize on-site retention of runoff, or be based on the types of pollutants that the site may generate, types of pollutants that are impairing the downstream receiving waters, and which BMPs are effective at addressing those pollutants.

Generally, infiltration BMPs have advantages over other types of BMPs, including reduction of the volume and rate of runoff, as well as full treatment of all potential pollutants potentially contained in the stormwater runoff. It is recognized however, that infiltration and retention BMPs may not be feasible on sites with high groundwater, low infiltration rates, or located on compacted engineered fill. In those situations, biofiltration based BMPs that provide opportunity for evapotranspiration and incidental infiltration may be a more feasible option. The WQMP specifies criteria that should be used to determine when particular BMPs are considered feasible.

Who should be involved in the selection, siting and design of LID BMPs?

Everyone involved with the project site development, including owners, architects, engineers, biologists, and geologists, should be informed about the proposed/required BMPs as early as possible in the planning of a project. This reduces the chance of costly redesign, the need for additional testing and produces a better and more integrated site overall. For most detention or retention basins and all infiltration BMPs, it is important that the responsible engineer/geologist be made aware of the location of BMPs, so they can make design recommendations including setbacks and perform the appropriate infiltration testing, as applicable. Landscape architects will need to know the locations and types of proposed BMPs as these might change the types of plants that can be used. Owners must be made aware of the construction costs, long-term maintenance requirements and costs, and total costs of ownership for the BMPs in order to make informed decisions during the BMP selection process.

Many of the BMP fact sheets reference the 'Engineering Authority' (EA). Who is the EA for my project?

The engineering authority for a project is the public agency responsible for reviewing and approving the proposed project. Usually the EA is the City/County wherein the project is located.

Do I need to do additional studies?

Most infiltration BMPs and basins will require a geotechnical report prepared by either a licensed geotechnical engineer, civil engineer or certified engineering geologist. The report must provide characterization of site specific soil conditions, recommendations of any required testing, and site-specific recommendations for setbacks as well as commentary on slope stability and potential offsite impacts. See Infiltration Testing Requirements and Basin Guidelines in Appendices A and C, respectively, for more information. Some sites will require other studies, such as biological resources, geomorphology, or groundwater hydrology.

Designing the BMPs

The BMPs in this Handbook are designed based on required capture volume or treatment flow rate. Volume-based BMPs are designed to capture a particular volume of stormwater runoff (referred to as V_{BMP} or the Design Capture Volume (DCV)), and either infiltrate that volume, re-use the water, or slowly and naturally filter pollutants from that stormwater, and discharge the volume within a specified "drawdown time" (the time required to regenerate the storage capacity of the BMP). Flow-based BMPs are designed to treat a required minimum flow rate of stormwater runoff (referred to as Q_{BMP}).

This Handbook contains worksheets to assist the designer in determining the required V_{BMP} and Q_{BMP} based on the location of the site. While there are likely significant direct or indirect volume reduction benefits associated with each of the included LID BMPs, these sizing worksheets are not intended to meet Hydromodification Performance Standards detailed in the SMR WQMP.

Can I make my BMP smaller?

The worksheets in this Handbook calculate the minimum required size for each LID BMP based on the amount of runoff routed to the BMP. However, early and aggressive implementation of LID Principles (site design) during the planning stages of a project can reduce the size of the effective drainage management area (DMA) for the BMP, which reduces runoff volume from the DMA, which in turn will help minimize the required size of the BMPs. To further reduce the required size, consider looking for additional ways to increase the percentage of permeable areas and porous surfaces on the site, and opportunities to drain impervious areas into pervious areas.

Can I place my BMP underground?

Underground BMPs can be an important part of an LID solution for a site. However, underground BMPs create some special challenges that must be addressed in order to provide a sustainable solution. Challenges include but are not limited to a need for effective pre-treatment, structural stability, vector control, maintenance, and the cost of replacement at the time that clogging cannot be remediated with maintenance. Special consideration needs to be given to how underground BMPs can be sustainably operated, maintained, and replaced when needed. This may include: greater emphasis on pre-treatment, inclusion of adequate inspection and maintenance features, regular inspections and effective maintenance of the BMP, and budgetary planning for major construction efforts when replacement is needed.

What are Drawdown Times?

Volume based BMPs are usually associated with a required drawdown time. The drawdown time refers to the amount of time required to regenerate the storage capacity of the BMP (i.e., drain the BMP from brim full). The specified or incorporated drawdown times are to ensure that adequate contact or detention time has occurred for treatment, while not creating vector or other nuisance issues. It is important to abide by the drawdown time requirements stated in the fact sheet for each specific BMP, or as specified by the local jurisdiction.

What is the tributary drainage area?

The tributary drainage area is the entire area that drains to the proposed onsite BMP. While small sites could be tributary to a single BMP, usually the site is broken up into several drainage management areas (DMAs), each draining to a discrete BMP. Although it is usually desirable to address offsite flows separately, if flows from offsite areas commingle with onsite flows they shall also be included in the sizing calculation. At the beginning of each fact sheet, the maximum (or minimum) tributary drainage area for each BMP is listed. The tributary areas for each BMP will be required to be clearly shown on one or more drainage exhibits. Such exhibits shall be clearly labeled to show which areas drain to which BMP.

What are pervious and impervious areas?

Project sites are made up of both pervious and impervious surfaces. The pervious portion of a site is where stormwater has the opportunity to infiltrate into the ground, such as but not limited to landscaped or natural areas. Impervious areas are where water has no opportunity to infiltrate and immediately becomes surface runoff (e.g. roofs, standard roadway pavements, concrete driveways or walkways, tightly compacted earthen materials, etc.). When a site is developed, the percentage of impervious area typically increases from the natural state. This higher impervious percentage increases the volume and flow rate of stormwater runoff.

2.0 Sizing Calculations

The following section includes sizing calculations for LID BMPs in the Santa Margarita River Watershed. There may be circumstances when flow-based Treatment Control BMPs are utilized and therefore this section also includes guidelines for calculating the design flow rate, Q_{BMP}.

2.1 Calculating V_{BMP}

Volume based BMPs and Biofiltration BMPs, including all of the BMPs in this manual, can be sized based on the design capture volume, (DCV or V_{BMP}).

The design capture volume (DCV or V_{BMP}) is based on capturing the volume of runoff generated from an 85th percentile, 24-hour storm event. Follow the steps below to calculate V_{BMP}. For convenience, these steps have also been integrated into an excel worksheet that has been provided in Appendix E of this Handbook.

1) Determine the tributary drainage area to the BMP, A_T. This includes all areas that will contribute runoff to the proposed BMP, including pervious areas, and runoff from off-site areas that commingle with on-site runoff. Calculate this area in acres.

2) Locate the project site on the full sized Isohyetal Map for the 85th Percentile 24-hour Storm Event contained in Appendix A of the SMR WQMP). These values were determined throughout Riverside County using rain gauges with the greatest periods of record. Use township, range and section information to locate the project site, and interpolate the closest value, D85, for the site. For areas near the edge of the county, extend the isohyetal lines linearly to the County boundary.

3) Determine the effective impervious fraction (I_f) for the area tributary to the BMP, using the following table:

Surface Type	Effective Impervious Fraction, I_f
Roofs	1.00
Concrete or Asphalt	1.00
Grouted or Gapless Paving Blocks	1.00
Compacted Soil (e.g. unpaved parking)	0.40
Decomposed Granite	0.40
Permeable Paving Blocks w/ Sand Filled Gap	0.25
Class 2 Base	0.30
Gravel or Class 2 Permeable Base	0.10
Pervious Concrete / Porous Asphalt	0.10
Open and Porous Pavers	0.10
Turf block	0.10
Ornamental Landscaping	0.10
Natural (A Soil)	0.03
Natural (B Soil)	0.15
Natural (C Soil)	0.30
Natural (D Soil)	0.40

If the area tributary to the BMP contains mixed post-project surface types, a composite or area-weighted average effective impervious fraction should be used. The following equation can be used for determining an area-weighted average:

$$\frac{\left[\left(I_f\right)_1 \cdot A_1\right] + \left[\left(I_f\right)_2 \cdot A_2\right] + [\ldots]}{A_T}$$

4) Calculate a runoff factor, 'C', using the following equation:

$$C = 0.858 \cdot {I_f}^3 - 0.78 \cdot {I_f}^2 + 0.774 * I_f + 0.04$$

5) Determine unit storage volume, V_U. This is found by multiplying the Design Storm Depth found in Step 2 by the runoff coefficient found in Step 4.

$$\mathrm{V_U} = \mathrm{D_{85}} \times \mathrm{C}$$

6) Determine V_{BMP} using the equation below or the worksheet provided in Appendix E of this Handbook. This is the volume to be used in the design of selected BMPs presented in this Handbook. Multiply the BMP tributary drainage area, A_T, by the unit storage volume, V_U, to give the BMP design storage volume.

$$\mathrm{V_{BMP}}(\mathrm{ft}^3) = \frac{\mathrm{V_U}(\mathrm{in-ac/ac}) \times \mathrm{A_T}(\mathrm{ac}) \times 43{,}560(\mathrm{ft}^2/\mathrm{ac})}{12\ (\mathrm{in/ft})}$$

If Biofiltration BMPs are used, they must be sized according to either of the following approaches:

- Have a total static storage volume including pore spaces and pre-filter detention volume, at least 0.75 times the V_{BMP} (aka DCV) not reliably retained on site. The pre-filter detention volume refers to the volume stored above the soil media and up to the maximum water quality ponding level. Pore volume refers to the volume available in the pores of the soil and/or gravel in the system.
- Treat 1.5 times the V_{BMP} (aka DCV) not reliably retained on site. This may be a volume-based or a flow-based design.

Application of these sizing methods is explained in the respective biofiltration fact sheets (3.5 and 3.6).

2.2 Calculating Q_{BMP}

While the BMPs in this Handbook are designed based on V_{BMP} (aka DCV) as discussed in 2.1 above, in some circumstances flow-based BMPs may be used. Flow-based BMPs are sized to treat the design flow rate.

Q_{BMP} is the runoff flow rate resulting from a design rainfall intensity of 0.2 inches per hour or 2 times the maximum runoff flow rate produced during 85th percentile hourly rainfall intensity. Follow the steps below to calculate Q_{BMP}.

1) Determine the tributary drainage area, A_T, that drains to the proposed BMP. This includes all areas that will contribute runoff to the proposed BMP, including pervious areas, impervious areas, and runoff from offsite areas that commingle with site runoff, whether or not they are directly or indirectly connected to the BMP. Calculate this area in units of acres.

2) Determine the effective impervious fraction (I_f) for the area tributary to the BMP, using the following table:

Surface Type	Effective Impervious Fraction, I_f
Roofs	1.00
Concrete or Asphalt	1.00
Grouted or Gapless Paving Blocks	1.00
Compacted Soil (e.g. unpaved parking)	0.40
Decomposed Granite	0.40
Permeable Paving Blocks w/ Sand Filled Gap	0.25
Class 2 Base	0.30
Gravel or Class 2 Permeable Base	0.10
Pervious Concrete / Porous Asphalt	0.10
Open and Porous Pavers	0.10
Turf block	0.10
Ornamental Landscaping	0.10
Natural (A Soil)	0.03
Natural (B Soil)	0.15

Natural (C Soil)	0.30
Natural (D Soil)	0.40

If the area tributary to the BMP contains mixed post-project surface types, a composite or area-weighted average effective impervious fraction should be used. The following equation can be used for determining an area-weighted average:

$$\frac{\left[\left(I_f\right)_1 \cdot A_1\right] + \left[\left(I_f\right)_2 \cdot A_2\right] + [\ldots]}{A_T}$$

3) Calculate a runoff factor, 'C', using the following equation:

$$C = 0.858 \cdot {I_f}^3 - 0.78 \cdot {I_f}^2 + 0.774 * I_f + 0.04$$

4) Determine the Design Rainfall Intensity using one of the following methods:
    - Use a value of 0.2 inches per hour, or,
    - Use local rainfall records, if suitable records exist, to calculate two times the maximum runoff during the 85th percentile hourly rainfall intensity.

5) Determine the BMP Design Flow Rate using the equation:

$$Q_{BMP} = C \times I \times A_T$$

Where,

A_T = Tributary Area to the BMP, in acres

I = Design Rainfall Intensity, from Step 4.

C = Runoff Factor, found in Step 3

For flow-based biofiltration BMPs, the Q_{BMP} calculated above needs to be multiplied by 1.5 to meet the sizing standard for biofiltration BMPs in the SMR watershed. Flow-based biofiltration BMPs are not acceptable in all cases.

3.0 BMP Fact Sheets

This section provides fact sheets for the following thirteen types of BMPs:

3.1 - Infiltration Basins

3.2 - Infiltration Trenches

3.3 - Permeable Pavement
3.a - Drywells

3.4 - Bioretention Facilities

3.5 - Biofiltration with Partial Infiltration

3.6 - Biofiltration with No Infiltration

3.7 – Regional Bioretention/Biofiltration Facility Guidance

3.8 - Bioretention Soil Media

3.9 - Tree Wells

3.10 - Extended Detention Basins

3.11 - Sand Filter Basins

3.12 - Harvest and Use

►For portability, the fact sheets for each BMP, as well as Calculation worksheets for sizing and documenting the design of these BMPs, are provided as separate downloadable files on the LID Handbook page at http://rcflood.org/NPDES/SMRWMA.aspx

BEFORE selecting any particular BMP for use on your project, review the requirements of the 2018 SMR WQMP, and the discussions in sections 1 and 2 of this Handbook. These provide important context and instructions that may dictate that particular BMPs be used.

3.1 INFILTRATION BASIN

Type of BMP	LID – Infiltration
Priority Level	Priority 1 – Full Retention
Treatment Mechanisms	Infiltration, Evapotranspiration (when vegetated), Evaporation, Sedimentation
Infiltration Rate Range	> 0.8 in/hr factored design infiltration rate
Maximum Drainage Area	50 acres

Description

An Infiltration Basin is a flat earthen basin designed to capture the design capture volume, V_{BMP}. The stormwater infiltrates through the bottom of the basin into the underlying soil over a 72 hour drawdown period. Flows exceeding V_{BMP} must discharge to a downstream conveyance system. Trash and sediment accumulate within the forebay as stormwater passes into the basin. Infiltration basins are highly effective in removing all targeted pollutants from stormwater runoff.

Figure 1 – Infiltration Basin

See Appendix A, and Appendix C, Section 1 of *Basin Guidelines*, for additional requirements.

Siting Considerations

The use of infiltration basins may be restricted by concerns over ground water contamination, soil permeability, and clogging at the site. See the Santa Margarita Region (SMR) Water Quality Management Plan (WQMP) for any specific feasibility considerations for using infiltration BMPs. Where this BMP is being used, the soil beneath the basin must be thoroughly evaluated in a geotechnical report since the underlying soils are critical to the basin's long term performance. To protect the basin from erosion, the sides and bottom of the basin must be vegetated, preferably with native or low water use plant species.

In addition, these basins may not be appropriate for the following site conditions:

- Industrial sites or locations where spills of toxic materials may occur
- Sites with very low soil infiltration rates
- Sites with high groundwater tables or excessively high soil infiltration rates, where pollutants can affect ground water quality
- Sites with unstabilized soil or construction activity upstream
- On steeply sloping terrain
- Infiltration basins located in a fill condition should refer to Appendix A of this Handbook for details on special requirements/restrictions

INFILTRATION BASIN BMP FACT SHEET

Setbacks

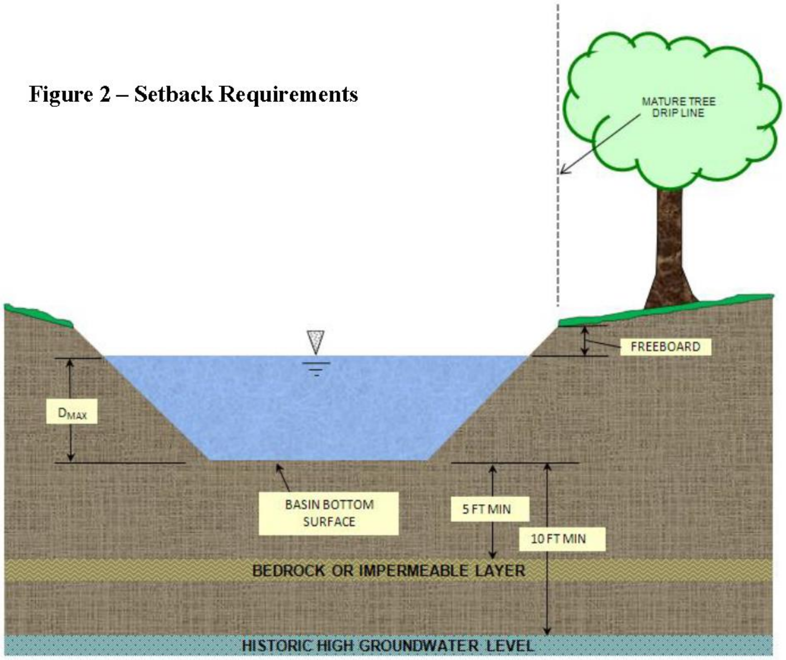
Always consult your geotechnical engineer for site specific recommendations regarding setbacks for infiltration trenches. Recommended setbacks are needed to protect buildings, existing trees, walls, onsite or nearby wells, streams, and tanks. Setbacks should be considered early in the design process since they can affect where infiltration facilities may be placed and how deep they are allowed to be. For instance, depth setbacks can dictate fairly shallow facilities that will have a larger footprint and, in some cases, may make an infiltration basin infeasible. In that instance, another BMP must be selected.

Infiltration basins typically must be set back:

- 10 feet from the historic high groundwater (measured vertically from the bottom of the basin, as shown in Figure 2)
- 5 feet from bedrock or impermeable surface layer (measured vertically from the bottom of the basin, as shown in Figure 2)
- From all existing mature tree drip lines as indicated in Figure 2 (to protect their root structure)
- 100 feet horizontally from wells, tanks or springs

Setbacks to walls and foundations must be included as part of the Geotechnical Report. All other setbacks shall be in accordance with applicable standards of the District's *Basin Guidelines* (Appendix C).

Figure 2 – Setback Requirements



INFILTRATION BASIN BMP FACT SHEET

Forebay

A concrete forebay shall be provided to reduce sediment clogging and to reduce erosion. The forebay shall have a design volume of at least 0.5% V_{BMP} and a minimum 1 foot high concrete splashwall / berm. Full height notch-type weir(s), offset from the line of flow from the basin inlet to prevent short circuiting, shall be used to outlet the forebay. It is recommended that two weirs be used and that they be located on opposite sides of the forebay (see Figure 2).

Overflow

Flows exceeding V_{BMP} must discharge to an acceptable downstream conveyance system. Where an adequate outlet is present, an overflow structure may be used. Where an embankment is present, an emergency spillway may be used instead. Overflows must be placed just above the design water surface for V_{BMP} and be near the outlet of the system. The overflow structure shall be similar to the District's Standard Drawing CB 110. Additional details may be found in the District's *Basin Guidelines* (Appendix C).

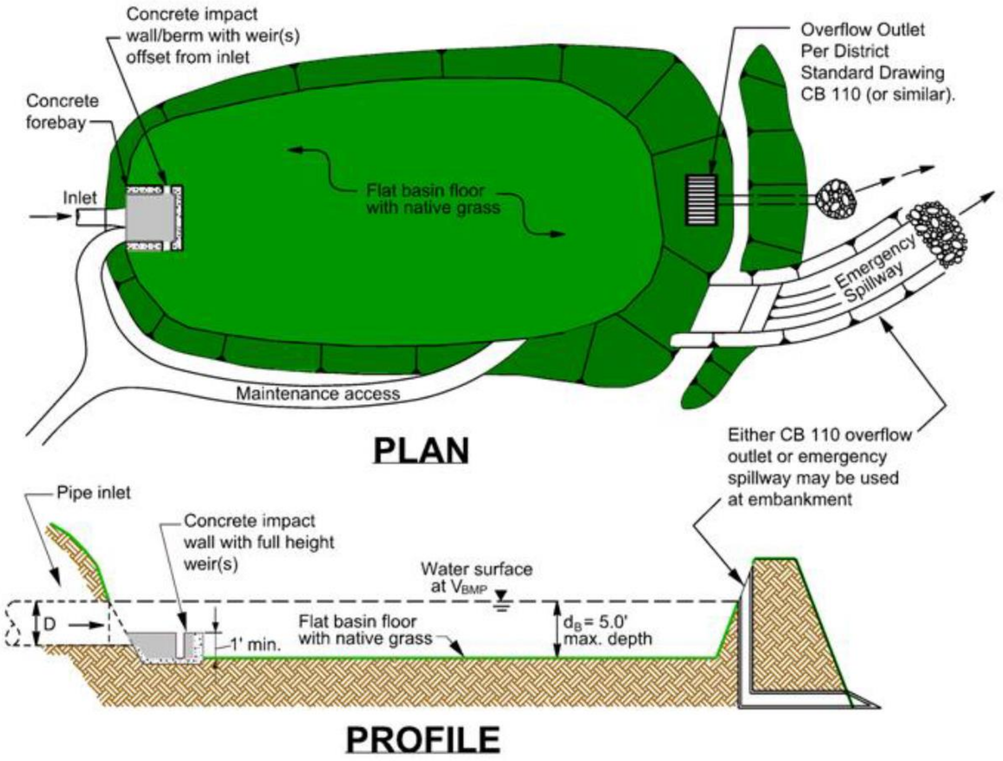


Figure 3 – Infiltration Basin

Landscaping Requirements

Basin vegetation provides erosion protection, improves sediment removal and assists in allowing infiltration to occur. The basin surface and side slopes shall be planted with native grasses.

Proper landscape management is also required to ensure that the vegetation does not contribute to water pollution through pesticides, herbicides, or fertilizers. Landscaping shall be in accordance with County of Riverside Ordinance 859 and the District's *Basin Guidelines* (Appendix C), or other guidelines issued by the Engineering Authority.

Maintenance

Normal maintenance of an infiltration basin includes the maintenance of landscaping, debris and trash removal from the surface of the basin, and tending to problems associated with standing water (vectors, odors, etc.). Significant ponding, especially more than 72 hours after an event, may indicate that the basin surface is no longer providing sufficient infiltration and requires aeration. See the District's *Basin Guidelines* (Appendix C) for additional requirements (i.e., fencing, maintenance access, etc.).

Table 1 - Inspection and Maintenance

Schedule	Inspection and Maintenance Activity
Ongoing including just before annual storm seasons and following rainfall events.	• Maintain vegetation as needed. Use of fertilizers, pesticides and herbicides should be strenuously avoided to ensure they don't contribute to water pollution. If appropriate native plant selections and other IPM methods are used, such products shouldn't be needed. If such projects are used, ○ Products shall be applied in accordance with their labeling, especially in relation to application to water, and in areas subjected to flooding. ○ Fertilizers should not be applied within 15 days before, after, or during the rain season. • Remove debris and litter from the entire basin to minimize clogging and improve aesthetics. • Check for obvious problems and repair as needed. Address odor, insects, and overgrowth issues associated with stagnant or standing water in the basin bottom. There should be no long-term ponding water. • Check for erosion and sediment laden areas in the basin. Repair as needed. Clean forebay if needed. • Revegetate side slopes where needed.
Annually. If possible, schedule these inspections within 72 hours after a significant rainfall.	• Inspection of hydraulic and structural facilities. Examine the inlet for blockage, the embankment and spillway integrity, as well as damage to any structural element. • Check for erosion, slumping and overgrowth. Repair as needed. • Check basin depth for sediment build up and reduced total capacity. Scrape bottom as needed and remove sediment. Restore to original cross-section and infiltration rate. Replant basin vegetation. • Verify the basin bottom is allowing acceptable infiltration. Use a disc or other method to aerate basin bottom only if there is actual significant loss of infiltrative capacity, rather than on a routine basis[1]. • No water should be present 72 hours after an event. No long term standing water should be present at all. No algae formation should be visible. Correct problem as needed.

1. **CA Stormwater BMP Handbook for New Development and Significant Redevelopment**

Table 2 - Design and Sizing Criteria for Infiltration Basins

Design Parameter	Infiltration Basin
Design Volume	V_{BMP}
Forebay Volume	0.5% V_{BMP}
Drawdown time (maximum)	72 hours
Maximum tributary area	50 acres [2]
Minimum infiltration rate	Must be sufficient to drain the basin within the required Drawdown time over the life of the BMP. The SMR WQMP may include specific requirements for minimum tested infiltration rates.
Maximum Depth	5 feet
Spillway erosion control	Energy dissipators to reduce velocities[1]
Basin Slope	0%
Freeboard (minimum)	1 foot [1]
Historic High Groundwater Setback (max)	10 feet
Bedrock/impermeable layer setback (max)	5 feet
Tree setbacks	Mature tree drip line must not overhang the basin
Set back from wells, tanks or springs	100 feet
Set back from foundations	As recommended in Geotechnical Report

1. **Ventura County's Technical Guidance Manual for Stormwater Quality Control Measures**
2. **CA Stormwater BMP Handbook for New Development and Significant Redevelopment**

Note: The information contained in this BMP Factsheet is intended to be a summary of design considerations and requirements. Additional information which applies to all detention basins may be found in the District's Basin Guidelines (Appendix C). In addition, information herein may be superseded by other guidelines issued by the co-permittee.

INFILTRATION BASIN SIZING PROCEDURE

1. Find the Design Volume, V_{BMP}.
   a) Enter the Tributary Area, A_{T}.
   b) Enter the Design Volume, V_{BMP}, determined from Section 2.1 of this Handbook.
2. Determine the Maximum Depth.
   a) Enter the infiltration rate. The infiltration rate shall be established as described in Appendix A: "Infiltration Testing".
   b) Enter the design Factor of Safety from Table 1 in Appendix A: "Infiltration Testing".
   c) The spreadsheet will determine D_1, the maximum allowable depth of the basin based on the infiltration rate along with the maximum drawdown time (72 hours) and the Factor of Safety.

$$D_1 = [(t) \times (I)] / 12s$$

Where I = site infiltration rate (in/hr)
s = safety factor
t = drawdown time (maximum 72 hours)

   d) Enter the depth of freeboard.

e) Enter the depth to the historic high groundwater level measured from the top of the basin.

f) Enter the depth to the top of bedrock or other impermeable layer measured from the finished grade.

g) The spreadsheet will determine D_2, the total basin depth (including freeboard, if used) of the basin, based on restrictions to the depth by groundwater and an impermeable layer.

D_2 = Depth to groundwater – (10 + freeboard) (ft);

or

D_2 = Depth to impermeable layer – (5 + freeboard) (ft)

Whichever is least.

h) The spreadsheet will determine the maximum allowable effective depth of basin, D_{MAX}, based on the smallest value between D_1 and D_2. D_{MAX} is the maximum depth of water only and does not include freeboard. D_{MAX} shall not exceed 5 feet.

3. Basin Geometry

a) Enter the basin side slopes, z (no steeper than 4:1).

b) Enter the proposed basin depth, d_B excluding freeboard.

c) The spreadsheet will determine the minimum required surface area of the basin:

$$A_s = V_{BMP} / d_B$$

Where A_s = minimum area required (ft^2)

V_{BMP} = volume of the infiltration basin (ft^3)

d_B= proposed depth not to exceed maximum allowable depth, D_{MAX} (ft)

d) Enter the proposed bottom surface area. This area shall not be less than the minimum required surface area.

4. Forebay

A concrete forebay with a design volume of at least 0.5% V_{BMP} and a minimum 1 foot high concrete splashwall shall be provided. Full-height rectangular weir(s) shall be used to outlet the forebay. The weir(s) must be offset from the line of flow from the basin inlet. It is recommended that two weirs be used and that they be located on opposite sides of the forebay (see Figure 2).

a) The spreadsheet will determine the minimum required forebay volume based on 0.5% V_{BMP}.

b) Enter the proposed depth of the forebay berm/splashwall (1foot minimum).

c) The spreadsheet will determine the minimum required forebay surface area.

d) Enter the width of rectangular weir to be used (minimum 1.5 inches). Weir width should be established based on a 5 minute drawdown time.

Infiltration Basin - Design Procedure

(Rev. 03-2012)

BMP ID:

Legend: Required Entries / Calculated Cells

Company Name:

Designed by:

Date:

County/City Case No.:

Design Volume

a) Tributary area (BMP subarea) A_T = acres

b) Enter V_{BMP} determined from Section 2.1 of this Handbook V_{BMP}= ft^3

Maximum Depth

a) Measured infiltration rate I = in/hr

b) Factor of Safety (See Table 1, Appendix A: "Infiltration Testing" from this BMP Handbook) FS =

c) Calculate D_1

$$D_1 = \frac{I\ (in/hr) \times\ 72\ hrs}{12\ (in/ft)\ \times FS}$$

D_1 = ft

d) Enter the depth of freeboard (at least 1 ft) ft

e) Enter depth to historic high ground water (measured from **top** of basin) ft

f) Enter depth to top of bedrock or impermeable layer (measured from **top** of basin) ft

g) D_2 is the smaller of:

Depth to groundwater - (10 ft + freeboard) and
Depth to impermeable layer - (5 ft + freeboard)

D_2 = ft

h) D_{MAX} is the smaller value of D_1 and D_2 but shall not exceed 5 feet D_{MAX} = ft

Basin Geometry

a) Basin side slopes (no steeper than 4:1) z = :1

b) Proposed basin depth (excluding freeboard) d_B = ft

c) Minimum bottom surface area of basin (A_S= V_{BMP}/d_B) A_S = ft^2

d) Proposed Design Surface Area A_D = ft^2

Forebay

a) Forebay volume (minimum 0.5% V_{BMP}) Volume = ft^3

b) Forebay depth (height of berm/splashwall. 1 foot min.) Depth = ft

c) Forebay surface area (minimum) Area = ft^2

d) Full height notch-type weir Width (W) = in

Notes:

3.2 INFILTRATION TRENCH

Type of BMP	LID – Infiltration
Priority Level	Priority 1 – Full Retention
Treatment Mechanisms	Infiltration, Evapotranspiration (when vegetated), Evaporation
Infiltration Rate Range	> 0.8 in/hr factored design infiltration rate
Maximum Drainage Area	10 acres

Description

Infiltration trenches are shallow excavated areas that are filled with rock material to create a subsurface reservoir layer. The trench is sized to store the design capture volume, V_{BMP}, in the void space between the rocks. Over a period of 72 hours, the stormwater infiltrates through the bottom of the trench into the surrounding soil. Infiltration basins are highly effective in removing all targeted pollutants from stormwater runoff.

Figure 1 shows the components of an infiltration trench. The section shows the reservoir layer and observation well, which is used to monitor water depth. An overflow pipe that is used to bypass flows once the trench fills with stormwater is also shown.

Site Considerations

The use of infiltration trenches may be restricted by concerns over groundwater contamination, soil permeability, and clogging at the site. See the Santa Margarita Region (SMR) Water Quality Management Plan (WQMP) for any specific feasibility considerations for using infiltration BMPs. Where this BMP is being used, the soil beneath the basin must be thoroughly evaluated in a geotechnical report since the underlying soils are critical to the basin's long term performance. These basins may not be appropriate for the following site conditions:

- Industrial sites or locations where spills of toxic materials may occur.
- Sites with very low soil infiltration rates.
- Sites with high groundwater tables or excessively high soil infiltration rates, where pollutants can affect groundwater quality.
- Sites with unstabilized soil or construction activity upstream.
- On steeply sloping terrain.
- Infiltration trenches located in a fill condition should refer to Appendix A of this Handbook for details on special requirements/restrictions.

This BMP has a flat surface area, so it may be challenging to incorporate into steeply sloping terrain.

Setbacks

Always consult your geotechnical engineer for site specific recommendations regarding setbacks for infiltration trenches. Recommended setbacks are needed to protect buildings, walls, onsite or nearby wells, streams, and tanks. Setbacks should be considered early in the design process as they affect where infiltration facilities may be placed and how deep they are allowed to be. For instance, depth setbacks can dictate fairly shallow facilities that will have a larger footprint and, in some cases, may make an infiltration trench infeasible. In that instance, another BMP must be selected.

In addition to setbacks recommended by the geotechnical engineer, infiltration trenches must be set back:

- 10 feet from the historic high groundwater mark (measured vertically from the bottom of the trench, as shown in Figure 1)
- 5 feet from bedrock or impermeable surface layer (measured vertically from the bottom of the trench, as shown in Figure 1)
- From all mature tree drip lines as indicated in Figure 1
- 100 feet horizontally from wells, tanks or springs

Setbacks to walls and foundations must be included as part of the Geotechnical Report.

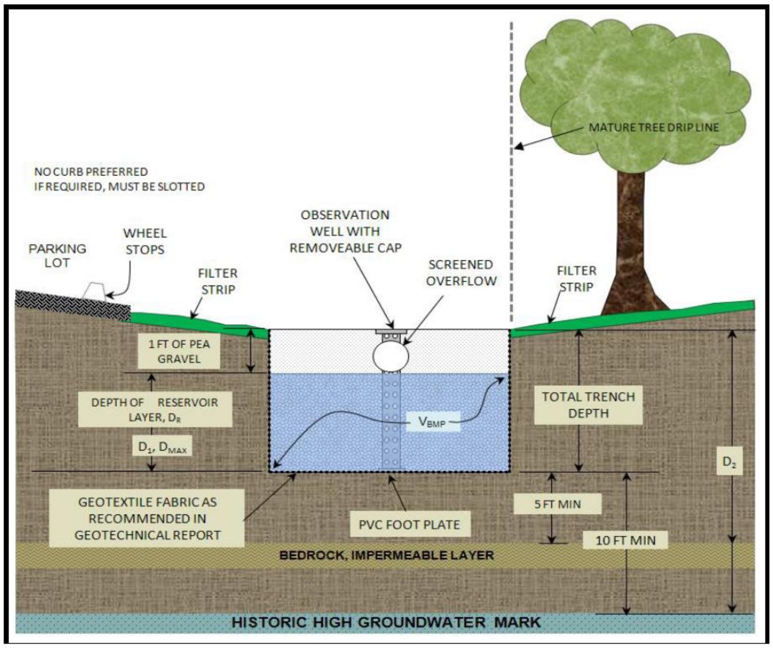
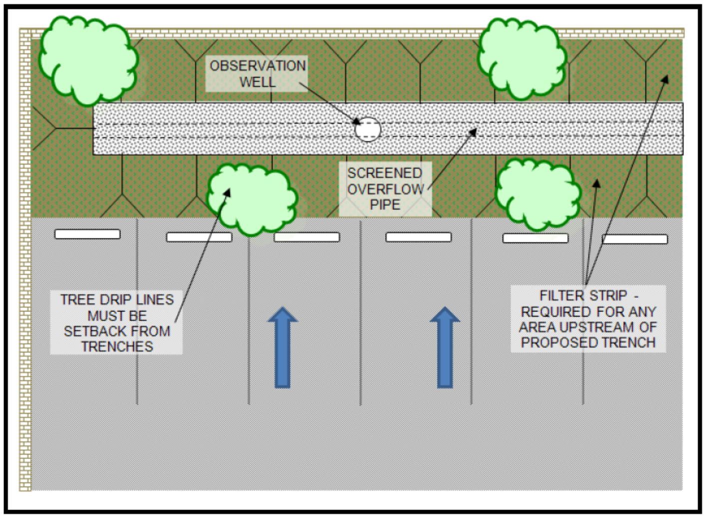


Figure 1 Section View of an Infiltration Trench

Sediment Control

Infiltration BMPs have the risk of becoming plugged over time. To prevent this, sediment must be removed before stormwater enters the trench. Both sheet and concentrated flow types have requirements that should be considered in the design of an infiltration trench.

When sheet type flows approach the trench along its length (as illustrated in Figure 2), a vegetated filter strip should be placed between the trench and the upstream drainage area. The filter strip must be a minimum of 5 feet wide and planted with grasses (preferably native) or covered with mulch.



Concentrated flows require a different approach. A 2004 Caltrans BMP Retrofit Report found that flow spreaders recommended in many water quality manuals are ineffective in distributing concentrated flows. As such, concentrated flows should either be directed toward a traditional vegetated swale (as shown on the right side of Figure 3) or to catch basin filters that can remove litter and sediment. Catch basins must discharge runoff as surface flow above the trench; they cannot outlet directly into the reservoir layer of the infiltration trench. If catch basins are used, the short and long term costs of the catch basin filters should be considered.

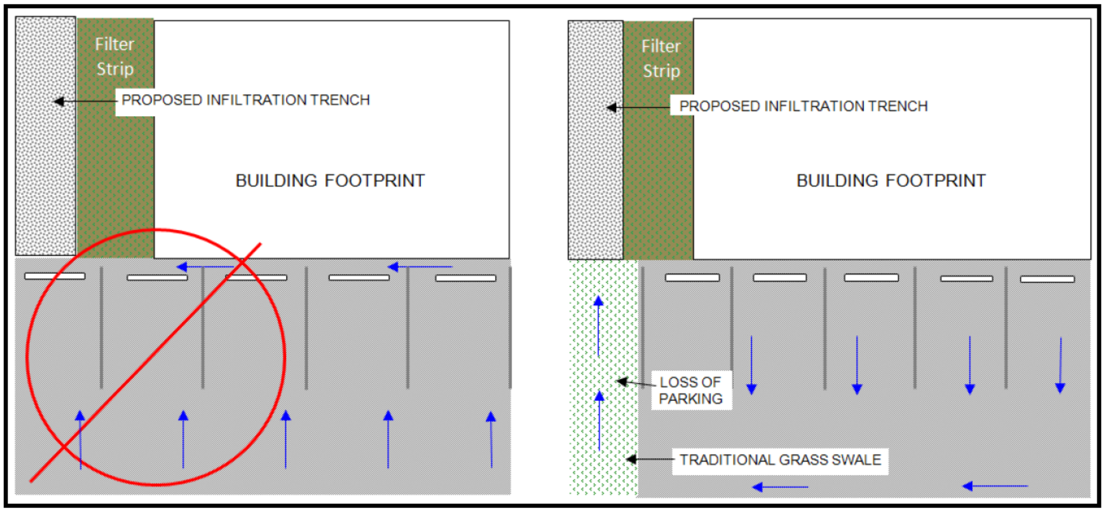


Figure 3 Plan View, Concentrated Flows

Additional Considerations

Class V Status

In certain circumstances, for example, if an infiltration trench is "deeper than its widest surface dimension," or includes an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute fluids below the surface of the ground, it would probably be considered by the EPA to be a Class V injection well. Class V injection wells are subject to regulations and reporting requirements via the Underground Injection Control (UIC) Program. To ensure that infiltration trenches are not considered Class V wells, the design procedure in this manual requires that the trench not be deeper than it is wide.

Geotechnical Report

A geotechnical report must be included for all infiltration trenches. Appendix A of this Handbook entitled "Infiltration Testing Guidelines", details which types of infiltration tests are acceptable and how many tests or boring logs must be performed. A Geotechnical Report must be submitted in support of all infiltration trenches. Setbacks to walls and foundations must be included in the Geotechnical Report.

Observation Wells

One or more observation wells should be provided. The observation well consists of a vertical section of perforated pipe, 4 to 6 inches in diameter, installed flush with top of trench on a foot plate and have a locking, removable cap.

Overflow

An overflow route is needed to bypass storm flows larger than the V_{BMP} or in the event of clogging. Overflow systems must connect to an acceptable discharge point such as a downstream conveyance system.

Maintenance Access

Normal maintenance of an infiltration trench includes maintenance of the filter strip as well as debris and trash removal from the surface of the trench and filter strip. More substantial maintenance requiring vehicle access may be required every 5 to 10 years. Vehicular access along the length of the swale should be provided to all infiltration trenches. It is preferred that trenches be placed longitudinally along a street or adjacent to a parking lot area. These conditions have high visibility which makes it more likely that the trench will be maintained on a regular basis.

INFILTRATION TRENCH BMP FACT SHEET

Inspection and Maintenance

Schedule	Inspection and Maintenance Activity
Every two weeks, or as often as necessary to maintain a pleasant appearance	- Maintain adjacent landscaped areas. Remove clippings from landscape maintenance activities. - Remove trash & debris
3 days after Major Storm Events	- Check for surface ponding. If ponding is only above the trench, remove, wash and replace pea gravel. May be needed every 5-10 years. - Check observation well for ponding. If the trench becomes plugged, remove rock materials. Provide a fresh infiltration surface by excavating an additional 2-4 inches of soil. Replace the rock materials.

Design and Sizing Criteria

Design Parameter	Design Criteria
Design Volume	V_{BMP}
Design Drawdown time	72 hrs
Maximum Tributary Drainage Area	10 acres
Maximum Trench Depth	8.0 ft
Width to Depth Ratio	Width must be greater than depth
Reservoir Rock Material	AASHTO #3 or 57 material or a clean, washed aggregate 1 to 3-in diameter equivalent
Filter Strip Width	Minimum of 5 feet in the direction of flow for all areas draining to trench
Filter Strip Slope	Max slope = 1%
Filter Strip Materials	Mulch or grasses (non-mowed variety preferred)
Historic High Groundwater Mark	10 ft or more below bottom of trench
Bedrock/Impermeable Layer Setback	5 ft or more below bottom of trench
Tree Setbacks	Mature tree drip line must not overhang the trench
Trench Lining Material	As recommended in Geotechnical Report

Infiltration Trench Design Procedure

1. Enter the area tributary to the trench, maximum drainage area is 10 acres.

2. Enter the Design Volume, $V_{BMP,}$ determined from Section 2.1 of this Handbook.

3. Enter the site infiltration rate, found in the geotechnical report.

4. Enter the factor of safety from Table 1 of Appendix A, Infiltration Testing.

5. Determine the maximum reservoir layer depth, $D_{MAX.}$ The value is obtained by taking the smaller of two depth equations but may never exceed 8 feet. The first depth, D_1 is related to the infiltration rate of the soil. The second depth, $D_{2,}$ is related to required setbacks to groundwater, bedrock/impermeable layer. These parameters are shown in Figure 1.

   Calculate D_1.

$$D_1 = \frac{I\left({}^{in}/_{hr}\right) \times 72\ (hrs)}{12\left({}^{in}/_{ft}\right) \times {}^{n}/_{100} \times FS}$$

   Where:

   I = site infiltration rate (in/hr), found in the geotechnical report
   FS = factor of safety, refer to Appendix A - Infiltration Testing
   n = porosity of the trench material, 40%

   Calculate D_2. Enter the depth to the seasonal high groundwater and bedrock/impermeable layer measured from the finished grade. The spreadsheet checks the minimum setbacks shown in Figure 1 and selects the smallest value. The equations are listed below for those doing hand calculations.

   Minimum Setbacks (includes 1 foot for pea gravel):
   = Depth to historic high groundwater mark - 11 feet
   = Depth to impermeable layer - 6 feet

   D_2 is the smaller of the two values.

   D_{MAX} is the smaller value of D_1 and $D_{2,}$ and must be less than or equal to 8 feet.

6. Enter the proposed reservoir layer depth, D_R. The value must be no greater than D_{MAX}.

7. Find the required surface area of the trench, A_S. Once D_R is entered, the spreadsheet will calculate the corresponding depth of water and the minimum surface area of the trench.

$$Design\ d_W = D_R \times \left({}^{n}/_{100}\right) \qquad A_S = \frac{V_{BMP}}{Design\ d_W}$$

Where:

A_S = minimum area required (ft^2)
V_{BMP} = BMP storage volume (ft^3)
Design d_W = Depth of water in reservoir layer (ft)

8. Enter the proposed design surface area; it must be greater than the minimum surface area.

9. Calculate the minimum trench width. This is to ensure that EPA's Class V Injection well status is not triggered. The total trench depth (shown in Figure 1) includes the upper foot where the overflow pipe is located. The minimum surface dimension is D_R + 1 foot.

Additional Items

The following items detailed in the preceding sections should also be addressed in the design.

- Sediment Control
- Geotechnical Report
- Observation well(s)
- Overflow

Reference Material

California Stormwater Quality Association. California Stormwater BMP Handbook New Development and Redevelopment. 2003.

County of Los Angeles Department of Public Works. Stormwater BMP Best Management Practice Design and Maintenance Manual for Publicly Maintained Storm Drain Systems. Los Angeles, CA, 2009.

LandSaver Stormwater Management System. Tech Sheet - Porosity of Structural Backfill. 2006.

United States Environmental Protection Agency. Office of Water, Washington D.C. Storm Water Technology Fact Sheet Vegetated Swales. 1999.

United States Environmental Protection Agency. Office of Water. Memorandum on Clarification on Which Stormwater Infiltration Practices/technologies Have the Potential to Be Regulated as "Class V" Wells by Underground Injection Control Program. By Linda Boornazian and Steve Heare. Washington D.C., 2008.

Ventura Countywide Stormwater Quality Management Program. Land Development Guidelines Biofilter Fact Sheet. Ventura, CA, 2001.

Ventura Countywide Stormwater Quality Management Program. Technical Guidance Manual for Stormwater Quality Control Measures. Ventura, CA, 2002.

Infiltration Trench - Design Procedure

BMP ID:

Legend: Required Entries
Calculated Cells

Company Name:
Date:
Designed by:
County/City Case No.:

Design Volume

Enter the area tributary to this feature, Max = 10 acres A_t= acres

Enter V_{BMP} determined from Section 2.1 of this Handbook V_{BMP}= ft^3

Calculate Maximium Depth of the Reservoir Layer

Enter measured infiltration rate I = in/hr

Enter Factor of Safety, FS (unitless) FS =

Obtain from Table 1, Appendix A: "Infiltration Testing" of this BMP Handbook

n = 40 %

Calculate D_1. $$D_1 = \frac{I\ (in/hr)\ x\ \ 72\ hrs}{12\ (in/ft)\ x\ (n\ /100)\ x\ FS}$$ D_1 = ft

Enter depth to historic high groundwater mark (measured from finished grade) ft

Enter depth to top of bedrock or impermeable layer (measured from finished grade) ft

D_2 is the smaller of:

Depth to groundwater - 11 ft; & Depth to impermeable layer - 6 ft D_2 = ft

D_{MAX} is the smaller value of D_1 and D_2, must be less than or equal to 8 feet. D_{MAX}= ft

Trench Sizing

Enter proposed reservoir layer depth D_R, must be $\leq D_{MAX}$ D_R = ft

Calculate the design depth of water, d_W

Design d_W = (D_R) x (n/100) Design d_W= ft

Minimum Surface Area, A_S $$A_S = \frac{V_{BMP}}{d_W}$$ A_S = ft^2

Proposed Design Surface Area A_D = ft^2

Minimum Width = D_R + 1 foot pea gravel ft

Sediment Control Provided? (Use pulldown) Yes

Geotechnical report attached? (Use pulldown) Yes

If the trench has been designed correctly, there should be no error messages on the spreadsheet.

3.3 Permeable Pavement

Type of BMP	LID – Infiltration
Priority Level	Priority 1 – Full Retention
Treatment Mechanisms	Infiltration, Evaporation
Infiltration Rate Range	> 0.8 in/hr factored design infiltration rate
Maximum Drainage Area	10 acres

Description

Permeable pavements can be either pervious asphalt and concrete surfaces, or permeable modular block. Unlike traditional pavements that are impermeable, permeable pavements reduce the volume and peak of stormwater runoff as well as mitigate pollutants from stormwater runoff, provided that the underlying soils can accept infiltration. Permeable pavement surfaces work best when they are designed to be flat or with gentle slopes. This factsheet discusses criteria that apply to infiltration designs.

The permeable surface is placed on top of a reservoir layer that holds the water quality stormwater volume, V_{BMP}. The water infiltrates from the reservoir layer into the native subsoil. Tests must be performed according to the Infiltration Testing Section in Appendix A to be able to use this design procedure.

In some circumstances, permeable pavement may be implemented on a project as a source control feature. Where implemented as a source control feature (sometimes referred to as a 'self-retaining' area), the pavement is not considered a 'BMP' that would be required to be designed and sized per this manual. Where permeable pavement receives runoff from adjacent tributary areas, the permeable pavement *may* be considered a BMP that must be sized according to this manual. Consult the Engineering Authority and the WQMP for any applicable requirements for designing and sizing permeable pavement installations.

Siting Considerations

The WQMP applicable to the project location should be consulted, as it may include criteria for determining the applicability of this and other Infiltration-based BMPs to the project.

Permeable pavements can be used in the same manner as concrete or asphalt in low traffic parking lots, playgrounds, walkways, bike trails, and sports courts. Most types of permeable pavement can be designed to meet Americans with Disabilities Act (ADA) requirements. Permeable pavements **should not** be used in the following conditions:

- Downstream of erodible areas
- Downstream of areas with a high likelihood of pollutant spills
- Industrial or high vehicular traffic areas (25,000 or greater average daily traffic)
- Areas where geotechnical concerns, such as soils with low infiltration rates, would preclude the use of this BMP.

Sites with Impermeable Fire Lanes

Oftentimes, Fire Departments do not allow alternative pavement types including permeable pavement. They require traditional impermeable surfaces for fire lanes. In this situation, it is acceptable to use an impermeable surface for the fire lane drive aisles and permeable pavement for the remainder of the parking lot.

Where impermeable fire lanes are used in the design, the impermeable surface must slope towards the permeable pavement, and the base layers shall remain continuous underneath the two pavement types, as shown in Figure 1. This continuous reservoir layer helps to maintain infiltration throughout the pervious pavement site, and can still be considered as part of the total required storage area.

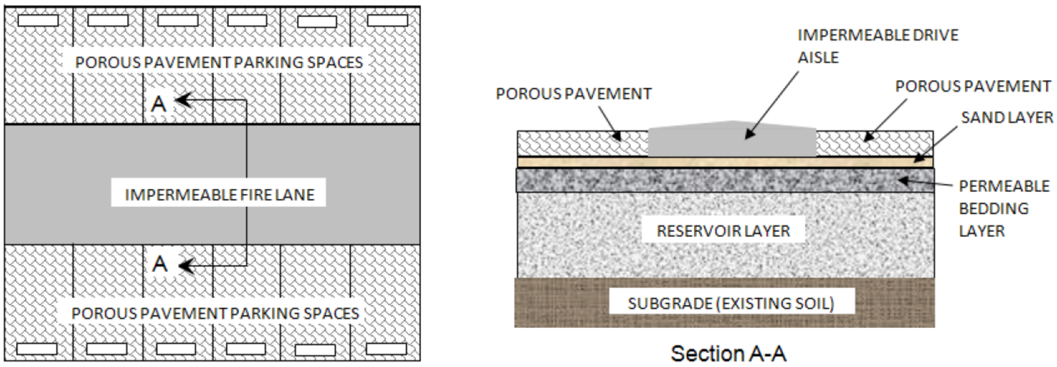


Figure 1: Impermeable Fire Lanes

Also, while a seal coat treatment may be used on the impermeable fire land, traditional seal coat treatments **shall not** be used on permeable pavement.

Setbacks

Always consult your geotechnical engineer for site specific recommendations regarding setbacks for permeable pavement. Recommended setbacks are needed to protect buildings, walls, onsite wells, streams and tanks.

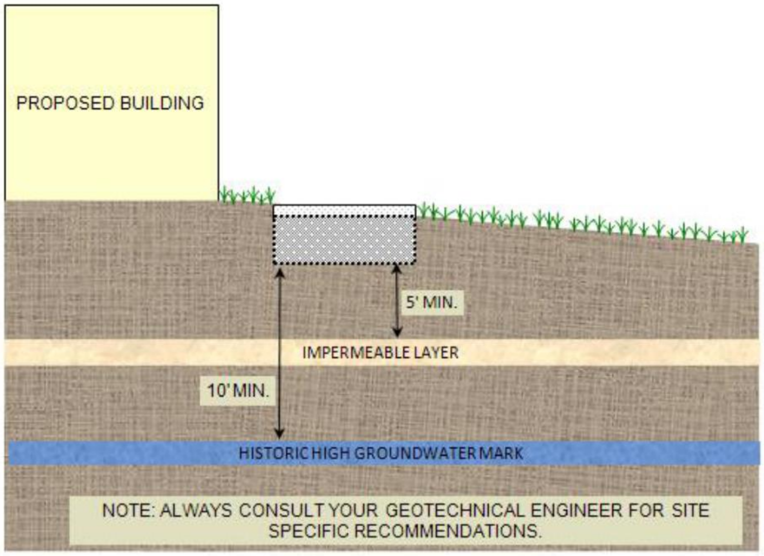


Figure 2: Permeable Pavement Setback Requirements

A minimum vertical separation of 10 feet is required from the bottom of the reservoir layer to the historic high groundwater mark, see Figure 2. A minimum vertical separation of 5 feet is required from the bottom of the reservoir layer to any impermeable layer in the soil. If the historic high groundwater mark is less than 10 feet below the reservoir layer section, or less than 5 feet from an impermeable layer, the infiltration design is not feasible.

Design and Sizing Criteria

To ensure that the pavement structural section is not compromised, a 24-hour drawdown time is utilized for this BMP instead of the longer drawdown time used for most volume based BMPs.

Reservoir Layer Considerations

Even with proper maintenance, sediment will begin to clog the soil below the permeable pavement. Since the soil cannot be scarified or replaced, this will result in slower infiltration rates over the life of the permeable pavement. Therefore, the reservoir layer is limited to a maximum of 12 inches in depth to ensure that over the life of the BMP, the reservoir layer will drain in an adequate time.

PERMEABLE PAVEMENT BMP FACT SHEET

***Note**: All permeable pavement BMP installations (not including Permeable Pavement as a source control BMP i.e. a self-retaining area) must be tested by the geotechnical engineer to ensure that the soils drain at a minimum allowable rate to ensure drainage.. See the Infiltration Testing Section of this manual for specific details for the required testing and applied factors of safety.*

Sloping Permeable Pavement

Ideally permeable pavement would be level, however most sites will have a mild slope. If the tributary drainage area is too steep, the water may be flowing too fast when it approaches the permeable pavement, which may cause water to pass over the pavement instead of percolating and entering the reservoir layer. If the maximum slopes shown in Table 1 are complied with, it should address these concerns.

Table 1: Design Parameters for Permeable Pavement

Design Parameter	Permeable Pavement
Maximum slope of permeable pavement	3%
Maximum contributing area slope	5%

Regardless of the slope of the pavement surface design, the bottom of the reservoir layers **shall be flat and level** as shown in Figure 3. The design shown ensures that the water quality volume will be contained in the reservoir layer. A terraced design utilizing non-permeable check dams may be a useful option when the depth of gravel becomes too great as shown in Figure 3.

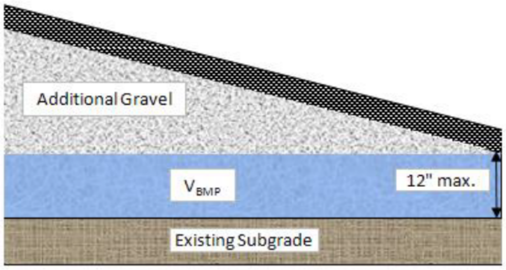


Figure 3: Sloped Cross Sections for Permeable Pavement

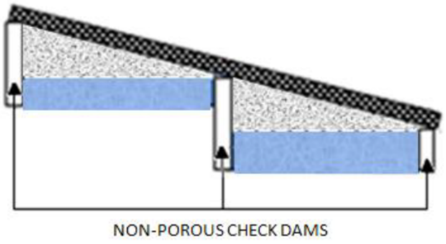


Figure 4: Permeable Pavement with Non-permeable Check Dams

In Figure 4, the bottom of the gravel reservoir layer is incorrectly sloped parallel to the pavement surface. Water would only be allowed to pond up to the lowest point of the BMP. Additional flows would simply discharge from the pavement. Since only a portion of the gravel layer can store water, this design would result in insufficient capacity. This is not acceptable.

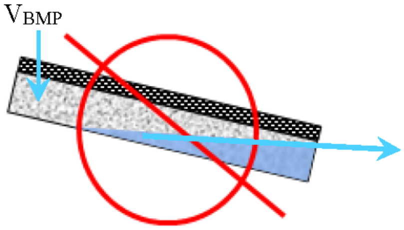


Figure 5: Incorrect Sloping of Permeable Pavement

To assure that the subgrade will empty within the 24 hour drawdown time, it is important that the maximum depth of 12 inches for the reservoir layer discussed in the design procedure is not exceeded. The value should be measured from the lowest elevation of the slope (Figure 4).

Minimum Surface Area

The minimum surface area required, A_S, is calculated by dividing the water quality volume, V_{BMP}, by the depth of water stored in the reservoir layer. The depth of water is found by multiplying the void ratio of the reservoir aggregate by the depth of the layer, b_{TH}. The void ratio of the reservoir aggregate is typically 40%; the maximum reservoir layer depth is 12".

Sediment Control

A pretreatment BMP should be used for sediment control. This pretreatment BMP will reduce the amount of sediment that enters the system and reduce clogging. The pretreatment BMP will also help to spread runoff flows, which allows the system to infiltrate more evenly. The pretreatment BMP must discharge to the surface of the pavement and not the subgrade. Grass swales may also be used as part of a treatment train with permeable pavements.

Liners and Filter Fabric

Always consult your geotechnical engineer for site specific recommendations regarding liners and filter fabrics. Filter fabric may be used around the edges of the permeable pavement; this will help keep fine sediments from entering the system. Unless recommended for the site, impermeable liners are not to be used below the subdrain gravel layer.

Overflow

An overflow route is needed in the permeable pavement design to bypass storm flows larger than the V_{BMP} or in the event of clogging. Overflow systems must connect to an acceptable discharge point such as a downstream conveyance system.

Roof Runoff

Permeable pavement can be used to treat roof runoff. However, the runoff cannot be discharged beneath the surface of the pavement directly into the subgrade, as shown in Figure 6. Instead the pipe should empty on the surface of the permeable pavement as shown in Figure 7. A filter on the drainpipe should be used to help reduce the amount of sediment that enters the permeable pavement.

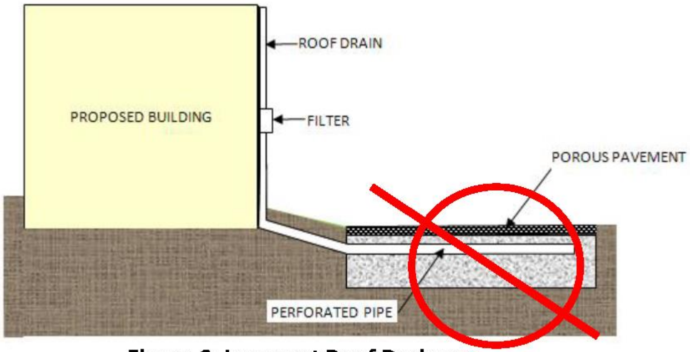


Figure 6: Incorrect Roof Drainage

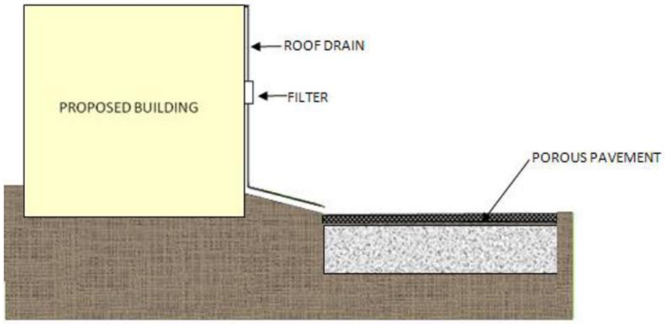


Figure 7: Correct Roof Runoff Drainage

Infiltration

Refer to the Infiltration Testing Section (Appendix A) in this manual for recommendations on testing for this BMP.

Pavement Section

The cross section necessary for infiltration design of permeable pavement includes:

- The thickness of the layers of permeable pavement, sand and bedding layers depends on whether it is permeable modular block or pervious pavement. A licensed geotechnical or civil engineer is required to determine the thickness of these upper layers appropriate for the pavement type and expected traffic loads.
- A 12” maximum reservoir layer consisting of AASHTO #57 gravel vibrated in place or equivalent with a minimum of 40% void ratio.

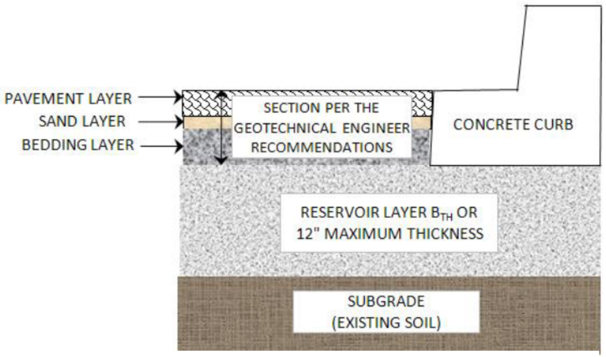


Figure 8: Infiltration Cross Section

Inspection and Maintenance Schedule –Modular Block

Schedule	Activity
Ongoing	• Keep adjacent landscape areas maintained. Remove clippings from landscape maintenance activities. • Remove trash and debris
Utility Trenching and other pavement repairs	• Remove and reset modular blocks, structural section and reservoir layer as needed. Replace damaged blocks in-kind. • Do not pave repaired areas with impermeable surfaces.
After storm events	• Inspect areas for ponding
2-3 times per year	• Sweep to reduce the chance of clogging
As needed	• Sand between pavers may need to be replaced if infiltration capacity is lost

Inspection and Maintenance Schedule –Pervious Concrete/Asphalt

Schedule	Activity
Ongoing	• Keep adjacent landscape areas maintained. Remove clippings from landscape maintenance activities. • Remove trash and debris
Utility Trenching other pavement repairs	• Replace structural section and reservoir layer in kind. • Re-pave using pervious concrete/asphalt. Do not pave repaired areas with impermeable surfaces.
After storm events	• Inspect areas for ponding
2-3 times per year	• Vacuum the permeable pavement to reduce the chance of clogging
As needed	• Remove and replace damaged or destroyed permeable pavement

Design Procedure Permeable Pavement

1. Enter the Tributary Area, A_T.

2. Enter the Design Volume, V_{BMP}, determined from Section 2.1 of this Handbook.

3. Enter the reservoir layer depth, b_{TH} for the proposed permeable pavement. The reservoir layer maximum depth is 12 inches.

4. Calculate the Minimum Surface Area, A_S, required.

$$A_S(\mathrm{ft}) = \frac{V_{BMP}\ (\mathrm{ft}^3)}{(0.4\ \times\ b_{TH}\ (\mathrm{in}))/12(\mathrm{in/ft})}$$

   Where, the porosity of the gravel in the reservoir layer is assumed to be 40%.

5. Enter the proposed surface area and ensure that this is equal to or greater than the minimum surface area required.

6. Enter the dimensions, per the geotechnical engineer's recommendations, for the pavement cross section. The cross section includes a pavement layer, usually a sand layer and a permeable bedding layer. Then add this to the maximum thickness of the reservoir layer to find the total thickness of the BMP.

7. Enter the slope of the top of the permeable pavement. The maximum slope is 3%.

8. Enter whether sediment control was provided.

9. Enter whether the geotechnical approach is attached.

10. Describe the surfaces surrounding the permeable pavement. It is preferred that a vegetation buffer is used around the permeable pavement.
11. Check to ensure that vertical setbacks are met. There should be a minimum of 10 feet between the bottom of the BMP and the top of the high groundwater table, and a minimum of 5 feet between the reservoir layer the top of the impermeable layer.

Reference Materials Used to Develop this Fact Sheet:

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Tennis, Paul D., Michael L. Leming and David J. Akers. Pervious Concrete Pavements. Silver Spring: Portland Cement Association and National Ready Mixed Concrete Association, 2004.

Urban Drainage and Flood Control District. Urban Storm Drainage Criteria Manual Volume 3 - Best Management Practices. Vol. 3. Denver, 2008. 3 vols.

Urbonas, Ben R. Stormwater Sand Filter Sizing and Design: A Unit Operations Approach. Denver: Urban Drainage and Flood Control District, 2002.

Permeable Pavement - Design Procedure	BMP ID	Legend:	Required Entries Calculated Cells

Company Name:

Designed by:

Date:

County/City Case No.:

Design Volume

Enter the area tributary to this feature $A_T=$ acres

Enter V_{BMP} determines from Section 2.1 of this Handbook $V_{BMP}=$ ft^3

Permeable Pavement Surface Area

Reservoir Layer Depth, b_{TH} $b_{TH}=$ inches

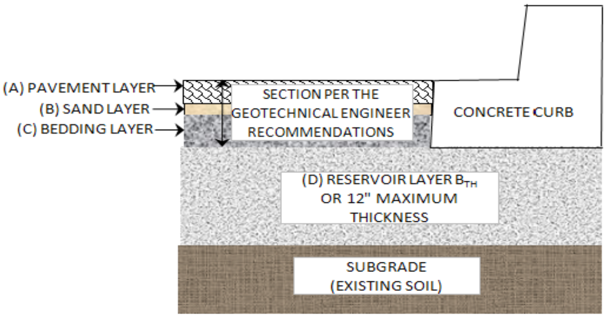
Minimum Surface Area Required, A_S

$$A_{S\,(ft)} = \frac{V_{BMP}\,(ft^3)}{(0.4 \times b_{TH}\,(in)) / 12(in/ft)}$$

$A_S=$ ft^2

Proposed Surface Area = ft^2

Permeable Pavement Cross Section



Per the Geotechnical	(A)		in
Engineer's	(B)		in
Recommendations	(C)		in
Reservoir Layer	(D)		in
Total Permeable Pavement Section			in
Slope of Permeable Pavement			%

Sediment Control Provided? (Use pulldown)

Geotechnical report attached? (Use pulldown)

Describe Surrounding Vegetation:

Notes:

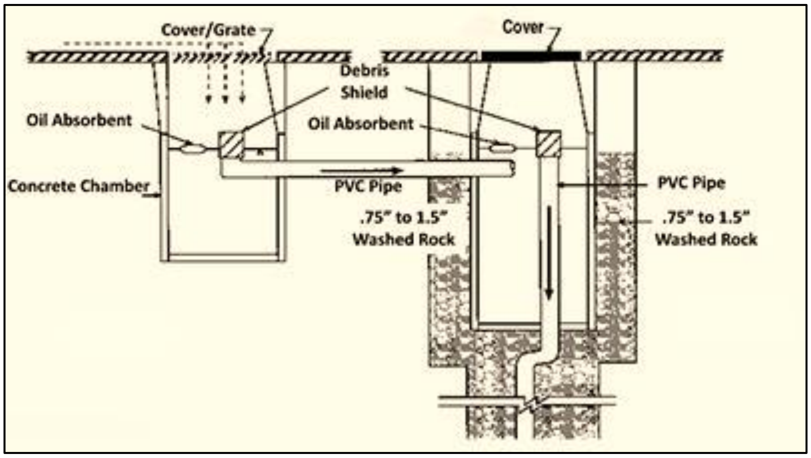
If the permeable pavement has been designed correctly, there should be no error messages on the spreadsheet.

Riverside County Best Management Practice Design Handbook
JUNE 2010

3.a Drywells

Type of BMP	LID – Infiltration
Priority	Priority 1 – Full Retention, and/or adding contingency for other infiltration BMPs.
Treatment Mechanisms	Infiltration
Infiltration Rate Range	> 0.8 in/hr factored design infiltration rate, higher rates may be advisable (e.g. 3 in/hr) on a project-by-project basis.
Sizing Type	Volume or Flow-based
Additional Requirements	Class V injection well subject to the U.S. Environmental Protection Agency (US EPA) Underground Injection Control (UIC) regulations.

Description



Dry wells are gravity-fed excavated pits lined with perforated casing and backfilled with gravel or stone. Dry wells penetrate layers of clay soils with poor infiltration rates to reach more permeable layers of soil, allowing for more rapid infiltration of stormwater. They can be used in conjunction with low impact development (LID) practices to reduce the harmful effects that traditional stormwater management practices have had on the aquatic ecosystem. Dry wells not only aid in stormwater runoff reduction, but they can also increase groundwater recharge, are economical, and have minimal space requirements.

Siting Considerations and Setbacks

In general, a careful site evaluation conducted by a registered civil engineer and geologist/geotechnical engineer should be made to determine if the use of a dry well is suitable at any particular location.

- Dry wells are only applicable where soils are adequate for infiltration and full infiltration is determined to be feasible based on applicable feasibility criteria;
- Located on the project, so that flows do not bypass the drywell, e.g. in conjunction with a basin for runoff collection;
- Building setback: 10 feet minimum;
- Water table: 10 feet minimum separation between dry well bottom and seasonal high water table;
- Public supply wells: 100 feet minimum setback;

- Separation from other drywells (center to center): 50 feet minimum;
- Penetration: 10 feet minimum into permeable porous soils;
- Dry well surface inlet: 3 inch minimum above bottom of retention basin;
- Infiltration should not cause geotechnical concerns related to slope stability, liquefaction, or compromise infrastructure stability;
- Pretreatment with at least a sedimentation well is required, or equivalent system, that is easily accessed by maintenance crews for inspection and maintenance.
- Infiltration should be into native soil.

U.S. Environmental Protection Agency (EPA) – Region 9 Regulations

Dry wells and other buried infiltrative devices serving property other than single-family homes are subject to the U.S. Environmental Protection Agency (US EPA) Underground Injection Control (UIC) regulations. A dry well is considered a Class V injection well, which is defined as a conduit for non-hazardous fluids that is deeper than it is wide. Dry wells may be authorized to operate as long as they are registered with the US EPA, and only inject uncontaminated stormwater. The US EPA has also set forth the following minimum requirements for Class V wells:

- Register injection wells at www.epa.gov/region09/water/groundwater/injection-wells-register.html
- Operate injection wells in a way that will not endanger underground sources of drinking water (USDW).
- Abandoned Class V wells should be properly destroyed, with notification to the US EPA, to prevent movement of contaminated fluids into USDW.

California
Falls under USEPA Region 9 UIC program for Class V injection wells.
Regional Water Quality Control Boards **can** prescribe discharge requirements for injection wells.
No state-wide permitting requirements for the use of dry wells.
Regional Water Quality Control Boards may require a report of discharge and other information. No formal, statewide process for registration or monitoring.
Injection well requirements must protect beneficial uses (comply with the Anti-Degradation policy).
Requirements may vary by region and municipality.

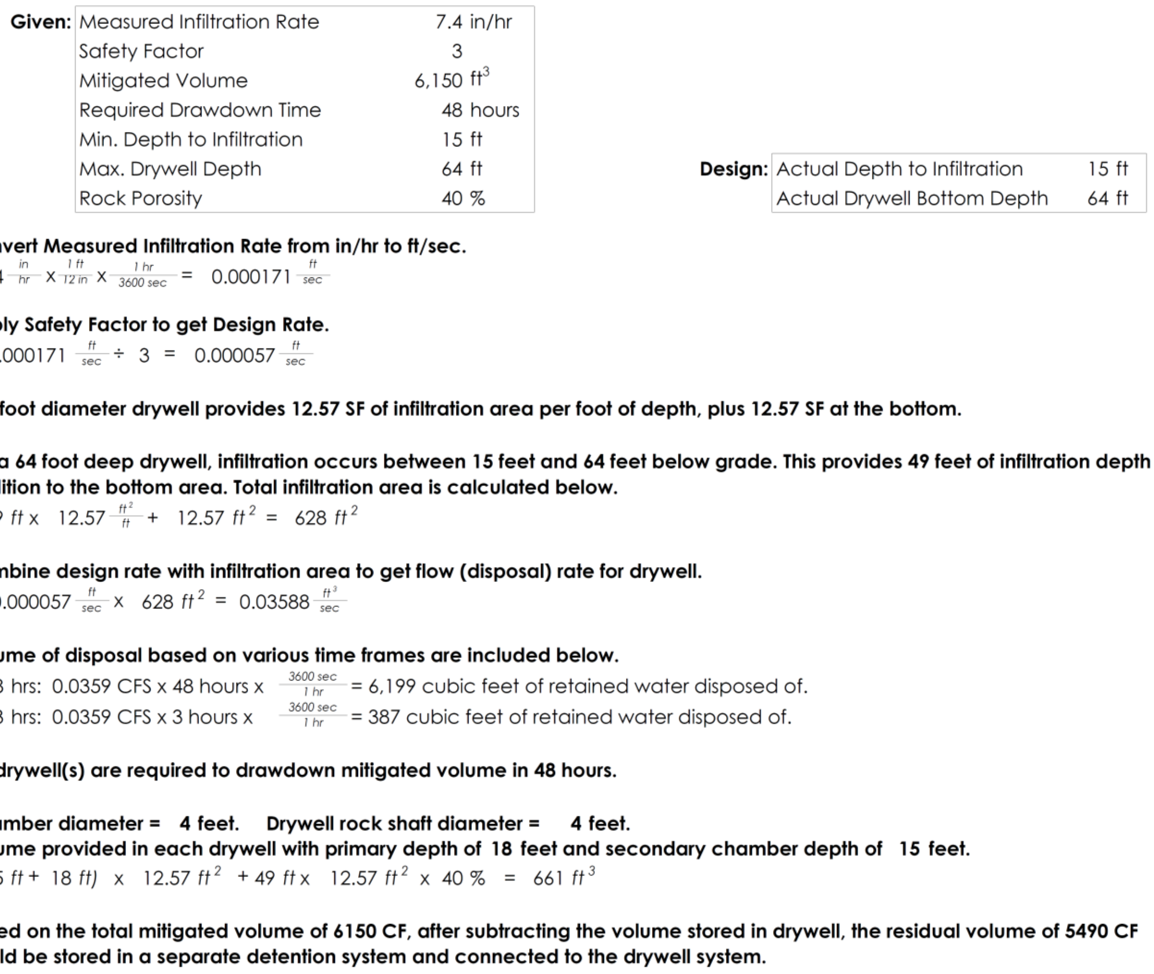
California Regional Water Quality Control Board

Currently there are no uniform state regulations or guidelines for dry wells in California. However, the Regional Water Quality Control Boards have the discretion to issue waste discharge requirements and to interpret and apply the Anti-Degradation policy to the construction of new dry wells. Therefore, most regulations and guidelines occur at the city or county level and vary by region. Available information suggests that dry wells can be used safely if careful site evaluations are performed to determine if a dry well is suitable for the location. They can be an alternative to typical storm drainage systems that provide numerous benefits, including reducing localized flooding, recharging the aquifer, supporting the implementation of LID practices in areas with clay soils, thereby minimizing alterations to the hydrologic cycle which have effects on valuable aquatic resources.

Design and Sizing Criteria

Note: Currently there are no uniform state regulations or guidelines on dry wells in California. The purpose of this fact sheet is to help explain the role of dry wells in meeting infiltration requirements. Therefore, this fact sheet does not describe specific design criteria like the other fact sheets in this manual. The Riverside County may develop specific design criteria and include in this fact sheet at a future time. For use in Riverside County, each project will need to prepare their own design criteria with enough detail and explanation so that the calculations can be independently verified, for compliance with Riverside County WQMP requirements.

Example Calculations:



Given:

Measured Infiltration Rate	7.4 in/hr
Safety Factor	3
Mitigated Volume	6,150 ft^3
Required Drawdown Time	48 hours
Min. Depth to Infiltration	15 ft
Max. Drywell Depth	64 ft
Rock Porosity	40 %

Design:

Actual Depth to Infiltration	15 ft
Actual Drywell Bottom Depth	64 ft

Convert Measured Infiltration Rate from in/hr to ft/sec.

$7.4 \frac{in}{hr} \times \frac{1\ ft}{12\ in} \times \frac{1\ hr}{3600\ sec} = 0.000171 \frac{ft}{sec}$

Apply Safety Factor to get Design Rate.

$0.000171 \frac{ft}{sec} \div 3 = 0.000057 \frac{ft}{sec}$

A 4 foot diameter drywell provides 12.57 SF of infiltration area per foot of depth, plus 12.57 SF at the bottom.

For a 64 foot deep drywell, infiltration occurs between 15 feet and 64 feet below grade. This provides 49 feet of infiltration depth in addition to the bottom area. Total infiltration area is calculated below.

$49\ ft \times 12.57 \frac{ft^2}{ft} + 12.57\ ft^2 = 628\ ft^2$

Combine design rate with infiltration area to get flow (disposal) rate for drywell.

$0.000057 \frac{ft}{sec} \times 628\ ft^2 = 0.03588 \frac{ft^3}{sec}$

Volume of disposal based on various time frames are included below.

48 hrs: 0.0359 CFS x 48 hours x $\frac{3600\ sec}{1\ hr}$ = 6,199 cubic feet of retained water disposed of.

3 hrs: 0.0359 CFS x 3 hours x $\frac{3600\ sec}{1\ hr}$ = 387 cubic feet of retained water disposed of.

1 drywell(s) are required to drawdown mitigated volume in 48 hours.

Chamber diameter = 4 feet. Drywell rock shaft diameter = 4 feet.
Volume provided in each drywell with primary depth of 18 feet and secondary chamber depth of 15 feet.

$(15\ ft + 18\ ft) \times 12.57\ ft^2 + 49\ ft \times 12.57\ ft^2 \times 40\ \% = 661\ ft^3$

Based on the total mitigated volume of 6150 CF, after subtracting the volume stored in drywell, the residual volume of 5490 CF could be stored in a separate detention system and connected to the drywell system.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Identify and control sources for sediment in tributary areas	Two to four times per year during wet season
Observe and record drawdown rate via the observation port	
Estimate degree of sediment and/or trash and debris accumulation in the pre-treatment system	
Identify any needed corrective maintenance that will require site-specific planning or design	
ON-GOING MAINTENANCE	
Pre-treatment system: Remove accumulated material from pre-treatment system	Annually or when material has accumulated to more than 50 percent of capacity of the pre-treatment system. If proprietary pretreatment is used, then maintain per manufacturer guidance.
CORRECTIVE (MAJOR) MAINTENANCE	
Add an additional drywell or excavate the entire facility, rehabilitate bottom and sides via over-excavation, and replace system components.	With excessive ponding or drawdown times.
Repair structural damage to inlets and outlets	As needed
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance

References Used to Develop this Fact Sheet

California Environmental Protection Agency, and Office of Environmental Health Hazard Assessment. Dry Wells Uses, Regulations, And Guidelines In California And Elsewhere. Sacramento and Oakland, CA, 2014.

Orange County: Stormwater Program. Technical Guidance Document (TGD) For The Preparation Of Conceptual/Preliminary and/or Project Water Quality Management Plans (WQMPS) In South Orange County. Orange County, CA, 2017.

San Diego County: Stormwater Program. BMP Design Manual, Appendix E. San Diego County, CA, 2016.

Federal Environmental Protection Agency. 40 CFR 144, 145, and 146, Underground Injection Control Regulations for Class V Injection Wells, Revision; Final Rule. 1999.

Federal Environmental Protection Agency. 40 CFR 144, Underground Injection Control Program - Notice of Final Determination for Class V Wells; Final Rule. 2002.

3.4 Bioretention Facility

Type of BMP	LID – Bioretention
Priority Level	Priority 1 – Full Retention
Treatment Mechanisms	Infiltration, Evapotranspiration, Evaporation,
Infiltration Rate Range	> 0.8 in/hr factored design infiltration rate
Maximum Drainage Area	This BMP is intended to be integrated into a project's landscaped area in a distributed manner. Typically, contributing drainage areas to Bioretention Facilities range from less than 1 acre to a maximum of around 5 acres. For facilities treating larger drainage basins, see Fact Sheet 3.7 for additional guidance on design of larger scale facilities.

Description

Bioretention Facilities are shallow, vegetated basins underlain by an engineered soil media designed to retain the design capture volume V_{BMP}. Bioretention Facilities function similarly to infiltration basins but have a shallower ponding depth and provide additional treatment through the inclusion of the soil media. Stormwater infiltrates through soil media and the bottom of the basin. Healthy plant and biological activity in the root zone maintain and renew the macro-pore space in the soil media and maximize plant uptake of pollutants and runoff. This helps extend the lifespan before clogging occurs and allows more of the soil column to function as both a sponge (retaining water) and a biofilter. In all cases, the bottom of a Bioretention Facility is unlined as the primary treatment process is infiltration. Flows exceeding V_{BMP} must discharge to a downstream conveyance system. Biofiltration basins can be effective in removing targeted pollutants from stormwater runoff. Low-nutrient soil media (see Fact Sheet 3.8) is necessary to provide treatment and avoid leaching of nutrients.

Siting Considerations

These facilities generally work best when they are designed in a relatively level area. Unlike other BMPs, Bioretention Facilities can be used in smaller landscaped spaces on the site, such as, parking islands, medians, and site entrances. Identification of opportunities for siting bioretention facilities should begin with the initial layout of the site. Landscaped areas on the site (such as may otherwise be required through minimum landscaping ordinances), can often be designed as Bioretention Facilities. This can be accomplished by:

- *Depressing* landscaped areas below adjacent impervious surfaces, rather than elevating those areas
- Grading the site to direct runoff from those impervious surfaces *into* the Bioretention Facility, rather than away from the landscaping
- Sizing and designing the depressed landscaped area as a Bioretention Facility.

For systems treating larger areas also consult Fact Sheet 3.7.

Bioretention Facilities should not be used downstream of areas where large amounts of sediment can clog the system. Placing a Bioretention Facility at the toe of a steep slope should also be avoided due to the potential for clogging the engineered soil media with erosion from the slope, as well as the potential for damaging the vegetation. Inclusion of additional design components such as pretreatment may be included to mitigate clogging potential at the discretion of the local jurisdiction.

The use of bioretention facilities may be restricted by risk of groundwater contamination, low soil permeability, and elevated potential for clogging at the site. Refer to Section 2.3.3 of the SMR WQMP for feasibility considerations for using bioretention BMPs. These BMPs may not be appropriate for the following site conditions:

- Industrial sites or locations where spills of toxic materials may occur, except where spill containment and/or hydrologic isolation is provided to mitigate the risk of groundwater contamination the satisfaction of the local jurisdiction
- Sites with very low soil infiltration rates or rates that cannot be reliably estimated prior to construction (e.g., deeper fills or deeper cuts)
- Sites with high groundwater tables where pollutants can affect groundwater quality
- Sites with unstabilized soil or construction activity upstream
- On steeply sloping terrain

Setbacks

Always consult your geotechnical engineer for site specific recommendations regarding setbacks for Bioretention Facilities. Recommended setbacks are needed to protect buildings, existing trees, walls, onsite or nearby wells, streams, and tanks. Setbacks should be considered early in the design process since they can affect where Biofiltration Facilities may be placed and how deep they are allowed to be.

Bioretention Facilities typically should be set back:

- 10 feet from the historic high groundwater (measured vertically from the bottom of the basin, as shown in Figure 1
- 5 feet from bedrock or impermeable surface layer (measured vertically from the bottom of the basin, as shown in Figure 1.
- From all existing mature tree drip lines as indicated in Figure 1 (to protect their root structure)
- 100 feet horizontally from wells, tanks or springs

Setbacks to walls and foundations must be included as part of the Geotechnical Report. All other setbacks shall be in accordance with applicable standards of the District's *Basin Guidelines* (Appendix C).

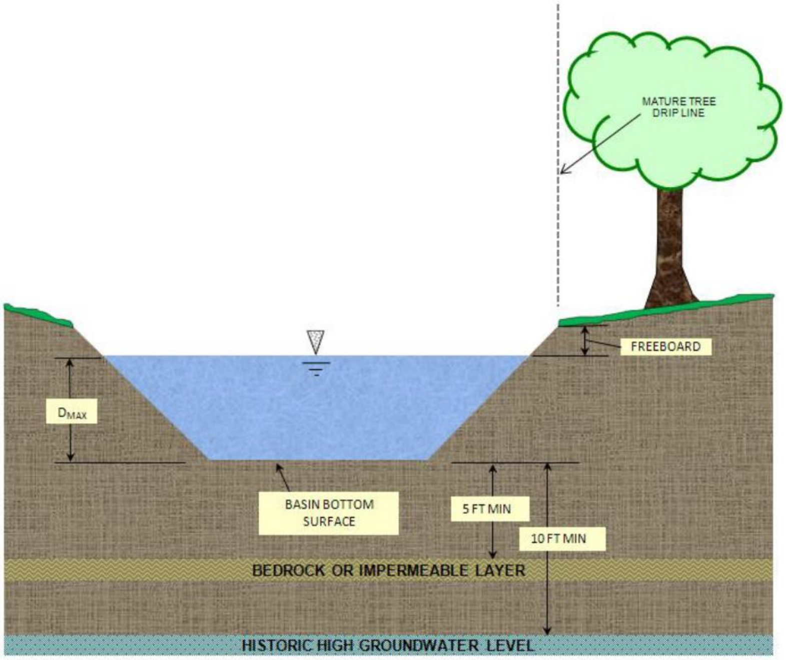


Figure 1 **: Setback Recommendations for a Bioretention Facility**

Pretreatment

Pretreatment should be considered to prevent premature clogging of bioretention BMPs. Pretreatment is strongly encouraged where the BMP will receive runoff from high traffic parking lots or roads, mixed land uses (with some erodible areas), or other land uses likely to generate elevated sediment.

For BMPs receiving overland flow, pretreatment may be provided using forebays with a volume equivalent to at least 10 percent (preferably 20 percent) of V_{BMP}. A forebay is effectively the first cell in the bioretention system, separated from the remaining area by a berm or cross plate. The forebay is designed to maximize sedimentation and will require more frequent, but more spatially-focused maintenance. This portion of the system can be concrete lined to facilitate simpler maintenance.

For BMPs with piped inlets, a forebay or sedimentation manhole may be applicable. In these systems, it is also necessary to consider energy dissipation near the inlet pipe, such as via a gravel/rock pad and berm system or concrete splash block, to avoid erosion of the bioretention media bed.

If the BMP will receive runoff primarily from roofs, low-traffic impervious surface, or similar low sediment generating surfaces, then pre-treatment is not necessary, but energy dissipation should still be considered, particularly if there is a piped inflow such as a downspout.

Design and Sizing Criteria

This section summarizes the recommended design parameters for Bioretention Facilities. Use of the recommended parameters will help provide the expected treatment and long term performance of the BMP. Deviations from the recommended parameters may be warranted and approved by the local jurisdiction based on site specific considerations. The recommended cross section for a Bioretention Facility includes:

- Vegetated area
- 6" minimum, 12" maximum, surface ponding, measured from the top of the mulch layer (for designs with deeper depths, consult Fact Sheet 3.7)
- Mulch layer (non-floating organic mulch or rock mulch)
- 24" recommended minimum depth of engineered soil media (36" preferred; 18" allowed in vertically-constrained conditions at the discretion of the local jurisdiction)
- Engineered soil media design filtration rate of 2.5 inches per hour (initial filtration rate should be higher).
- 6" optional filter course layer (required if aggregate storage layer is included)
- Optional gravel storage layer below media
- Optional capped underdrain pipe (see Resilient Design Features section below for specific criteria and conditions related to this option)

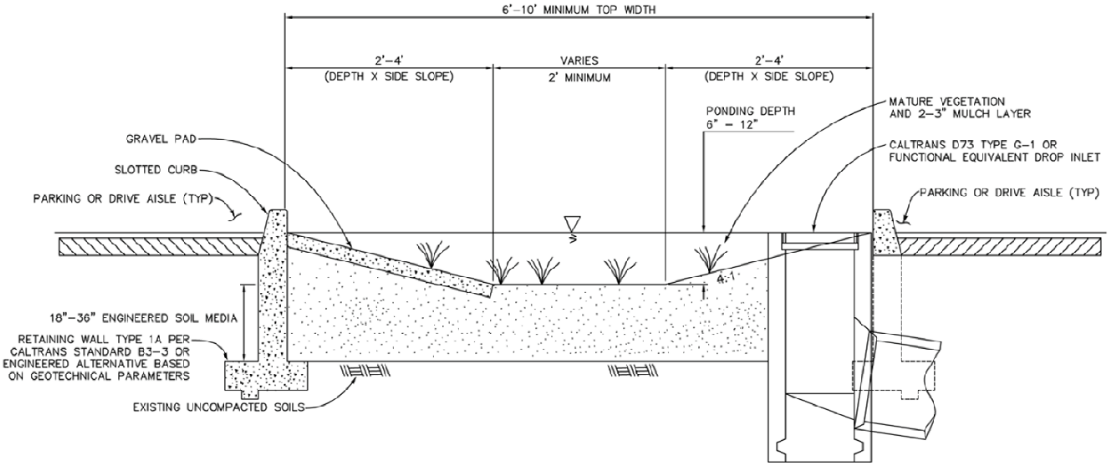


Figure 2: Standard Cross Section for a Bioretention Facility

Pore space in the soil and gravel layer can be credited as storage volume. However, several considerations must be noted:

- Ponding depth above the soil surface (6 to 12 inches) is important to assure that design flows do not bypass the BMP when runoff exceeds the soil infiltration rate.
- In cases where the Bioretention Facility contains engineered soil media deeper than 36 inches, the pore space within the engineered soil media can only be counted to the 36-inch depth.
- A maximum of 30 percent pore space can be used for the soil media whereas a maximum of 40 percent pore space can be used for the gravel and filter course layers.
- Additional depth below the storage layer (via gravel) may be used to increase retention storage, under the following conditions:
    - The total system infiltrates the stored water in less than 72 hours
    - The depth below the media does not exceed the amount of water that can be filtered through the media during a typical DCV storm duration (5 hours, unless otherwise documented).

Adaptable/Resilient Design Option

At the discretion of the engineer and with the approval of the local jurisdiction, bioretention BMPs may be designed with a gravel drainage layer and a **capped** underdrain. This is effectively a biofiltration design (Fact Sheet 3.5), but there is no design discharge from the underdrains. The benefit of this configuration is that it allows simpler adaptation to a biofiltration BMP if this is warranted, documented, and approved.

This option **may only** be approved for use under the conditions described in Section 2.3.3.g of the WQMP, including:

1) The BMP must meet applicable infiltration BMP sizing standards without any discharge through the underdrain.

2) The Project-Specific WQMP must also meet all applicable sizing standards (biofiltration sizing, hydromodification, if applicable) standards if the underdrain is uncapped.

3) The underdrain must remain capped. Inspections conducted as part of the O&M Plan must corroborate that the underdrain remains capped.

4) If conditions are identified that require the underdrain to be uncapped to allow the BMP to be enlarged or otherwise modified to remedy the documented unacceptable performance, this must include: (a) documentation of the conditions that prompt and justify the require design revision, (b) revision of the Project-Specific WQMP to reflect the revised configuration, and (c) jurisdictional review, approval, and recordation of the revised Project Specific WQMP with commensurate updates to the O&M Plan.

See Section 5.3.6 for guidance on Project-Specific WQMP updates. Note that this is the same process that would be required to wholly redesign and reconstruct an underperforming BMP. However, if adaptable design features are included, the actual physical change could be limited to uncapping the underdrain.

Design Adaptations

Bioretention facilities can be designed to meet both pollutant control and hydromodification control performance standards. Combined facilities typically include increased storage (surface and or subsurface) and flow control devices (i.e. outlet orifices and/or weirs). Outlets elevations must be set above the V_{BMP} ponding level and the facilities must satisfy both the pollutant control and hydromodification control performance standards.

For systems exceeding 12 inches ponding depth and/or 5 acres tributary area, see additional design considerations in Fact Sheet 3.7.

Subsurface storage is not required but may be provided in the form of a gravel storage layer. Refer to the Subsurface Storage Requirements section for additional information and criteria.

Engineered Soil Media and Filter Course Aggregate Requirements

Refer to Fact Sheet 3.8 for specifications for engineered soil media and aggregate layers serving as filter course and drain rock in bioretention BMPs.

Subsurface Storage Requirements

Applicants may choose to provide a portion of the BMP storage volume as subsurface storage in a gravel storage layer. Use of subsurface storage instead of surface storage can be useful when the available surface ponding depth is limited or when a deeper profile is desired to reduce footprint requirements.

The gravel storage layer shall not provide a greater storage volume than can be routed through the soil media during the typical design storm duration (i.e. 2.5 inches/hour x 5 hours = 12 inches effective water depth). Alternatively, a separate routing calculation may be performed by the applicant to demonstrate that the provided volume does not result in surface overflow (bypass of the BMP) before the gravel storage layer is full.

When gravel storage layers are used, the filter course layer should be specifically designed to prevent migration of the engineered soil media into the storage layer. Refer to Fact Sheet 3.8 for filter course requirements. Inclusion of a filter course layer is mandatory unless filter fabric is allowed per manufacturer's recommendation and is acceptable to the local jurisdiction.

Vegetation Requirements

Vegetative cover is important to minimize erosion and ensure that treatment occurs in the Bioretention Facility. The area should be designed for at least 70 percent mature coverage throughout the Bioretention Facility. To prevent the BMP from being used as walkways, Bioretention Facilities shall be planted with densely planted shrubs and grasses. Grasses shall be shall be compatible with periodic inundation, preferably ones that do not need to be mowed. The application of fertilizers and pesticides should be minimal. To maintain oxygen levels for the vegetation and promote biodegradation, it is important that vegetation not be completely submerged for any extended period of time. Vegetation should be selected to withstand the anticipated drawdown time and ponding depths. Trees should only be used where they can be rooted into underlying native soil.

A 2 to 3-inch layer of standard shredded aged hardwood mulch shall be placed as the top layer inside the Bioretention Facility. Rounded stone mulch may be considered. A sacrificial layer of coarse sand could be considered between the bioretention soil and stone mulch to reduce surface compaction. The ponding depth shown in Figure 2 above shall be measured from the top surface of the 2 to 3-inch mulch layer.

Curb Cuts and Energy Dissipation

If the Bioretention Facility is sited to receive runoff from adjacent impervious areas, 1-foot-wide (minimum) curb cuts should be placed approximately every 10 feet around the perimeter of the Bioretention Facility. Figure 3 shows a curb cut in a Bioretention Facility. Curb cut flow lines must be at or above the V_{BMP} water surface ponding level. Additionally, vertical curb cuts may be a tripping hazard. Where feasible, curb cuts should be tapered from the bottom to top of curb as shown below. When tapered cuts are used, the minimum bottom cut width remains 1 foot.

Figure 3: Curb Cut located in a Bioretention Facility

To reduce erosion, a gravel or riprap pad shall be placed at each inlet point to the Bioretention Facility. The pad inside the Bioretention Facility should be flush with the finished surface at the curb cut and extend to the bottom of the slope. The size of gravel or riprap should be selected to withstand the expected peak flows into the basin.

In addition, an apron of stone or concrete, a foot square or larger should be placed inside each inlet to prevent vegetation from growing up and blocking the inlet. See Figure 4.

When runoff is routed to the facility via a pipe, gutter, ditch or other conveyance structure, the conveyance should outlet to the forebay portion of the BMP and include appropriate energy dissipation devices to prevent erosion and scouring of the forebay (i.e. limit outlet velocities to less than 2 feet per second).

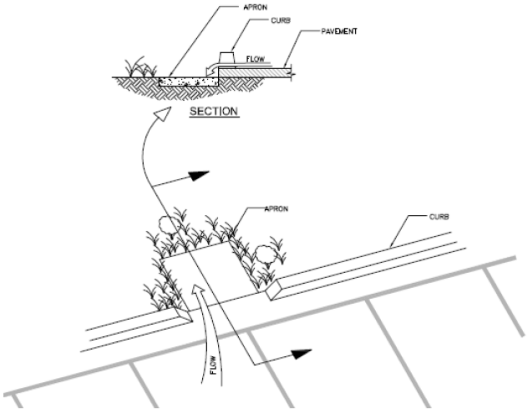


Figure 4: Apron located in a Bioretention Facility

Terracing the Facility

It is recommended that Bioretention Facilities be level. In the event the facility site slopes and lacks proper design, water would fill the lowest point of the BMP and then discharge from the basin without being treated. To ensure that the water will be held within the Bioretention Facility on sloped sites, the BMP must be terraced with nonporous check dams to provide the required storage and treatment capacity.

The terraced version of this BMP shall be used on non-flat sites with no more than a 3 percent slope. The surcharge depth cannot exceed 0.5 feet, and side slopes shall not exceed 4:1. Table 1 below shows the spacing of the check dams, and slopes shall be rounded up (i.e., 2.5 percent slope shall use 10' spacing for check dams).

Table 1: Check Dam Spacing

6" Check Dam Spacing	
Slope	Spacing
1%	25'
2%	15'
3%	10'

Roof Runoff

Roof downspouts may be directed towards Bioretention Facilities. However, the downspouts must discharge onto a concrete splash block or other appropriate energy dissipation device to protect the Bioretention Facility from erosion.

Retaining Walls

When Bioretention facilities are located adjacent to structures, walkways, roadways, parking lots, etc., it is recommended that Retaining Wall Type 1A, per Caltrans Standard B3-3 or equivalent, be constructed around the entire perimeter of the Bioretention Facility. This practice will protect the sides of the Bioretention Facility from collapsing during construction and maintenance or from high service loads adjacent to the BMP. Where such service loads would not exist adjacent to the BMP, an engineered alternative may be used if signed by a licensed civil engineer.

Side Slope Requirements

Bioretention Facilities Requiring Side Slopes

The design should assure that the Bioretention Facility does not present a tripping hazard. Bioretention Facilities proposed near pedestrian areas, such as areas parallel to parking spaces or along a walkway, should have a gentle slope to the bottom of the facility. Side slopes inside of a Bioretention Facility should generally be 4:1 unless steeper is approved by the local jurisdiction. A typical cross section for the Bioretention Facility is shown in Figure 2.

Bioretention Facilities Not Requiring Side Slopes

Where cars park perpendicular to the Bioretention Facility, side slopes are not required. A 12-inch maximum drop may be used for vertical walls, and the Bioretention Facility should be planted with shrubs to prevent pedestrian access. In this case, a curb is not placed around the Bioretention Facility, but wheel stops shall be used to prevent vehicles from entering the Bioretention Facility, as shown in Figure 5: Bioretention Facility Layout without Side Slopes

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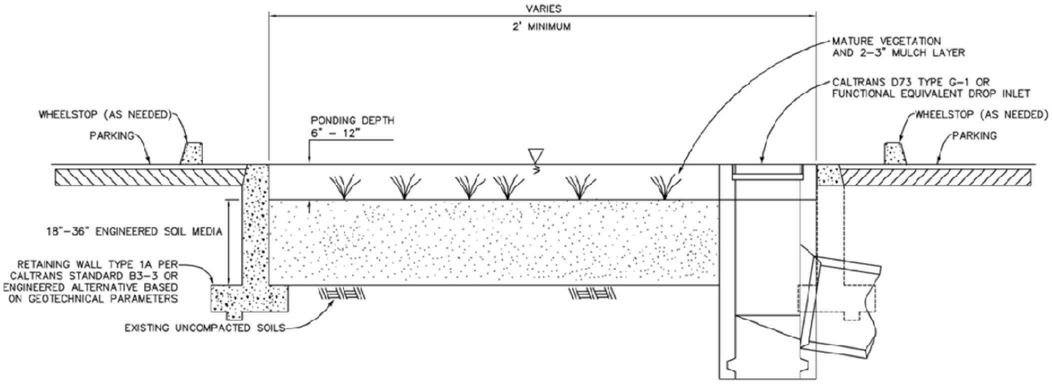

Figure 5: Bioretention Facility Layout without Side Slopes

Overflow

An overflow route is needed in the Bioretention Facility design to bypass stored runoff from storm events larger than V_{BMP} or in the event of facility clogging. Overflow systems must connect to an acceptable discharge point, such as a downstream conveyance system as shown in Figure 2 and Figure 6.. The inlet to the overflow structure shall be elevated inside the Bioretention Facility to be flush with the ponding surface for the design capture volume (V_{BMP}) as shown in Figure 6. This will allow the design capture volume to be fully infiltrated by the Bioretention Facility, and for larger events to safely be conveyed to downstream systems. The overflow inlet shall **not** be located in the entrance of a Bioretention Facility, as shown in Figure 6.

Figure 6: Incorrect Placement of an Overflow Inlet

Underdrain Gravel and Pipes

An underdrain gravel layer and capped perforated pipes may be provided in accordance with Appendix B – Underdrains. This is an optional configuration that is recommended when the design infiltration rate is between 0.8 and 2inches per hour. When the BMP is installed, the underdrain must be capped, such that no water is discharged. The underdrain serves only as a backup plan, which allows the facility to be converted to a biofiltration with partial infiltration facility if the post-construction infiltration rate is significantly less than measured during planning and design. Removal of the underdrain cap and conversion of the bioretention facility to a biofiltration with partial infiltration facility must be approved by the local jurisdiction with appropriate modifications to the Project-Specific WQMP and O&M Plan, as applicable.

Inspection and Maintenance Schedule

Inspection and maintenance of Bioretention Facilities is required to provide long term performance of these systems. Table 2 below provides a summary of the typical maintenance activities that may be applicable. Project specific activities and schedules may vary and are required to be included as part of the applicant's O&M Plan. At a minimum, the Bioretention Facility area shall be inspected for erosion, dead vegetation, soggy soils, or standing water. The use of fertilizers and pesticides on the plants inside the Bioretention Facility should be minimized.

Table 2: Maintenance Summary

Activity
• Maintain vegetation as needed. Use of fertilizers, pesticides and herbicides should be avoided as much as possible to ensure they do not contribute to water pollution. If appropriate native plant selections and other IPM methods are used, such products should not be needed. If such projects are used, ○ Products should be applied in accordance with their labeling, especially in relation to application to water, and in areas subjected to flooding. ○ Fertilizers should not be applied within 15 days before, after, or during the rainy season. • Remove debris and litter from the entire basin to minimize clogging and improve aesthetics. • Check for obvious problems and repair as needed. Address odor, insects, and overgrowth issues associated with stagnant or standing water in the basin bottom. • Check for erosion and sediment laden areas in the basin. Repair as needed. Clean forebay if needed. • Revegetate side slopes where needed. • Inspect areas for ponding • Inspect for erosion and clogging, repair as needed. • Inspect of hydraulic and structural facilities: examine the inlet for blockage, the embankment and spillway for integrity, and damage to any structural element. • Check for erosion, slumping and overgrowth. Repair as needed. • Check basin depth for sediment build up and reduced total capacity. Scrape bottom as needed and remove sediment. Restore to original cross-section and infiltration rate. Replant basin vegetation. • Verify the basin bottom is allowing acceptable infiltration. Scarify the surface using a rake, etc., to restore infiltration, working to avoid damage to plants if possible. • No water should be present 72 hours after an event. No long term standing water should be present at all. No algae formation should be visible. Correct problem as needed.

Bioretention Facility Sizing and Design Procedure

1) Enter the area tributary, A_T, to the Bioretention Facility.

2) Enter the Design Capture Volume, V_{BMP}, determined from Section 2.1 of this Handbook.

3) Select the type of design used. There are two types of Bioretention Facility designs: the standard design used for most project sites that include side slopes, and the modified design used when the BMP does not use side slopes.

4) Enter the depth of the engineered soil media, d_S. The recommended minimum depth is 24”. A depth of 36” is preferred to provide a enhanced root zone. Engineered soil media deeper than 36” will only get credit for the pore space in the first 36”.

5) Enter the depth of the gravel storage layer, d_g (if included). This dimension includes the associated 6-inch filter course layer (do not double count this dimension).

6) Calculate the total effective depth, d_E, within the Bioretention Facility. The maximum allowable pore space of the soil media is 30% while the maximum allowable pore space for the gravel layer is 40%.

   This is calculated as:

$$d_E(ft) = d_P(ft) + [(0.3) \times d_S(ft) + (0.4) \times dg(ft)]$$

   Where:

   d_p = ponding depth
   d_s = soil depth
   d_g = gravel depth

7) Check that drawdown time is acceptable (72 hours, or shorter if needed to support selected vegetation):
   a. Drawdown Time = d_E / K_{design}

   Where:

   K_{design} = design infiltration rate (factored) determined per Section 2.3 of the WQMP and Appendix A of this LID-BMP Manual.

8) Check that storage in gravel does not exceed the amount that can enter these systems during a typical storm event. The depth of effective stored water should be less than 12 inches unless higher permeability media is used to allow faster filling of this layer.

9) Calculate the required effective footprint area, this shall be measured at the mid-ponding depth of the BMP. For systems with side slopes, this should be the contour that is midway between the floor of the basin and the overflow elevation of the basin. The footprint of

the underlying gravel storage should extend to this contour. For systems with vertical walls, the effective footprint area is the full footprint.

This is calculated as:

$$\mathrm{A_{BMP}}(\mathrm{sq\ ft}) = \mathrm{V_{BMP}}(cu\ ft)/d_E(ft)$$

10) Enter the proposed effective surface area. This area shall not be less than the minimum required effective surface area.

11) Verify that side slopes are no steeper than 4:1 in the standard design, and are not required in the modified design.

12) Provide the slope of the site around the Bioretention Facility, if used. The maximum slope is 3 percent for a standard design.

13) Provide the check dam spacing, if the site around the Bioretention Facility is sloped.

14) Describe the vegetation used within the Bioretention Facility.

If the underdrain is proposed to be capped, the project shall provide a Capped Underdrain Checklist and provide supporting documentation, include design worksheets to demonstrate the BMP is sized appropriately to work as a Biofiltration BMP.

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Bioretention Facility - Design Procedure

BMP ID

Legend:
Required Entries
Calculated Cells

Company Name:
Date:
Designed by:
County/City Case No.:

Design Volume

Enter the area tributary to this feature A_T= acres

Enter V_{BMP} determined from Section 2.1 of this Handbook V_{BMP}= ft^3

Enter the measured infiltration rate I= in/hr

Enter the Factor of Safety (See Table 1, Appendix A: "Infiltration Testing" of this BMP Design Handbook) FS =

Enter factored infiltration rate (design) $I_{factored}$= in/hr

Bioretention Facility Surface Area

Depth of Surface Ponding Layer (6" minimum, 12" maximum) d_P = inches
Depth of Engineered Soil Media (24" to 36"; 18" allowed if vertically constı d_s = inches
Depth of Gravel Storage Layer (Optional Layer; up to 30") d_g = inches

Note: Check that storage in gravel does not exceed the amount that can enter these systems during a typical storm event. The depth of effective stored water should be less than 12 inches (30 inch bulk depth) unless higher permeability media is used to allow faster filling of this layer.

Total Effective Depth, d_E

$d_E(ft) = d_p(ft) + [(0.3) \times d_S(ft) + (0.4) \times d_g(ft)]$ d_E = feet

Required Effective Footprint Area, A_{BMP}

$$A_{BMP}\ (ft^2) = \frac{V_{BMP}\ (ft^3)}{d_E\ (ft)}$$

A_{BMP} = ft^2

Proposed Surface Area (shall not be less than A_{BMP}) A= ft^2

Note: This area shall be measured at the mid-ponding depth of the BMP. For systems with side-slopes, this should be the contour that is midway between the floor of the basin and the maximum water qualty ponding depth of the basin. The underlying gravel layer should extend to this contour. For systems with vertical walls, the effective area is the full footprint.

Drawdown Time (must be less than 72 hours) T_{Dd} = hr

Bioretention Facility Properties

Side Slopes in Bioretention Facility z = :1

Longitudinal Slope of Site (3% maximum) %

Check Dam Spacing feet

Describe Vegetation:

Notes:

Riverside County-SMR LID BMP Design Handbook
February 2018

Capped Underdrain Checklist

BMP ID ______

Company Name: ______ Date: ______

Designed by: ______ County/City Case No: ______

In order to propose a capped underdrain for an infiltration BMP, all of the following shall be marked yes with supporting documentation.

1) The BMP must be categorized as an infiltration BMP for the Project-Specific WQMP preparation. The Project-Specific WQMP must demonstrate that the BMP will meet applicable standards without any discharge through the underdrain.
Yes____
No____

2) The Project-Specific WQMP must also demonstrate that the BMP would meet the biofiltration sizing standards (and hydromodification flow control standard, if applicable) with the underdrain uncapped. These sizing calculations must also be documented in the Project-Specific WQMP.
Yes____
No____

3) The underdrain must remain capped. This aspect of O&M inspection must be clearly defined in the O&M Plan. Inspections conducted as part of the O&M Plan must corroborate that the underdrain remains capped.
Yes____
No____

4) If conditions are identified that require the underdrain to be uncapped to allow the BMP to be enlarged or otherwise modified to remedy the documented unacceptable performance, then the process for implementing this change must include:

a. Documentation of the conditions that prompt and justify the require design revision. This could include construction-phase infiltration testing, observations of extended standing water following construction, etc. This must be accepted by the [Insert Jurisdiction].
b. Revision of the Project-Specific WQMP to reflect the changed design. Sizing calculations provided within the original Project-Specific WQMP will have already verified adequate sizing for the uncapped condition.
c. Jurisdictional review, approval, and recordation of the revised Project Specific WQMP with commensurate updates to the O&M Plan.

Notes:
______
______
______

3.5 Biofiltration with Partial Infiltration

Type of BMP	LID – Biofiltration with Partial Infiltration
Priority Level	Priority 2 – Biofiltration
Treatment Mechanisms	Infiltration, Evapotranspiration, Evaporation, Biofiltration
Infiltration Rate Range	0.1 to 0.8 in/hr factored design infiltration rate
Maximum Drainage Area	This BMP is intended to be integrated into a project's landscaped area in a distributed manner. Typically, contributing drainage areas to Bioretention Facilities range from less than 1 acre to a maximum of around 5 acres. For facilities treating larger drainage basins see Fact Sheet 3.7 for additional guidance on design of larger scale facilities.

Description

Biofiltration with Partial Infiltration Facilities are shallow, vegetated basins underlain by an engineered soil media designed to retain a portion of the design capture volume, V_{BMP}, and provide biofiltration treatment for the portion not retained. Biofiltration with Partial Infiltration Facilities function similarly to bioretention facilities but always include a gravel storage layer and perforated underdrain where the gravel layer forms a sump below the discharge elevation of the underdrains. Healthy plant and biological activity in the root zone maintain and renew the macro-pore space in the soil media and maximize plant uptake of pollutants and runoff. This can extend the time until the BMP clogs and allows more of the soil column to function as both a sponge (retaining water) and an effective biofilter. In all cases, the bottom of a Biofiltration with Partial Infiltration Facility is unlined (for lined version, see Fact Sheet 3.6). When the infiltration rate and sump storage capacity for infiltration is exceeded, fully biofiltered flows are discharged via underdrains. In this way, these facilities are designed to maximize incidental volume reduction. Flows exceeding the design flowrate must discharge to a downstream conveyance system.

Biofiltration with Partial Infiltration Facilities can be effective in removing targeted pollutants from stormwater runoff. **Low-nutrient soil media (see Fact Sheet 3.8) is critical** to provide treatment and avoid leaching of nutrients.

Proprietary biofiltration devices may be categorized as Biofiltration with Partial Infiltration Facilities when they are combined with supplemental retention BMPs. Refer to the Biofiltration Fact Sheet for information regarding proprietary biofiltration BMPs. In order to use these BMPs as Biofiltration with Partial Retention, the applicant must provide evidence (calculations, narrative, etc.) to demonstrate that supplemental retention is provided to accompany proprietary biofiltration BMPs and is equivalent to the volume retention that would be provided by a Biofiltration with Partial Infiltration Facility. This does not refer to detention storage upstream of proprietary BMPs to reduce discharge rates through the BMPs.

BIORETENTION WITH PARTIAL INFILTRATION BMP FACT SHEET

Siting Considerations

These facilities work best when they are designed in a relatively level area. Biofiltration with Partial Infiltration Facilities can be used in smaller landscaped spaces on the site, such as:

- ✓ Parking islands
- ✓ Medians
- ✓ Site entrances

Identification of opportunities for siting bioretention facilities should begin with the initial layout of the site. Landscaped areas on the site (such as may otherwise be required through minimum landscaping ordinances), can often be designed as Biofiltration with Partial Infiltration Facilities. This can be accomplished by:

- *Depressing* landscaped areas below adjacent impervious surfaces, rather than elevating those areas,
- Grading the site to direct runoff from impervious surfaces *into* the Biofiltration with Partial Infiltration Facility, rather than away from the landscaping, and
- Sizing and designing the depressed landscaped area as a Biofiltration with Partial Infiltration Facility as described in this Fact Sheet.

Design of Biofiltration with Partial Infiltration Facilities should also consider, and mitigate or avoid, potential impacts related to sediment clogging. For example, facilities should not be used downstream of naturally high sediment producing areas (steep vegetated slopes or natural offsite areas) without including additional pretreatment mechanisms.

Setbacks

There are no default setbacks for use in feasibility screening for Biofiltration with Partial Infiltration BMPs. In general, incidental infiltration poses minor risks. However, if there are geotechnical or groundwater concerns documented in the project's geotechnical report and Project-Specific WQMP, these may preclude any level of infiltration.

Pretreatment

Pretreatment mechanisms are not always required for Biofiltration with Partial Infiltration Facilities; however, they can extend the life and decrease the frequency of required maintenance of a BMP by reducing the amount of sediment loading to the facility.

Pretreatment is strongly encouraged where the BMP will receive runoff from high traffic parking lots or roads, mixed land uses (with some erodible areas), or other land uses likely to generate elevated sediment.

For BMPs receiving overland flow, pretreatment may be provided using forebays with a volume equivalent to at least 10 percent (preferably 20 percent) of V_{BMP}. A forebay is effectively the first cell in the bioretention system, separated from the remaining area by a berm or cross plate. Forebays are designed to maximize sedimentation and will require more frequent, but more spatially-focused maintenance. This portion of the system can be concrete lined to facilitate simpler maintenance.

For BMPs with piped inlets, a forebay or sedimentation manhole may be applicable. In these systems, it is also necessary to consider energy dissipation near the inlet pipe, such as via a gravel pad and berm system or concrete splash block, to avoid erosion of the bioretention media bed.

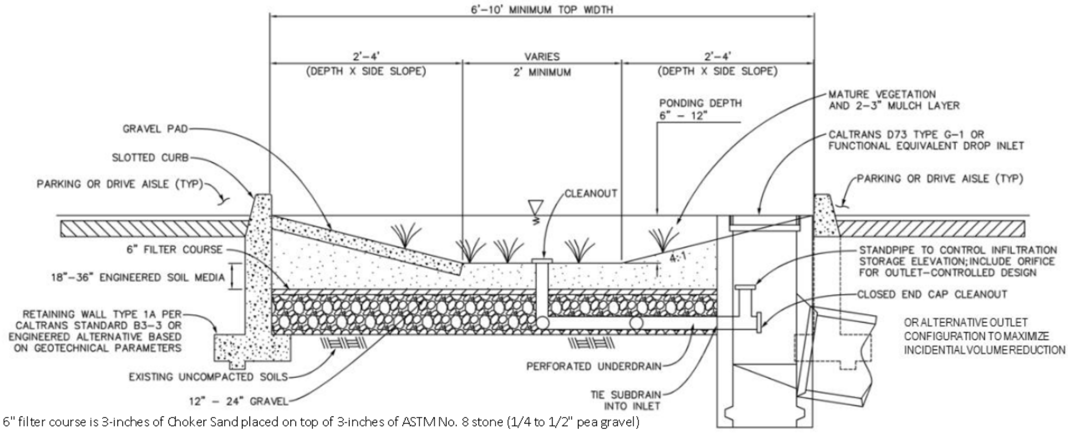
If the BMP will receive runoff primarily from roofs, low-traffic impervious surface, or similar low sediment generating surfaces, then pre-treatment is not necessary, but energy dissipation should still be considered, particularly if there is a piped inflow such as a downspout.

Design and Sizing Criteria

This section summarizes the recommended design parameters for Biofiltration with Partial Infiltration Facilities. Use of the recommended parameters will help provide the expected treatment and long-term performance of the BMP. Deviations from the recommended parameters may be warranted and approved by the local jurisdiction based on site specific considerations. The recommended cross section necessary for a Biofiltration with Partial Infiltration Facility includes:

- Vegetated area
- 6” minimum, 12” maximum, surface ponding, measured from the top of the mulch layer (for designs with deeper depths, consult Fact Sheet 3.7)
- 2 to 3” mulch layer
- 24” recommended minimum depth of engineered soil media (36” preferred; 18” allowed in vertically-constrained conditions at the discretion of the local jurisdiction)
- 6” filter course layer
- 18” gravel storage layer (up to 30” if desired)
- 6” minimum diameter perforated underdrain (refer to Appendix B)

BIORETENTION WITH PARTIAL INFILTRATION BMP FACT SHEET



6" filter course is 3-inches of Choker Sand placed on top of 3-inches of ASTM No. 8 stone (1/4 to 1/2" pea gravel)

Figure 1: Standard Section for a Biofiltration with Partial Infiltration Facility

An upturned underdrain outlet, with the discharging section set to an elevation equal to the top of the filter course layer is the preferred configuration to maximize incidental volume reduction. However, if site-specific conditions require, the elevation of the upturned elbow may be reduced or omitted at the discretion of the local jurisdiction.

Pore space in the soil and gravel layer can be credited as storage volume. However, several considerations must be noted:

- Ponding depth above the soil surface (6 to 12 inches) is important to assure that design flows do not bypass the BMP when runoff exceeds the soil's absorption rate.
- In cases where the Bioretention Facility contains engineered soil media deeper than 36 inches, the pore space within the engineered soil media can only be counted to the 36-inch depth.
- A maximum of 30 percent pore space can be used for the soil media whereas a maximum of 40 percent pore space can be used for the gravel and filter course layers.
- Additional depth below the storage layer (via gravel) may be used to increase retention storage, under the following conditions:
    - The total system infiltrates the stored water in less than 72 hours
    - The depth below the media does not exceed the amount of water that can be filtered through the media during a typical DCV storm duration (5 hours, unless otherwise documented).

Outlet Controlled Approach

Biofiltration with Partial Infiltration Facilities may include the use of engineered soil media with a higher design filtration rate (up to 50 inches per hour) when combined with a flow restricting outlet control on the facility's perforated underdrain. This configuration can provide greater protection against clogging because the underdrain outlet controls the rate at which stormwater is filtered through the media, rather than the media itself. The underdrain outlet controls are designed to provide a flowrate equivalent to the typical design media filtration rate of 2.5 to 5 inches per hour.

Design Adaptations

Biofiltration with Partial Infiltration facilities can be designed to meet both pollutant control and hydromodification control performance standards. Combined facilities typically include increased storage (surface and/or subsurface) and flow control devices (i.e. outlet orifices and/or weirs). Outlets elevations for extra surface ponding must be set above the V_{BMP} ponding level such that there is no discharge of untreated water for the V_{BMP}, and the facilities must satisfy both the pollutant control and hydromodification control performance standards. For systems with ponding depth greater than 12 inches, also refer to Fact Sheet 3.7.

Subsurface storage greater than the minimum 18-inch gravel storage layer may be provided. Additional subsurface storage may allow designers to provide a smaller footprint BMP, reduce the subsurface depth of the BMP, or allow for additional volume retention. Refer to the Subsurface Storage section for additional information and criteria.

Engineered Soil Media Requirements and Aggregate Specifications

Refer to Fact Sheet 3.8 for engineered soil media requirements and specifications and aggregate specifications serving as filter course and underdrain stone in Biofiltration BMPs. ***Low-nutrient soil media design described in Fact Sheet 3.8 is critical to provide treatment and avoid leaching of nutrients.***

Subsurface Storage Requirements

Subsurface storage may be provided in the form of additional gravel thickness. For pollutant control, the depth of extra storage should not exceed 12 inches effective depth of water to ensure that the pores can be filled before surface overflow would be expected (5-hour typical storm x 2.5 in/hr = 12 inches = 30 inches of gravel).

The filter course layer shall be specifically designed to prevent migration of the engineered soil media into the storage layer. The filter course specifications are provided in Fact Sheet 3.8. Inclusion of a filter course layer is mandatory unless filter fabric is allowed per manufacturer's recommendation and is acceptable to the local jurisdiction.

Vegetation Requirements

Vegetative cover is important to minimize erosion and ensure that treatment occurs in the Biofiltration with Partial Infiltration Facility. The area should be designed for at least 70 percent mature coverage throughout the facility. To prevent the BMP from being used as walkways, Bioretention Facilities shall be planted with densely planted shrubs and grasses. Grasses shall be shall be compatible with periodic inundation, preferably ones that do not need to be mowed. The application of fertilizers and pesticides should be minimal. To maintain oxygen levels for the vegetation and promote biodegradation, it is important that vegetation not be completely submerged for any extended period of time. Vegetation should be selected to withstand the anticipated drawdown time and ponding depths.

A 2 to 3-inch layer of standard shredded aged hardwood mulch should be placed as the top layer inside the Biofiltration with Partial Infiltration Facility. The 6 to 12-inch ponding depth shown in Figure 1 above should be measured from the top surface of the mulch layer. Rounded stone mulch may be considered provided that it does not compact the underlying soils. A sacrificial layer of fine sand could be considered between the bioretention soil and stone mulch.

Curb Cuts and Energy Dissipation

If the Biofiltration with Partial Infiltration Facility is sited to receive runoff from adjacent impervious areas, 1-foot-wide (minimum) curb cuts should be placed approximately every 10 feet around the perimeter of the Bioretention Facility. Figure 3 shows a curb cut in a Biofiltration with Partial Infiltration Facility. Curb cut flow lines must be at or above the V_{BMP} water surface ponding level. Additionally, vertical curb cuts may be a tripping hazard. Where feasible, curb cuts should be tapered from the bottom to top of curb as shown below. When tapered cuts are used, the minimum bottom cut width remains 1 foot.

Figure 2: Example Curb Cut

To reduce erosion, a gravel or riprap pad shall be placed at each inlet point to the Biofiltration with Partial Infiltration Facility. The pad inside the Biofiltration with Partial Infiltration Facility should be flush with the finished surface at the curb cut and extend to the bottom of the slope. The size of gravel or riprap should be selected to withstand the expected peak flows into the basin.

In addition, place an apron of stone or concrete, a foot square or larger, inside each inlet to prevent vegetation from growing up and blocking the inlet. See Figure 4.

When runoff is routed to the facility via a pipe, gutter, ditch or other conveyance structure, the conveyance should outlet to the forebay portion of the BMP and include appropriate energy dissipation devices to prevent erosion and scoring of the forebay (i.e. limit outlet velocities to 2 feet per second).

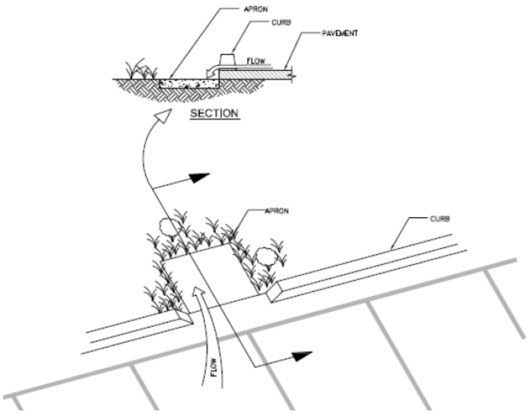


Figure 3: Apron located in a Biofiltration with Partial Retention Facility

Terracing the Facility

It is recommended that Biofiltration with Partial Infiltration Facilities be level. In the event the facility site slopes and lacks proper design, water would fill the lowest point of the BMP and then discharge from the basin without being treated. To ensure that the water will be held within the Biofiltration with Partial Infiltration Facility on sloped sites, the BMP must be terraced with nonporous check dams to provide the required storage and treatment capacity. The terraced version of this BMP shall be used on non-flat sites with no more than a 3 percent slope. The surcharge depth cannot exceed 0.5 feet, and side slopes shall not exceed 3:1. Table 1 below shows the spacing of the check dams, and slopes shall be rounded up (i.e., 2.5 percent slope shall use 10' spacing for check dams).

Table 1: Check Dam Spacing

6” Check Dam Spacing	
Slope	Spacing
1%	25'
2%	15'
3%	10'

Roof Runoff

Roof downspouts may be directed towards Biofiltration with Partial Infiltration Facilities. However, the downspouts must discharge onto a concrete splash block or other appropriate energy dissipation device to protect the Biofiltration with Partial Infiltration Facility from erosion.

Retaining Walls

When Bioretention facilities are located adjacent to structures, walkways, roadways, parking lots, etc., it is recommended that Retaining Wall Type 1A, per Caltrans Standard B3-3 or equivalent, be constructed around the entire perimeter of the Biofiltration with Partial Infiltration Facility. This practice will protect the sides of the Biofiltration with Partial Infiltration

Facility from collapsing during construction and maintenance or from high service loads adjacent to the BMP. Where such service loads would not exist adjacent to the BMP, an engineered alternative may be used if signed by a licensed civil engineer.

Side Slope Requirements

Biofiltration with Partial Infiltration Facilities Requiring Side Slopes
The design should assure that the Biofiltration with Partial Infiltration Facility does not present a tripping hazard. Biofiltration with Partial Infiltration Facilities proposed near pedestrian areas, such as areas parallel to parking spaces or along a walkway, should have a gentle slope to the bottom of the facility. Side slopes inside of a Biofiltration with Partial Infiltration Facility should generally be 4:1 unless steeper is approved by the local jurisdiction. A typical cross section for the Bioretention Facility is shown in Figure 1.

Biofiltration with Partial Infiltration Facilities Not Requiring Side Slopes
Where cars park perpendicular to the Biofiltration with Partial Infiltration Facility, side slopes are not required. A 12-inch maximum drop may be used for vertical walls, and the Biofiltration with Partial Infiltration Facility should be planted with shrubs to prevent pedestrian access. In this case, a curb is not placed around the Biofiltration with Partial Infiltration Facility, but wheel stops shall be used to prevent vehicles from entering the Biofiltration with Partial Infiltration Facility, as shown in Figure 5.

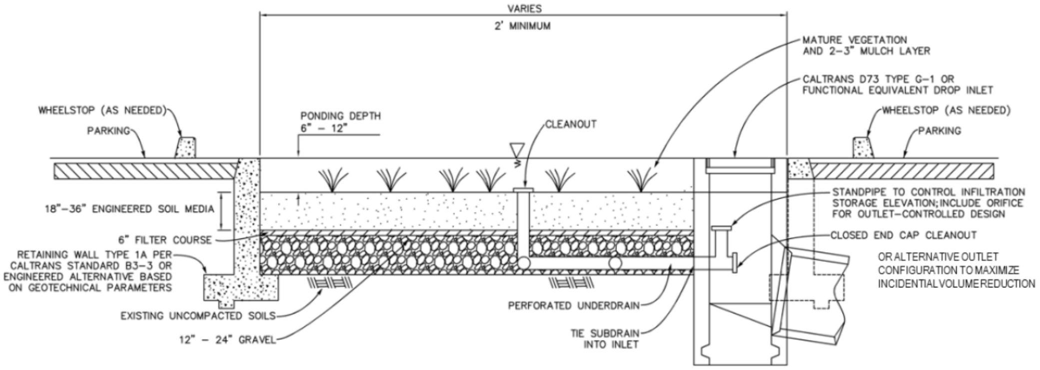


Figure 4: Biofiltration with Partial Infiltration Facility Cross Section without Side Slopes

Overflow

An overflow route is needed in the Biofiltration with Partial Infiltration Facility design to bypass stored runoff from storm events larger than V_{BMP} or in the event of facility or subdrain clogging. Overflow systems must connect to an acceptable discharge point, such as a downstream conveyance system as shown in Figure 1 and Figure 5. The inlet to the overflow structure shall be elevated inside the Biofiltration with Partial Infiltration Facility to be flush with the ponding surface for the design capture volume (V_{BMP}) as shown in Figure 5. This will allow the design capture volume to be fully treated by the Biofiltration with Partial Infiltration Facility, and for larger events to safely be conveyed to downstream systems. The overflow inlet shall **not** be located in the entrance of a Biofiltration with Partial Infiltration Facility, as shown in Figure 6.

Figure 5: Incorrect Placement of an Overflow Inlet

Underdrain Gravel and Pipes

An underdrain gravel layer and perforated pipes shall be provided in accordance with Appendix B – Underdrains. The underdrain shall be elevated at least 3" from the bottom of the gravel storage layer and be designed with an upturned elbow with an elevation equal to the top height of the filter course. This configuration will maximize retention and provides the most flexibility for BMP retrofitting. Inclusion of an upturned elbow is recommended but site-specific adaptations of this design are permitted at the discretion of the local jurisdiction.

Inspection and Maintenance Schedule

Inspection and maintenance of Biofiltration with Partial Retention Facilities is required to provide long term performance of these systems. Table 2 below provides a summary of the typical maintenance activities that may be applicable. Project specific activities and schedules may vary and are required to be included as part of the applicant's O&M Plan, At a minimum the Biofiltration with Partial Infiltration Facility area shall be inspected for erosion, dead vegetation, soggy soils, or standing water. The use of fertilizers and pesticides on the plants inside the Biofiltration with Partial Infiltration Facility should be minimized.

Table 2: Maintenance Summary

Activity
• Maintain vegetation as needed. Use of fertilizers, pesticides and herbicides should be strenuously avoided to ensure they do not contribute to water pollution. If appropriate native plant selections and other IPM methods are used, such products should not be needed. If such projects are used, ○ Products shall be applied in accordance with their labeling, especially in relation to application to water, and in areas subjected to flooding. ○ Fertilizers should not be applied within 15 days before, after, or during the rainy season. • Remove debris and litter from the entire basin to minimize clogging and improve aesthetics. • Check for obvious problems and repair as needed. Address odor, insects, and overgrowth issues associated with stagnant or standing water in the basin bottom. There should be no long-term ponding water. • Check for erosion and sediment laden areas in the basin. Repair as needed. Clean forebay if needed. • Revegetate side slopes where needed. • Inspect areas for ponding • Inspect for erosion and clogging, repair as needed. • Inspection of hydraulic and structural facilities. Examine the inlet for blockage, the embankment and spillway integrity, as well as damage to any structural element. • Check for erosion, slumping and overgrowth. Repair as needed. • Check basin depth for sediment build up and reduced total capacity. Scrape bottom as needed and remove sediment. Restore to original cross-section and infiltration rate. Replant basin vegetation. • Verify the basin bottom is allowing acceptable infiltration. Scarify the surface using a rake, etc., to restore infiltration, working to avoid damage to plants if possible. • No water should be present 72 hours after an event. No long term standing water should be present at all. No algae formation should be visible. Correct problem as needed.

Biofiltration with Partial Infiltration Facility Sizing and Design Procedure

Biofiltration with Partial Infiltration Facilities provide treatment through two mechanisms, bioretention and biofiltration. The combined sizing procedure is presented below:

1) Enter the area tributary, A_T, to the Biofiltration with Partial Infiltration Facility.

2) Enter the required Design Capture Volume, V_{BMP} determined from Section 2.1 of this Handbook.

3) Enter the estimated footprint for the BMP (use available space or default of 3% of contributing impervious surface area). **This is the effective footprint of the BMP.** It is measured at the mid ponding depth of the BMP. For example, if the BMP has a ponding depth of 12 inches, then the effective footprint is the wetted surface area when the BMP is holding 6 inches of ponded water. The engineered soil media and stone reservoir should have at least this footprint below the BMP. For systems with vertical walls, the effective area is the same as the total area.

4) Estimate the portion of the V_{BMP} retained by the BMP.

$$V_{Retained} = 18\,inches \times \left(0.4\frac{in}{in}porosity\right) \times Area_{BMP} \times \frac{1\,ft}{12\,inches}$$

If deeper depth of gravel storage is used, then revise this calculation accordingly.

5) Estimate the portion of V_{BMP} not reliably retained by the BMP

$$V_{Not\ Reliably\ Retained} = V_{BMP} - V_{Retained}$$

6) Enter the depth of surface ponding layer, d_P. The minimum depth of surface ponding layer can be 6" so that the runoff is uniformly spread throughout the basin. The maximum depth can be 12". Higher depths may be allowed for facilities designed per the criteria in Fact Sheet 3.7.

7) Enter the depth of the engineered soil media, d_S. The recommended minimum depth is 24". A depth of 36" is preferred to provide an enhanced root zone. Engineered soil media deeper than 36" will only get credit for the pore space in the first 36".

8) Enter the design media filtration rate of the media (I_{design}) of 2.5 in/hr to be used for sizing. Actual installed filtration rate may be higher.

9) Enter the allowable routing period ($T_{routing}$) of 5 hours. Routing period is estimated based on 15th percentile storm duration for storms similar to 85th percentile rainfall depth at the Temecula gage.

10) Calculate the effective biofiltration depth, d_{E_bio}, within the Biofiltration with Partial Infiltration Facility. The effective depth of biofiltration is calculated as:

$$d_{E\_bio} (ft) = (d_P + (0.3 \text{ x } d_S) + (I_{design} \text{ x } T_{routing})) (ft)$$

Where:

I_{design} = the media filtration rate (or effective filtration rate if an outlet control is included)

The retention storage has already been accounted, so the effective biofiltration storage should only include the storage above the discharge elevation of the underdrain. The maximum allowable pore space of the soil media is 30%. This calculation accounts for water biofiltered filtered during the event.

11) Calculate the effective *static* biofiltration depth, $d_{E\_bio\_static}$, within the Biofiltration with Partial Infiltration Facility. The effective depth of biofiltration storage is calculated as:

$$d_{E\_bio\_static} (ft) = (d_P + (0.3 \text{ x } d_S) (ft)$$

This is similar to the effective biofiltered depth, but does not include the depth infiltrated during the storm event.

12) Calculate the amount of $V_{biofiltered}$ and $V_{biofiltered\_static}$

$$V_{biofiltered} = d_{E\_bio \text{ (with routing)}} \text{ x } A_{effective}$$

$$V_{biofiltered\_static} = d_{E\_bio\_static} \text{ x } A_{effective}$$

13) Compare the results of above to the required biofiltration volume. There are two options for demonstrating conformance:

a) $V_{biofiltered \text{ (with routing)}} > 150\%$ of $V_{not \text{ } reliably \text{ } retained}$

OR

b) $V_{biofiltered\_static} > 0.75 \text{ x } V_{not \text{ } reliably \text{ } retained}$

14) If neither of these criteria are met, then return to Step 3, increase retention depth, increase footprint, or both, and rerun calculations. This calculation is inherently iterative.

15) Verify that side slopes are no steeper than 4:1 in the standard design, and are not required in the modified design. Demonstrate that the assumed effective area is provided at the mid ponding contour of the BMP.

16) Provide the diameter, minimum 6 inches, of the perforated underdrain used in the Biofiltration with Partial Infiltration Facility. See Appendix B for specific information regarding perforated pipes.

17) Provide the slope within the Biofiltration with Partial Infiltration Facility, if used. The maximum slope is 3 percent for a standard design.

18) Provide the check dam spacing, the Biofiltration with Partial Infiltration Facility is sloped.

19) Describe the vegetation used within the Biofiltration with Partial Infiltration Facility.

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Urbonas, Ben R. Stormwater Sand Filter Sizing and Design: A Unit Operations Approach. Denver: Urban Drainage and Flood Control District, 2002.

Biofiltration with Partial Infiltration Facility - Design Procedure	BMP ID	Legend:	Required Entries	🟦
			Calculated Cells	▨

Company Name:

Designed by:

Date:

County/City Case No.:

Design Volume

Enter the area tributary to this feature $A_T=$ acres

Enter V_{BMP} determined from Section 2.1 of this Handbook $V_{BMP}=$ ft^3

Enter initial estimate of footprint of BMP, $Area_{BMP}$ (Guidance: A reasonable starting point is 3% of the tributary impervious area) $Area_{BMP}=$ ft^2

Note: This area shall be measured at the mid-ponding depth of the BMP. For systems with side-slopes, this should be the contour that is midway between the floor of the basin and the maximum water quality ponding elevation of the basin. The underlying gravel layer (infiltration storage layer) should extend to this contour. For systems with vertical walls, the effective area is the full footprint.

Portion of DCV Reliably Retained

Depth of Gravel Infiltration Storage Layer (18" minimum; 30" maximum) dg = inches

Portion of V_{BMP} Reliably Retained via Infiltration Storage in Gravel Layer

$V_{retained} = d_g\ (in) \times 0.4 \times Area_{BMP}\ (ft^2) \times 1/12$ $V_{Retained} =$ 0.0 ft^3

Portion of V_{BMP} not Reliably Retained

$V_{Not\ Reliably\ Retained} = V_{BMP} - V_{Retained}$ $V_{Not\ Reliably\ Retained} =$ 0.0 ft^3

Biofiltration with Partial Retention Facility Surface Area

Depth of Surface Ponding Layer (6" minimum, 12" maximum) $d_P =$ inches

Depth of Engineered Soil Media (24" to 36"; 18" if vertically constrained) $d_S =$ inches

Design Media Filtration Rate (2.5 in/hr) $I_{design} =$ in/hr

Allowable Routing Period, $T_{routing}$ (5 hrs) $T_{routing} =$ hr

Effective Biofiltration Depth, d_{E_bio}

$d_{E\_bio}\ (ft) = (d_P + (0.3 \times d_S) + (I_{design} * T_{routing}))\ (ft)$ $d_{E\_bio} =$ 0.0 ft

Effective Static Depth, $d_{E\_bio\_static}$

$d_{E\_bio\_static} = (d_P + (0.3 * d_S)\ )\ (ft)$ $d_{E\_bio\_static} =$ 0.0 ft

$V_{biofiltered} = d_{E\_bio} * Area_{BMP}$ $V_{biofiltered} =$ 0.0 ft^3

$V_{biofiltered\_static} = d_{E\_bio\_static} * Area_{BMP}$ $V_{biofiltered\_static} =$ 0.0 ft^3

Riverside County-SMR LID BMP Design Handbook
February 2018

Sizing Option 1 Result

Criteria 1: $V_{\text{biofiltered (with routing)}} > 150\%$ of $V_{\text{not reliably retained}}$ Results: PASS

Sizing Option 2 Result

Criteria 2: $V_{\text{biofiltered\_static}} > 0.75 \times V_{\text{Not Reliably Retained}}$ Results: PASS

Note

If neither of these criteria are met, then increase retention depth, increase footprint, or both, and rerun calculations. This calculation is inherently iterative.

Biofiltration with Partial Retention Facility Properties

Side Slopes in Partial Retention with Biofiltration Facility z = :1

Diameter of Underdrain inches

Longitudinal Slope of Site (3% maximum) %

Check Dam Spacing feet

Describe Vegetation:

Notes:

3.6 Biofiltration Facility (no infiltration/limited infiltration)

Type of BMP	LID – Biofiltration
Priority Level	Priority 2 – Biofiltration without infiltration
Treatment Mechanisms	Evapotranspiration, Evaporation, Biofiltration
Infiltration Rate Range	Less than 0.1 in/hr (factored) or other feasibility criteria limits any amount of infiltration
Maximum Drainage Area	This BMP is intended to be integrated into a project's landscaped area in a distributed manner. Typically, contributing drainage areas to Bioretention Facilities range from less than 1 acre to a maximum of around 5 acres. For facilities treating larger drainage basins see Fact Sheet 3.7 for additional guidance on design of larger scale facilities.

Description

Biofiltration Facilities are shallow, vegetated basins that filter water through vegetation and engineered soil media prior to discharge via underdrain or overflow to the downstream conveyance system. Healthy plant and biological activity in the root zone maintain and renew the macro-pore space in the soil media and maximize plant uptake of pollutants and runoff. This can extend the time until the BMP clogs and allows more of the soil column to function as both a sponge (retaining water) and an effective biofilter.

Biofiltration Facilities are similar to Biofiltration with Partial Infiltration Facilities except Biofiltration Facilities are generally lined and include a shallower gravel underdrain layer. **This fact sheet is condensed to include only the design aspects and criteria that are different when designing biofiltration compared to biofiltration with partial infiltration**. The user should refer to the Biofiltration with Partial Infiltration Fact Sheet (3.5) and apply the criteria in that fact sheets with the exception of the differences below.

Differences from Biofiltration with Partial Infiltration

Infiltration constraints do not apply. There are no setbacks or considerations related to infiltration feasibility. Infiltration does not occur in appreciable amounts in these facilities.

Underdrain placement and gravel depth is similar to biofiltration with partial infiltration, but for different purposes. These systems should still include a gravel layer of 12 to 18 inches below the underdrain discharge elevation wherever the system discharges to a nutrient-impaired water body. (This applies to all projects in Santa Margarita Watershed). This sump serves to promote nitrogen removal. This can be achieved with an upturned elbow on the outlet. Alternative outlet configurations are acceptable at the discretion of the local jurisdiction.

Planter box configuration is allowed. Biofiltration Facilities that do not include infiltration can also be placed above ground as planter boxes. Planter boxes must have a minimum width of 2 feet, a maximum surcharge depth of 12 inches. No side slopes are necessary. Planter boxes must be constructed so as to ensure that the top surface of the engineered soil media will remain level. This option may be constructed of concrete, brick, stone or other stable materials that will not warp or bend. Chemically treated wood or galvanized steel, which has the ability to contaminate stormwater, should not be used. Planter boxes must be lined with an impermeable liner on all sides, including the bottom. Other general criteria for design are the same as biofiltration with partial infiltration.

Figure 1: Planter Box

Use of proprietary devices as biofiltration BMPs may be allowed. Approved proprietary biofiltration devices may be classified as Biofiltration facilities . Proprietary biofiltration facilities are small footprint, manufactured devices that have been designed to provide biofiltration treatment through the use of high filtration rate media. Proprietary biofiltration BMPs can be considered equivalent to standard biofiltration facilities for the “no infiltration” feasibility condition. See Section 2.3.7 of the 2018 WQMP for approval requirements. Separate sizing methods, maintenance requirements, and design criteria may apply to proprietary biofiltration BMPs.

Sizing calculations are similar, but do not include the infiltration compartment. Because there is no volume retained via infiltration in these facilities, sizing methods differ.

Biofiltration Sizing and Design Procedure

Biofiltration Facilities provide treatment through biofiltration and do not provide appreciable retention (though a minor amount is possible via evapotranspiration). The sizing and design procedure is presented below:

1) Enter the area tributary, A_T, to the Bioretention Facility.

2) Enter the required Design Volume, V_{BMP} (also referred to as DCV) determined from Section 2.1 of this Handbook.

3) Enter the estimated footprint for the BMP (use available space or default of 3% of contributing impervious surface area). **This is the effective footprint of the BMP.** It is measured at the mid ponding depth of the BMP. For example, if the BMP has a ponding depth of 12 inches, then effective footprint is the wetted surface area when the BMP is holding 6 inches of ponded water. For systems with vertical walls, the effective area is the same as the total area.

4) Enter the depth of surface ponding layer, d_P. The minimum depth of surface ponding layer can be 6" so that the runoff is uniformly spread throughout the basin. The maximum depth can be 12".

5) Enter the depth of the engineered soil media, d_S. The recommended minimum depth is 24". A depth of 36" is preferred to provide an enhanced root zone. Engineered soil media deeper than 36" will only get credit for the pore space in the first 36".

6) Enter the design media filtration rate of the media (I_{design}) of 2.5 in/hr to be used for sizing. Actual installed filtration rate may be higher.

7) Enter the allowable routing period ($T_{routing}$) of 5 hours. Routing period is estimated based on the 15th percentile storm duration for storms similar to 85th percentile rainfall depth at the Temecula gage.

8) Calculate the effective biofiltration depth, d_{E_bio}. The effective depth of biofiltration is calculated as:

$$d_{E\_bio}\,(ft) = (d_P + (0.3 \times d_S) + (I_{design} \times T_{routing}))\ (ft)$$

The internal gravel storage is permanently saturated in this design and should not be considered in this calculation. The effective biofiltration storage should only include the storage above the discharge elevation of the underdrain. The maximum allowable pore space of the soil media is 30%. This calculation accounts for water biofiltered during the event.

9) Calculate the effective *static* biofiltration depth, $d_{E\_bio\_static}$, within the Biofiltration with Facility. The effective depth of biofiltration storage is calculated as:

$$d_{E\_bio\_static}\,(ft) = (d_P + (0.3 \times d_S)\ (ft)$$

This is similar to the effective biofiltration depth above, but does not include the depth infiltrated during the storm event.

10) Calculate the amount of $V_{biofiltered}$ and $V_{biofiltered\_static}$

$$V_{biofiltered} = d_{E\_bio\ (with\ routing)} \times A_{effective}$$

$$V_{biofiltered\_static} = d_{E\_bio\_static} \times A_{effective}$$

11) Compare the results of above to the required biofiltration volume. There are two options for demonstrating conformance:

a) $V_{biofiltered\ (with\ routing)} > 150\%$ of V_{BMP}

OR

b) $V_{biofiltered\_static} > 0.75 \times V_{BMP}$

Both calculations assume that no portion of the V_{BMP} is retained. This is slightly conservative as it does not account for soil soaking and drying. But soil pores are credited as biofiltration volume. This simplification has negligible effect.

12) If neither of these criteria are met, then return to Step 3, increase the footprint and rerun calculations. This calculation is inherently iterative.

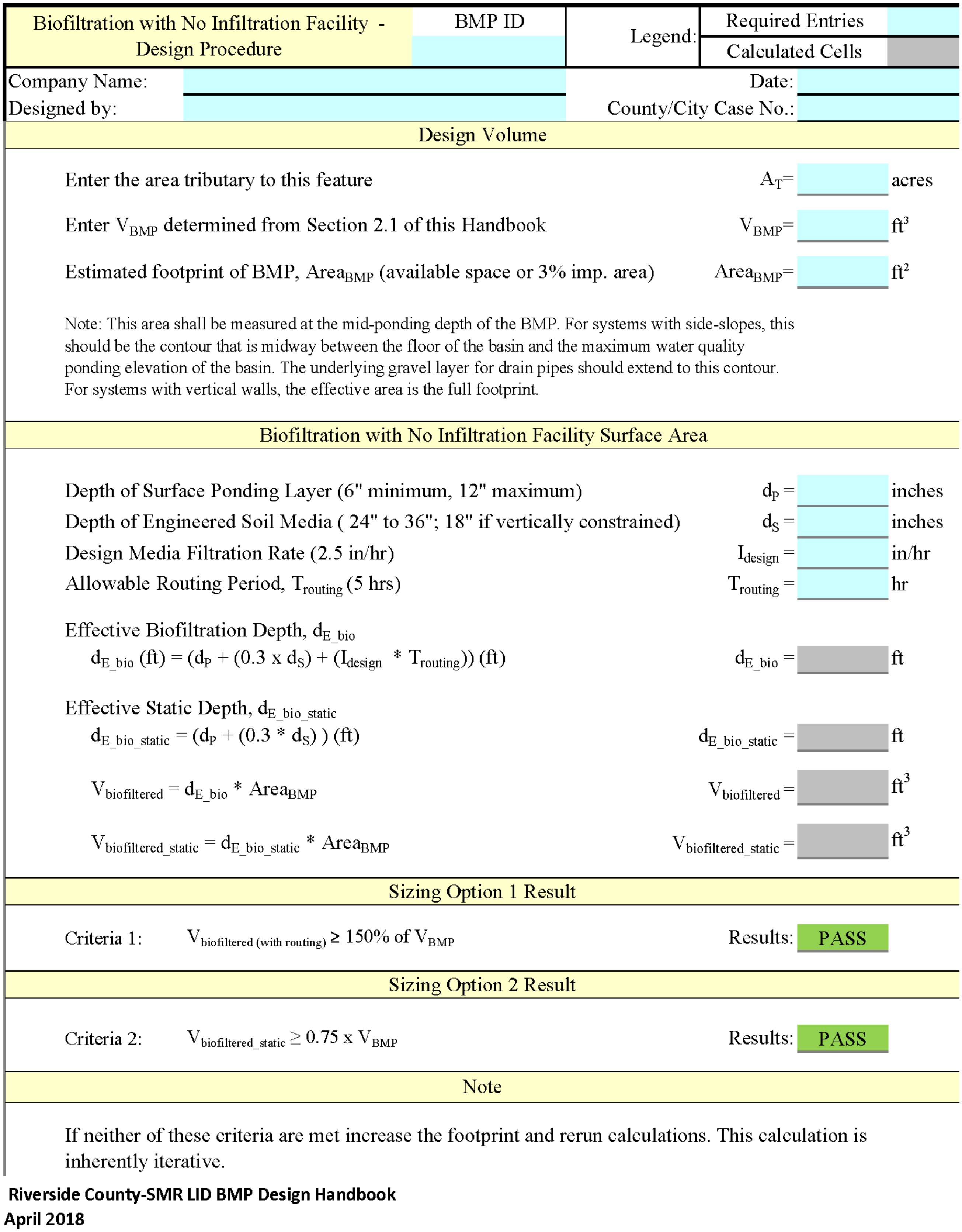
13) Verify that side slopes are no steeper than 4:1 in the standard design, and are not required in the modified design. Demonstrate that the assumed effective area is provided at the mid ponding contour of the BMP.

14) Provide the diameter, minimum 6 inches, of the perforated underdrain used in the Biofiltration Facility. See Appendix B for specific information regarding perforated pipes.

15) Provide the slope within the Biofiltration with Partial Infiltration Facility, if used. The maximum slope is 3 percent for a standard design.

16) Provide the check dam spacing, the Biofiltration with Partial Infiltration Facility is sloped.

17) Describe the vegetation used within the Biofiltration Facility.



Biofiltration with No Infiltration Facility - Design Procedure	BMP ID	Legend:	Required Entries	🟦
			Calculated Cells	⬜

Company Name: Date:
Designed by: County/City Case No.:

Design Volume

Enter the area tributary to this feature	A_T=		acres
Enter V_{BMP} determined from Section 2.1 of this Handbook	V_{BMP}=		ft³
Estimated footprint of BMP, $Area_{BMP}$ (available space or 3% imp. area)	$Area_{BMP}$=		ft²

Note: This area shall be measured at the mid-ponding depth of the BMP. For systems with side-slopes, this should be the contour that is midway between the floor of the basin and the maximum water quality ponding elevation of the basin. The underlying gravel layer for drain pipes should extend to this contour. For systems with vertical walls, the effective area is the full footprint.

Biofiltration with No Infiltration Facility Surface Area

Depth of Surface Ponding Layer (6" minimum, 12" maximum)	d_P =		inches
Depth of Engineered Soil Media (24" to 36"; 18" if vertically constrained)	d_S =		inches
Design Media Filtration Rate (2.5 in/hr)	I_{design} =		in/hr
Allowable Routing Period, $T_{routing}$ (5 hrs)	$T_{routing}$ =		hr

Effective Biofiltration Depth, d_{E_bio}

d_{E_bio} (ft) = (d_P + (0.3 x d_S) + (I_{design} * $T_{routing}$)) (ft) d_{E_bio} = ⬜ ft

Effective Static Depth, $d_{E\_bio\_static}$

$d_{E\_bio\_static}$ = (d_P + (0.3 * d_S)) (ft) $d_{E\_bio\_static}$ = ⬜ ft

$V_{biofiltered}$ = d_{E_bio} * $Area_{BMP}$ $V_{biofiltered}$ = ⬜ ft³

$V_{biofiltered\_static}$ = $d_{E\_bio\_static}$ * $Area_{BMP}$ $V_{biofiltered\_static}$ = ⬜ ft³

Sizing Option 1 Result

Criteria 1: $V_{biofiltered\ (with\ routing)} \geq$ 150% of V_{BMP} Results: PASS

Sizing Option 2 Result

Criteria 2: $V_{biofiltered\_static} \geq 0.75 \times V_{BMP}$ Results: PASS

Note

If neither of these criteria are met increase the footprint and rerun calculations. This calculation is inherently iterative.

Riverside County-SMR LID BMP Design Handbook
April 2018

Biofiltration with No Retention Facility Properties

Side Slopes in Partial Retention with Biofiltration Facility z = ____ :1

Diameter of Underdrain ____ inches

Longitudinal Slope of Site (3% maximum) ____ %

Check Dam Spacing ____ feet

Describe Vegetation: ____

Notes: ____

Riverside County-SMR LID BMP Design Handbook
April 2018

3.7 Guidance for Large Bioretention/Biofiltration BMP Facilities

No BMP worksheet is provided. For use, include designs on the WQMP site map with a cross section. Adequate details on the grading plans are required to demonstrate the project design incorporates all of the applicable design criteria.

Applicability	Large sites, multi-parcel sites, BMPs treating greater than 5 acres This fact sheet is intended to be used in combination with Fact Sheet 3.4, 3.5, or 3.6 to provide guidance for how to scale up the design of small scale features to larger scale basins
LID BMPs	Bioretention, Biofiltration with Partial Infiltration, and Biofiltration with No Infiltration

Limits on Use and Applicability

This fact sheet provides guidance for the design, installation, and maintenance of regional scale bioretention/biofiltration Best Management Practices (BMPs) for large multi-parcel projects. The requirements included in this fact sheet are in addition to, those specified in the LID BMP Handbook Fact Sheets for Bioretention (3.4), Biofiltration with Partial Infiltration (3.5), and Biofiltration with No Infiltration (3.6). The user will still need to refer to those fact sheets. This fact sheet then provides additional or overriding criteria for facilities that are designed at a larger scale. These additional criteria are necessary to address unique design challenges associated with larger facilities.

Use of regional scale facilities is at the discretion of the Copermittee. Before continuing with design of regional scale facilities, PDPs shall consult with the Copermittee with jurisdiction over the project site.

Categories of Regional Bioretention/Biofiltration Facilities

The same categories of regional bioretention/biofiltration facilities apply at a regional scale and need to be selected based on the feasibility criteria at the location.

- Bioretention (full infiltration) – Fact Sheet 3.4
- Biofiltration with partial infiltration – Fact Sheet 3.5
- Biofiltration (no infiltration/limited infiltration) – Fact Sheet 3.6

Using a regional facility does not preclude the requirement to evaluate infiltration feasibility criteria. Large facilities require a thorough and detailed assessment of the sites underlying infiltration rates and geotechnical environment. Refer to the Santa Margarita Watershed WQMP for complete feasibility analysis requirements.

Basic Design Requirements and Provisions

Basin Guidelines

All regional facilities shall be designed in accordance with the “Basin Guidelines” included in Appendix C of the LID BMP Handbook. Section 1 of the “Basin Guidelines” presents guidelines and standards for the design and maintenance of water quality basins used within Riverside County including provisions for:

- General Criteria
- Geotechnical Reports
- Basin Grading Parameters
- Setbacks
- Outlet Structures and Spillways
- Maintenance Access
- Landscaping
- Fencing, and
- Additional Requirements

Site Geotechnical Investigation

A site-specific geotechnical investigation is required to determine subsurface conditions, infiltration rates, the seasonal high ground water elevation (SHGWE), and impacts to site environs as listed in the Feasibility Criteria. The investigation must be conducted by or under direct supervision of a State of California-licensed engineering geologist, geotechnical engineer, or civil engineer with experience in geotechnical engineering, and in compliance with the *SMR WQMP*. The Geotechnical Report shall meet the minimum requirements of the "Basin Guidelines" and provide the following additional information:

- Infiltration rates (in accordance with the "Infiltration Testing Guidelines" included in Appendix A)
- Seasonal high groundwater levels
- Potential for groundwater mounding below the facility or down gradient
- Geotechnical hazards
- Other impacts to site environs, such as water balance impacts on biological resources
- Utilities

Summary of BMP Design Parameters

The BMP design parameters contained in the respective fact sheets for Bioretention, Biofiltration with Partial Infiltration, and Biofiltration with No Infiltration apply to the design of large scale facilities of the same type; however, additional criteria also apply. Table 1 below provides a summary of the standard and augmented design components required for large scale facilities. Where augmented components are specified, additional design criteria are provided in this fact sheet to augment the criteria in the standard fact sheets.

Table 1. Design Requirements for BMP Components

Component	Design Requirements
Pretreatment	Augmented
Cross Section Geometry	Augmented
Overflow	Augmented
Engineered Soil Media	Standard
Subsurface Storage Layer	Standard
Underdrain	Augmented
Energy Dissipation	Augmented
Internal Flow Distribution	Augmented
Media Properties and Outlet Control	Augmented
Landscaping	Standard
Vector Control	Standard
Maintenance Access	Augmented
Construction Considerations	Augmented
Sizing	Standard

Augmented Design Requirements for Regional Scale Facilities

This section contains the augmented design parameters and requirements that are unique to Large Bioretention/Biofiltration Facilities. These provisions help to maintain BMP function and performance in larger facilities and provide additional storage and routing options that are not applicable to smaller scale facilities.

Cross Section Geometry

The following design parameters for regional scale facilities shall be used in place of the corresponding parameters for standard facilities:

- The ponding depth above the engineered soil media shall not exceed 3 feet or the maximum depth that can be drained in 72 hours. A shorter drawdown time may be specified if necessary to support the selected vegetation.

- The engineered soil media shall be a minimum of 2 feet deep.

- Side slopes shall conform to the Basin Guidelines in Appendix C.

Pretreatment

Pretreatment shall be provided in order to reduce the sediment load entering the facility and to maintain the infiltration/filtration rate of the basin. This is more critical for regional facilities as they tend to be deeper and therefore have a larger sediment load per unit area of media.

Where feasible, the following pre-treatment approach is recommended:

- Stabilization or bypass of all exposed soil areas in the watershed.

- Use of a manufactured pre-treatment system with a GULD certification for "pre-treatment" or "basic treatment" per Washington State TAPE Program. Currently approved products: are here: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/technologies.html. Use Internet Explorer for this web page.

The minimum pretreatment mechanism shall be a sedimentation basin or forebay with a volume equivalent to 20 percent of the BMP volume and shall be separated by a berm with a height of at least half of the total ponding depth of the facility.

Overflow

Regional facilities shall conform to the requirements included in the "Basin Guidelines" (Appendix C). These guidelines provide guidance for the design of outlet structures and spillways.

Underdrain

Hydraulic calculations shall be used to determine necessary size of underdrains. It should not be assumed that the 6-inch diameter default for smaller systems will be adequate for larger systems. Subdrains shall be sloped with positive drainage of at least 0.5%.

Rigid non-perforated observation pipes with a diameter equal to the underdrain diameter shall be connected to the underdrain every 50 feet to provide a clean-out port as well as an observation well to monitor dewatering rates.

- The wells/cleanouts shall be connected to the underdrain with the appropriate manufactured connections.
- The wells/cleanouts shall extend 6 inches above the top elevation of the bioretention facility mulch, and shall be capped with a lockable screw cap. Cleanouts may be integrated with vents, in which case the vent should extend above the facility high water line.
- The ends of underdrain pipes not terminating in an observation well/cleanout shall be capped.

Energy Dissipation

Energy dissipation must be provided to prevent erosion of the engineered soil media layer. Internal erosion is a greater risk for larger BMPs due to the higher flow rates and velocities routed to them. Energy dissipation is required meeting the following provisions:

1. All significant inlets shall enter the sediment forebay, if a sediment forebay is provided as the required pretreatment device. Significant inlets include any piped, channeled or conveyed inlets. If a forebay is not provided, a stilling well is recommended.
2. Energy dissipation shall be provided at each inlet to the facility (including curb-cuts) and shall be engineered to control the velocity of inflows to less than 2 feet per second to prevent scour of the media bed.

3. Woody plants (trees, shrubs, etc.) shall not be placed directly in the entrance flow path, but may be used in other portions of the regional facility.

Side Slope Erosion Control

Side slopes of regional facilities can contribute large sediment loads if not full stabilized prior to commissioning of the system. The design and construction phasing shall demonstrate how side slopes will be stabilized to minimize erosion. Example design approaches include:

- Revegetation with dense grass, including irrigation
- Flexible soil armoring grid products combined with revegetation

Flow Distribution System

An internal flow distribution system should be considered to convey pre-treated inflows more evenly across the media bed. This helps avoid scour caused by concentrated flow of water over the media surface near the inlet. It is also desirable to avoid short circuiting[1]. Example design approaches for flow distribution include:

- Design a distribution channel or perforated pipe around a portion of the perimeter (1/2 to 2/3 of the perimeter of the system) and internal to the facility, where needed, to distribute flows within the facility.
- A distribution channel could consist of shallow swale (3 to 6 inches deep) in the media bed, armored with turf reinforcement matting, other geotextile, or cobbles, to withstand higher velocities.
- The distribution system should be designed to drain completely between storm events.

Media Bed Hydraulics and Outlet Control

The following design approach for media outlet control should be considered to help improve filtration processes and media longevity for systems that are designed as biofiltration (with or without partial infiltration)

1. An outlet-controlled underdrain system, consisting of an orifice or other flow control device that controls the rate at which water discharges from the system underdrain.[2]

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[1] Short-circuiting of flows refers to a disproportionately high fraction of the total filtration occurring in the immediate vicinity of the inlet. These conditions are undesirable as this can overwhelm biological functions and treatment processes in the areas receiving the majority of the flow and result in lower treatment performance on average.

[2] When an outlet-controlled underdrain is used, the rate of flow through the media is controlled by the rate that water can discharge from the underdrain orifice rather than the filtration rate of the media. The filtration rate of the media may vary spatially and will change with time. The use of an outlet controlled underdrain promotes more uniform infiltration across the media bed and longer average contact time with the biofiltration media. It also allows

2. When an outlet control is used, the initial media permeability may be higher (20 to 80 in/hr).

3. The outlet control is then designed such that the average infiltration rate through the media (i.e., the rate at which water passes through the media; as controlled by the outlet, not by the saturated hydraulic conductivity of the media) is approximately 2.5 to 5 in/hr.

4. The facility must drain freely to an acceptable discharge point.

5. If the design configuration has potential for trapped air in the underdrain system to interfere with infiltration through the media bed (i.e., an "airlock"), it may be necessary to vent at an elevation above the high water line.

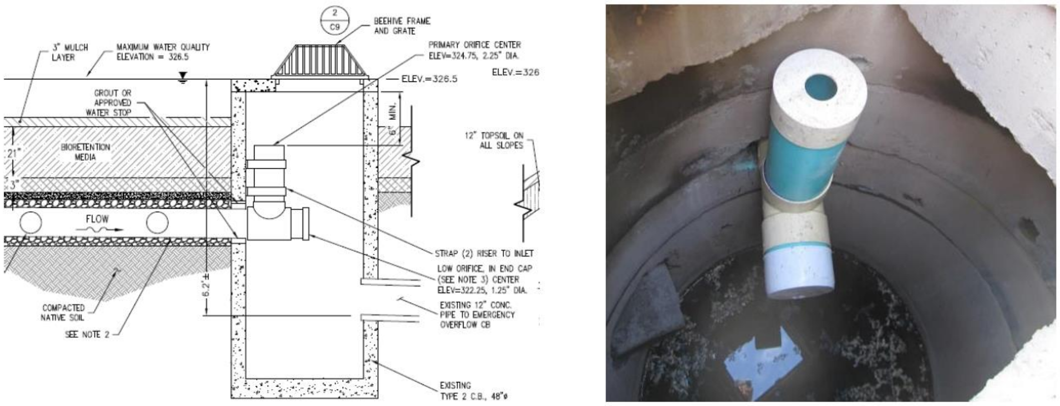

Figure 1. Example Outlet Control Structure

Design for LID and Hydromodification Control

Large bioretention/biofiltration basins can be designed for both LID and hydromodification control. Figure 2 shows schematics of how LID and hydromodification designs can be integrated.

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the biofiltration media to be designed with a higher initial saturated hydraulic conductivity, such that a greater degree of clogging can occur before maintenance of the media bed is required.

GUIDANCE FOR LARGE BIORETENTION/BIOFILTRATION BMP FACILITIES

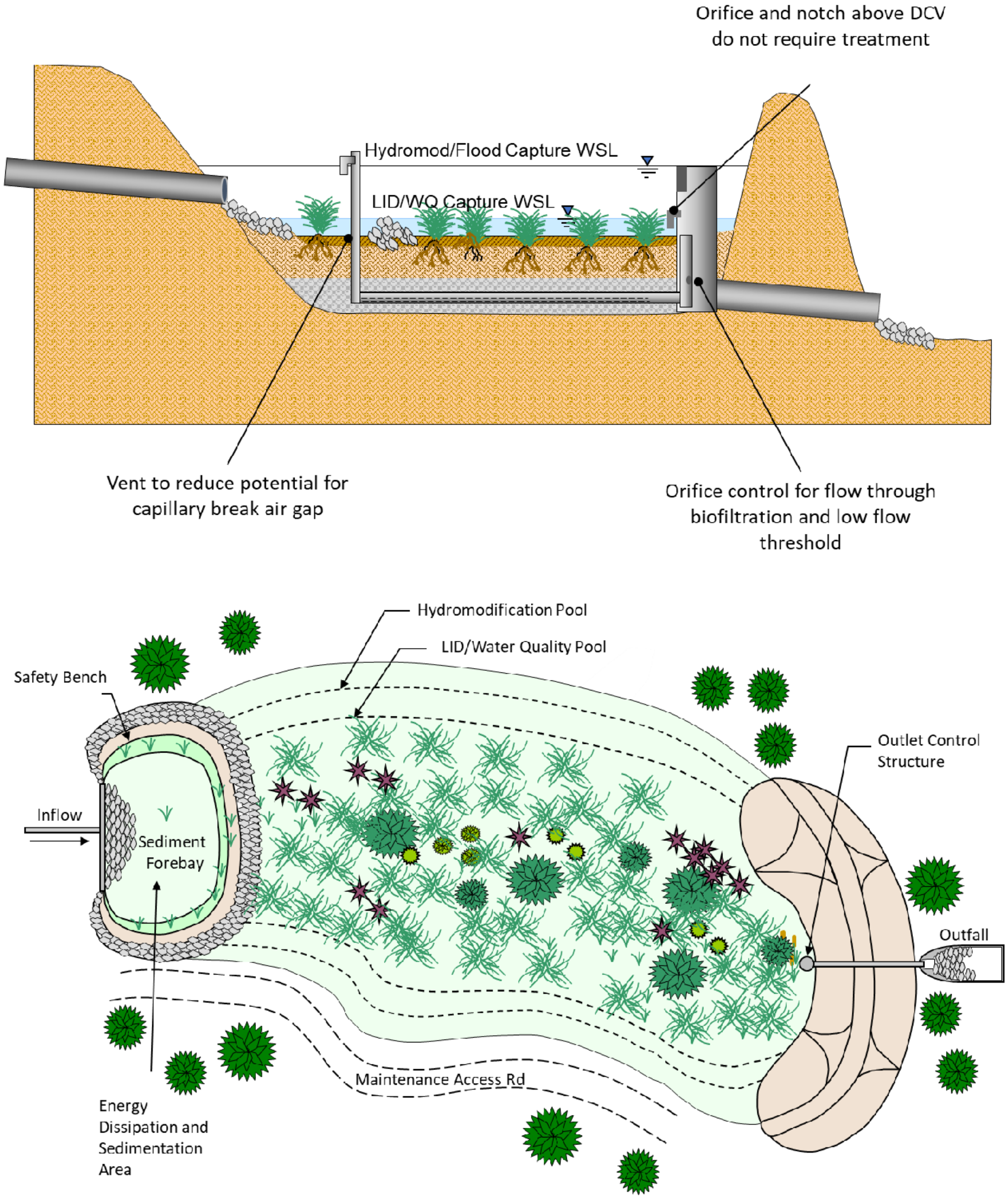
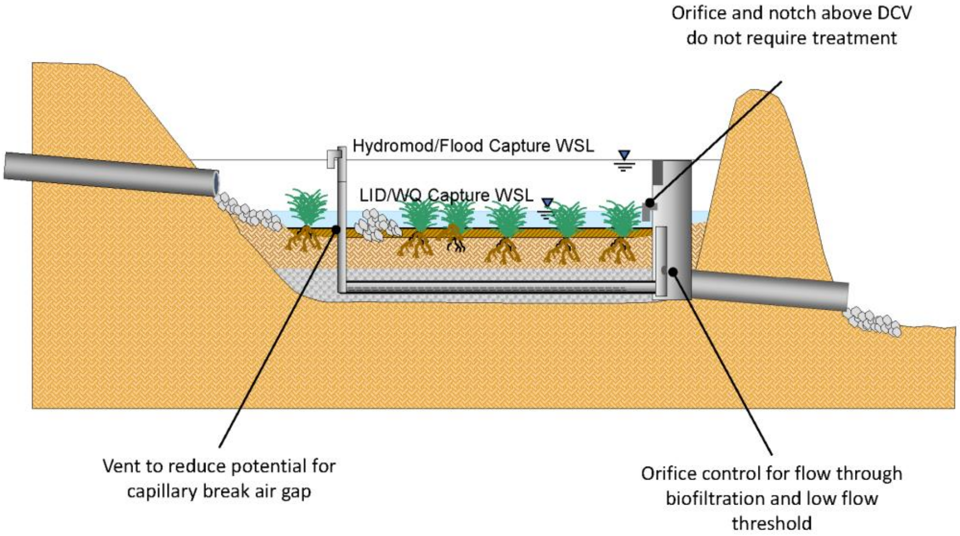
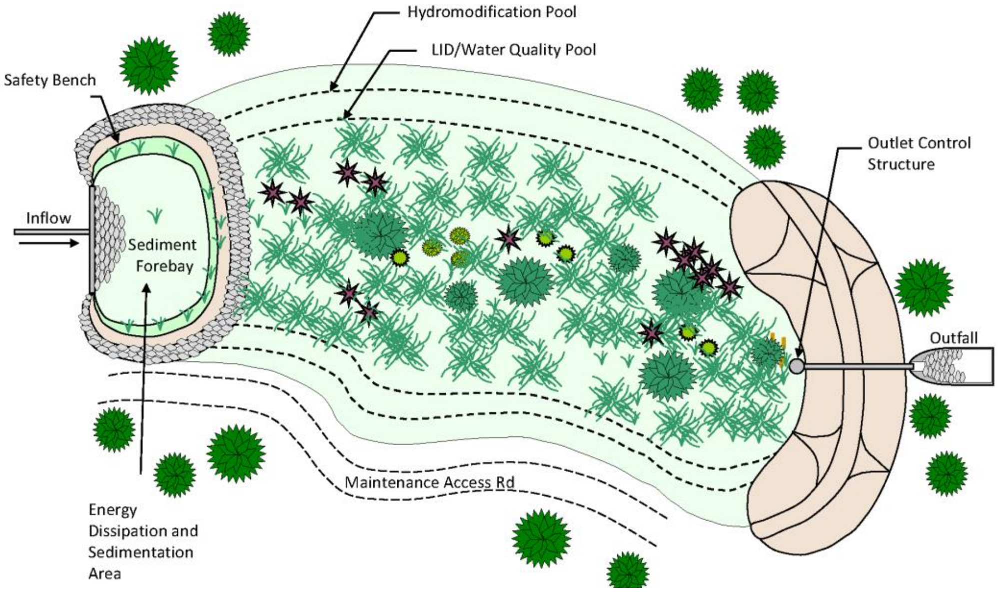


Figure 2. Example Schematic of Combination LID/Hydromodification Basin

Maintenance Access

Access for maintenance activities shall be provided as outlined in the “Basin Guidelines.”


Orifice and notch above DCV do not require treatment
Hydromod/Flood Capture WSL
LID/WQ Capture WSL
Vent to reduce potential for capillary break air gap
Orifice control for flow through biofiltration and low flow threshold


Hydromodification Pool
LID/Water Quality Pool
Safety Bench
Outlet Control Structure
Inflow
Sediment Forebay
Outfall
Maintenance Access Rd
Energy Dissipation and Sedimentation Area

2

GUIDANCE FOR LARGE BIORETENTION/BIOFILTRATION BMP FACILITIES

Construction Considerations

The following factors should be considered in construction of regional facilities. These criteria are not intended to be comprehensive or replace the need for complete construction specifications consistent with standard engineering practices and applicable standards.

1. Irrigation should be considered to provide for robust plant establishment and growth and help improve long term permeability of the soil

2. Regional bioretention/biofiltration facilities should not be hydraulically connected to the storm drain system until all contributing drainage areas are stabilized (e.g., with stable vegetative cover or pavement) or are controlled with robust erosion and sediment controls. For phased projects, where interim conditions include sediment producing open space and/or graded pads that will be under construction after the facility is brought online, a high level of sediment control must be provided. It is preferred to bypass any areas that are still under construction or otherwise not stabilized.

3. To preserve and avoid the loss of infiltration capacity, the following construction guidelines should be specified:

    - Provisions address sedimentation, per above.

    - Compaction of the subgrade with heavy equipment should be minimized to the maximum extent possible. If the use of heavy equipment on the base of the facility cannot be avoided, the infiltrative capacity should be restored by tilling or aerating prior to placing the infiltrative bed.

    - If a full infiltration design is proposed, the exposed soils should be inspected by a geotechnical engineer after excavation to confirm that soil conditions are suitable.

4. Batch-level testing of bioretention soil media should be considered. For regional systems including large quantities of soil, batch level testing can help control variability between batches.

5. In-situ testing of bioretention soil media, such as with a single ring infiltrometer, should be considered on a specified interval. This can help confirm that placement methods are not resulting in significant loss of permeability.

6. The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

7. As discussed above, side slopes of the basin should be well stabilized to avoid erosion onto the media bed.

8. An establishment period for vegetation should be specified in the construction plans or landscape contractor agreements.

Sizing Methodologies

In general, the sizing methods described in Fact Sheet 3.4, 3.5, and 3.6 are applicable.

Augmented Maintenance Considerations

Maintenance activities described in Fact Sheet 3.4, 3.5, and 3.6 are generally applicable. When developing the O&M Plan for regional facilities, additional consideration should be given to the scale of the regional facilities. For example:

- Maintenance may require larger or specialized equipment compared to normal bioretention/biofiltration maintenance.
- Access drive isles within the media bed may be needed. These drive isles could be reinforced with geotextiles, such as grid paver filled with gravel or BSM, to maintain permeability while supporting maintenance vehicle access.
- Methods that are allowable for maintenance may need to be specified (e.g., limitations on vehicle traffic on the media bed)
- A rotating maintenance cycle across different parts of the facility may be appropriate. This helps limit the impact to overall treatment processes when vegetation or media needs to be periodically replaced. For example, one third of the system could experience more intensive maintenance each year.

3.8 Bioretention/Biofiltration Soil Media and Drainage Aggregates

No BMP worksheet is provided. For use, include soil specifications on the grading plans. Adequate details on the grading plans are required to demonstrate the project design incorporates all of the applicable design criteria.

Type of BMP	For Use with Bioretention, Biofiltration with Partial Infiltration, and Biofiltration with No Infiltration
Treatment Mechanisms	Biofiltration
Other Names	Engineered Soil Media

Description

Bioretention Soil Media (BSM) is a formulated soil mixture that filters pollutants from stormwater, retains moisture, and supports healthy vegetation. It is used in LID BMPs including Bioretention, Biofiltration with Partial Infiltration, and Biofiltration with No Infiltration. BSM consists of **60-80% sand, up to 20% topsoil, and 20% of an organic amendment**, by volume.

BSM must support healthy plant growth and should provide filtering of runoff. When used in Biofiltration BMPs that discharge filtered runoff to surface waters, BSM should be specially formulated to enhance filtering of runoff, reduce the risk of pollutant leaching from BSM, and limit the potential for clogging.

All areas within the Santa Margarita Region (SMR) of Riverside County drain to the Santa Margarita River and Santa Margarita Estuary, both of which are listed as impaired for nutrients under the approved 2010 303(d) list. Accordingly, **all BSM should be formulated to reduce the potential for nutrient leaching, especially when used in flow-through Biofiltration BMPs.** Where a BMP may discharge to a waterbody that is impaired for other pollutants, BSM should be formulated to reduce leaching of those pollutants as well.

The applicability of BSM testing requirements and other provisions of this Fact Sheet depend on the type of BMP and BMP design guidelines as shown in Table 1.

Table 1. Applicability of BSM Specification and Testing Requirements.

Testing Element	Bioretention (full infiltration)	Biofiltration (Partial and No Infiltration)
General Criteria and Composition	X	X
Basic Testing of Mixed BSM	X	X
Hydraulic Evaluation of Mixed BSM		X
Chemical Suitability of Mixed BSM		X
Sand for BSM	X[1]	X[1]
Topsoil for BSM	X[1]	X[1]
Organic Amendments for BSM	X	X
Mulch for BSM	X	X

[1] – Elements of these specifications may be waived by the local jurisdiction if testing of mixed BSM is acceptable.

BIORETENTION/BIOFILTRATION SOIL MEDIA AND DRAINAGE AGGREGATE

General Criteria and Composition

- **BSM should consist of 60-80% sand, up to 20% topsoil, and 20% of an organic amendment, by volume.** Both mixed BSM and BSM components are subject to specific testing requirements depending on BMP type and design elements (see Table 1). To meet applicable requirements, suggested BSM component fractions and types are presented in Table 2. These are suggestions only; **acceptance of BSM depends on BSM and BSM component testing results.**
- Alternative BSM components and proportions may be used if they meet all applicable testing requirements. Acceptance of any such alternative BSM is subject to approval from the local jurisdiction.
- BSM should support the growth of hardy drought-tolerant native vegetation, which is typically adapted to thrive in limited nutrient environments. Excessive levels of nutrients in BSM can increase the presence of weeds and other undesirable vegetation and can cause export of nutrients from BSM. Accordingly, **all BSM should be evaluated according to the "Basic Whole Mixture Testing Requirements"** section.
- Sand, topsoil, and organic amendment components of BSM, and mulch are subject to requirements contained in sections of this Fact Sheet titled "Sand for BSM", "Topsoil for BSM", "Organic Amendments for BSM", and "Mulch for BSM", respectively. Specifications for sand and top soil can be waived at the discretion of the local jurisdiction if whole mix texting shows acceptable properties.
- To reduce the potential for nutrient leaching from BSM, it should be formulated according to the following guidelines (Also presented in Table 2).
    - For Bioretention BMPs, nutrient-sensitive compost may be used as the organic amendment according to requirements in the "Organic Amendments" section of this Fact Sheet.
    - **For Biofiltration BMPs, mixed BSM must meet requirements in the "Chemical Suitability for Mixed BSM" section of this Fact Sheet.** To meet these requirements, it is suggested that compost not be used as an organic amendment due to its potential to leach nutrients, even when carefully sourced to reduce such leaching. Instead, coconut coir pith, peat moss, or other alternative organic amendments are recommended. For guidance on these and other alternative organic amendments see the "Alternative Organic Amendments" subsection of this Fact Sheet.
- BSM should be formulated to support the long-term design flow rate of a given BMP.
    - For Biofiltration BMPs, BSM plays a critical role in BMP hydraulic performance and should be formulated depending on whether underdrain outlet controls are used. **BSM for Biofiltration BMPs should be evaluated according to the "Hydraulic Evaluation of Mixed BSM" section of this Fact Sheet.** Meeting these requirements may require that the fines content of sand or top soil be limited (see Table 2). Some sources of top soil and sand may not provide adequate permeability.
- BSM should always be **blended before it is delivered to the site** using a mechanical mixing method (e.g. drum mixer) to ensure uniform mixing. Using a loader to mix materials on site is typically not adequate for uniform mixing and is discouraged. If sand or topsoil components are sourced from the Project site, mixing may be conducted using loaders.

- **Testing samples of the mixed BSM that is delivered to the site is highly recommended,** especially for larger BMPs. Prior testing from a material manufacturer may be acceptable in place of project-specific data if it is not more than 6 months old and represents the actual mix proportions and components in the BSM delivered to the site.
- Procurement, handling, and placement of BSM should adhere to guidelines in the "Construction Guidelines" section of this Fact Sheet.

Table 2. Recommended BSM mixture component proportions and types to meet applicable requirements.

Component Type	Bioretention	Biofiltration (Partial and No Infiltration)	
		Without outlet control	With outlet control
Sand Type	Washed	Washed	Washed
Sand Fraction, by volume	60%	60-80%	80%
Topsoil Type	Sandy Loam or Loamy Sand	Sandy Loam or Loamy Sand	NA
Topsoil Fraction, by volume	20%	Up to 20%	0%
Organic Type	Nutrient-sensitive compost	Coconut coir pith, peat, or low nutrient compost	Coconut coir pith, peat, or low nutrient compost
Organic Fraction, by volume	20%	20%	20%

Basic Testing for Mixed BSM

Basic whole mixture testing should be conducted for any BSM used in stormwater BMPs. This should ideally be completed for actual mixed BSM that is used in site BMPs, but may be from a representative sample analysis not more than 6 months old. Sample(s) should be submitted to an agronomic laboratory for analysis of all parameters listed in this section. Laboratory analytical reports must document that mixed BSM conforms to the following requirements:

- pH: 6.0 – 8.5
- Salinity: 0.5 to 3.0 mmho/cm as electrical conductivity.
- Sodium absorption ratio: < 6.0
- Chloride: < 800 ppm
- Cation Exchange Capacity (CEC): > 10 meq/100 g.
- Organic Matter: 2 to 5% on a dry weight basis.
- Carbon:Nitrogen Ratio: 12 to 40; preferably 15 to 40.
- Sieve Fractions: Should adhere to the sieve fractions presented in Table 3 based on particle size analysis by ASTM Method D422 or similar.

Table 3. Sieve analysis requirements for mixed BSM

Textural Class (ASTM D422)	Size Range	Mass Fraction
Gravel	Larger than 2 mm	0 to 25 percent of total sample
Clay	Smaller than 0.005 mm	0 to 5 percent of non-gravel fraction

Hydraulic Testing of Mixed BSM

BSM that is used in Biofiltration BMPs plays a critical role in controlling flow through BMPs. BSM that flows too quickly can result in short contact times and poor hydraulics for pollutant removal. BSM that flows too slowly can limit surface infiltration rates below design assumptions, resulting in bypass during storms smaller than the design storm.

Hydraulic Testing Requirements: Samples of mixed BSM used in Biofiltration BMPs should be submitted for laboratory analysis of hydraulic conductivity. BSM samples used in this analysis should preferably be sourced from the actual BSM batch that will be used in a given BMP but analytical results from a representative sample not more than 6 months old may also be accepted. Analysis of hydraulic conductivity may be conducted according to one of the following methods:

- Permeability of Granular Soils: ASTM D2434, or,
- Analysis of hydraulic conductivity by USDA Handbook 30 method 34b, or similar approved laboratory method.

Hydraulic conductivity must be within the limits presented in Table 4 for BSM acceptance.

Table 4. Hydraulic suitability requirements for BSM.

BMP Hydraulic Regime	**Minimum K_{sat} (in/hr)**	**Maximum K_{sat} (in/hr)**
Biofiltration with Unrestricted Outlet (media control)	8	24
Biofiltration with Restricted Outlet (outlet control)	20	80
Bioretention	NA – Hydraulic Testing Not Required	

Chemical Suitability for Mixed BSM

To reduce the potential for pollutant leaching to surface waters, a sample of BSM used in Biofiltration BMPs should be submitted for laboratory analysis for pollutant leaching potential. The BSM sample should be from the actual batch of BSM that is used in the BMP or from a representative sample not more than 6 months old. This analysis should be performed according to the “Saturated Media Extract” methods (USDA Agricultural Handbook No. 60), which is commonly performed by agronomic laboratories.

Pollutant leaching test results for BSM should comply with limits for nitrate, phosphorus, and copper:

- Nitrate: < 3 mg/L
- Phosphorus: < 1 mg/L
- Copper: < 0.025 mg/L

Testing may be performed after laboratory rinsing of media with up to 15 pore volumes of water. Alternative organic amendments, may be needed to meet these criteria. The above pollutant leaching criteria may be waived at the discretion of the local jurisdiction.

Mulch for BSM

Bioretention and Biofiltration planting areas should generally be covered with 2 to 3 inches of well-aged, double or triple shredded mulch at the time of construction. An additional 1 to 2 inches of mulch should be added annually. Mulch should be non-floating to avoid clogging overflow structures. Inorganic mulches, such as rock, may be used.

Sand for BSM

The requirements in this section may be waived at the discretion of the local jurisdiction if criteria are met for applicable whole mix testing.

Sand should meet requirements for ASTM C33 “fine aggregate concrete sand.” It may be sourced from commercial soil suppliers or from natural soil deposits (such as may be found on site). Sand should conform to the following requirements:

- Be free of any waste, wood, coatings (e.g. clay, stone dust, carbonate, etc.), or any other deleterious materials.
- Conform to the particle size distribution requirements for ATSM C33 “fine aggregate concrete sand” in Table 5 based on sieve size analysis by ASTM Method D422 or similar. This should be documented by laboratory analysis results for the actual sand that was used in the BSM, or a representative sample analysis not more than 6 months old.
- All aggregate passing the #200 sieve should be non-plastic.

Table 5. Sieve size fractions for ASTM C33 “fine aggregate concrete sand”.

Sieve Size (ASTM D422)	Sieve Size (mm)	Percent Passing (by weight)	
		Minimum	Maximum
3/8 inch	9.5	100	100
#4	4.8	95	100
#8	2.4	80	100
#16	1.2	50	85
#30	0.60	25	60
#50	0.42	5	30
#100	0.15	0	10
#200	0.08	0	5

Topsoil for BSM

Topsoil can be an important part of BSM and can improve pollutant filtering, nutrient retention, and water holding. Because of these benefits, it is generally recommended as a component of BSM for Bioretention BMPs. However, topsoil (especially the fine fraction) can limit flow of water through BSM, so it may not be suitable for BSM.

If topsoil is used as a component of BSM it should be a sandy loam or loamy sand that is free of hazardous materials. It may be sourced from regional soil suppliers or from the project site, providing that it meets all requirements in this Section. Decomposed granite and derivatives of decomposed granite are not considered to be topsoil. All topsoil should meet the following requirements as confirmed by laboratory analytical reports from samples used in the mixed BSM, or from a representative sample analysis not more than 6 months old:

- Texture: Sandy loam or loamy sand according to the US Department of Agriculture Textural Classification System.

Sieve Fractions: Should adhere to the sieve fractions presented in Table 6 based on particle size analysis by ASTM Method D422 or similar. *Sieve analysis may be waived at the discretion of the local jurisdiction if permeability criteria are met for applicable whole mix testing.*

Table 6. Sieve analysis requirements for topsoil used in BSM

Textural Class (ASTM D422)	Size Range	Mass Fraction
Gravel	Larger than 2 mm	0 to 25 percent of total sample
Clay	Smaller than 0.005 mm	0 to 15 percent of non-gravel fraction

Organic Amendments for BSM

Organic amendments are a critical component of BSM to help filter pollutants from runoff, retain moisture, and support healthy vegetation. However, organic amendments, especially compost, can be a source of nutrients and other pollutants that can impact receiving waters.

Nutrient leaching from organic amendments is a particular concern for BSM that is used in Biofiltration BMPs which can discharge directly to surface waters. Accordingly, BSM used in Biofiltrations BMPs must conform to requirements contained in the “Chemical Suitability of Mixed BSM” section of this Fact Sheet. Alternative Organic Amendments are recommended to comply with chemical suitability requirements.

Bioretention BMPs discharge treated water to groundwater, so they pose less risk from nutrient export from BSM.

All organic amendments should conform to the requirements in either “Compost for BSM” or “Alternative Organic Amendments for BSM”.

Compost for BSM

Compost should be a well-decomposed, stable, weed-free organic source derived from waste materials including yard debris, wood wastes, crop residues, or other organic materials. It should not be derived from biosolids. Compost should preferably be certified through the US Composting Council (USCC) Seal of Testing Assurance (STA) Program.

Compost should comply with the requirements in the list below. Given the stringent nature of these requirements, it is expected that not all composts will comply with the requirements. All requirements should be confirmed by laboratory analytical reports from samples of the compost used in the mixed BSM, or from a representative sample analysis not more than 6 months old.

- Feedstock: Compost feedstock should be specified. Compost should not be derived, in whole or in part, from biosolids.
- Source: Compost should be sourced from a facility that is permitted through CalRecycle. It should also preferably be sourced from a facility that is certified through the USCC STA program.
- Physical contaminants: Not to exceed 1% by dry weight.
- Organic Matter: 35% - 75% on a dry weight basis.
- pH: 6.0 – 8.5
- Salinity: < 10 mmho/cm as electrical conductivity
- Carbon:Nitrogen Ratio: 12:1 – 40:1. Ideal C:N ratio is greater than 15:1 to reduce the potential for nutrient leaching, especially when compost is intended to be used as the organic amendment of BSM in Biofiltration BMPs.
- Maturity/Stability: Shall conform to either:
  - Solvita Maturity Index: ≥ 5.5
  - CO_2 Evolution: < 2.5 mg CO_2-C per g compost organic matter per day or < 5 mg CO_2-C per g compost C per day, whichever unit is reported.
- Select pathogens: Shall pass US EPA Class A Standard, 40 CFR Section 503.32(a).
- Trace metals: Shall pass US EPA Class A Standard, 40 CFR Section 503.13.

Alternative Organic Amendments for BSM

Amendments used as a substitute for compost should provide comparable pollutant filtration, water holding, and support for vegetation. Coconut coir pith and peat are two alternative organic amendments that have been successfully used to replace compost in BSM. If either of these amendments is used, they should conform to the requirements under the headers below.

If other organic amendments are used a certified agronomist should certify that they would provide substantially equivalent pollutant filtration (i.e. nutrient retention and cation exchange capacity), water holding capacity, and would help to support healthy vegetation. Acceptance of any other organic amendment is subject to approval by the local jurisdiction.

Coconut Coir Pith:

If coconut coir pith is used as a component of BSM it should conform to the following requirements:

- Production Regime: Must be rinsed with freshwater to reduce potential salt water residues and screened to remove coarse fibers.
- Aging: Must be aged a minimum of 6 months.
- Salinity: < 2.0 mmho/cm as electrical conductivity.
- Total Carbon: > 35% on a dry weight basis.
- Total Nitrogen: < 1.5% on a dry weight basis.
- C:N Ratio: > 40.

Sphagnum Peat:
If sphagnum peat is used as a component of BSM is should conform to the following requirements:

- Salinity: < 3.0 mmho/cm as electrical conductivity.
- Total Carbon: > 35% on a dry weight basis.
- Total Nitrogen: < 1.5% on a dry weight basis.

Aggregate Materials for BSM Drainage Layers

Drainage of BSM requires the use of specific aggregate materials for filter course (aka choking layer) materials and for an underlying drainage and storage layer. Open graded ASTM No 57 stone (12" to 24" of gravel) is used as the drain rock layer. ASTM No. 8 stone (1/4 to 1/2"pea gravel) is placed on top of this layer in a 3 inch lift. Choker sand is placed on top of the pea gravel in a 3-inch lift immediately below the BSM.

Rock and sand products used in BMP drainage should comply with size classifications in Table 7 and Table 8. All sand and stone products used in BSM drainage layers shall be clean and should preferably be washed.

Table 7. Particle size requirements for rock products.

Sieve Size	Percent Passing Sieves	
	AASHTO No. 57	ASTM No. 8
3 in	-	-
2.5 in	-	-
2 in	-	-
1.5 in	100	-
1 in	95 – 100	-
0.75 in	-	-
0.5 in	25 – 60	100
0.375 in	-	85 – 100
No. 4	10 max.	10 – 30
No. 8	5 max.	0 – 10
No. 16		0 – 5
No. 50		-

Table 8. Particle size requirements for choker sand

Sieve Size	Percent Passing Sieves
	Choker Sand - ASTM C33
0.375 in	100
No. 4	95 – 100
No. 8	80 – 100
No. 16	50 – 85
No. 30	25 – 60
No. 50	5 – 30
No. 100	0 – 10
No. 200	0 – 3

Delivery, Storage, and Handling

BSM and Aggregates should not be delivered or placed in frozen, wet, or muddy conditions. The Contractor should protect materials from absorbing excess water and form erosion at all times. The Contractor shall not store materials unprotected during large rainfall events (>0.25 inches). If water is introduced into material while it is stockpiled, the Contractor shall allow the material to drain to an acceptable level before it is placed.

BSM shall be thoroughly mixed prior to delivery using mechanical mixing methods such as a drum mixer. BSM shall be lightly compacted and placed in loose lifts approximately 12 inches thick to ensure reasonable settlements without excessive compaction. Compaction within the BSM area should not exceed 75 to 85% standard proctor within the designated depth of BSM. Machinery shall not be used in the BSM area to place BSM. A conveyor or spray system shall be used for placement in large facilities. Low ground pressure equipment may be authorized for large facilities at the discretion of the local jurisdiction.

Placement methods and BSM quantities shall account for approximately 10% volume loss due to compaction and settling. Planting methods and timing shall account for settling of media without exposing plant root systems.

The local jurisdiction may request up to three double ring infiltrometer tests (ASTM D3385) or approved alternative tests to confirm that placed materials meet applicable hydraulic suitability criteria. If the infiltration rate of placed material does not meet applicable criteria, the local jurisdiction may require replacement and/or decompaction of materials.

Quality Control and Acceptance

Acceptance of materials will be based on test results that are certified by the Contractor to be representative of the materials that are delivered to the site. Laboratory testing should ideally be conducted on stockpiled materials prior to delivery to the site. Testing results may be from previously sampled materials if they are not more than 6 months old and if the Contractor certifies that they are representative of the materials that are actually delivered to the site.

3.9 Tree Wells

No BMP worksheet is provided. For use, include designs on the WQMP site map with a cross section. Adequate details on the grading plans are required to demonstrate the project design incorporates all of the applicable design criteria.

Soil Infiltration Range	Suitable for all soil infiltration rates; soils less than 0.8 in/hr (factored) require supplemental underdrain
Treatment Mechanisms	Interception, Infiltration, Evapotranspiration, Filtration
Maximum Drainage Area	This BMP is intended to be integrated into a project's landscaped area in a distributed manner, for all infiltration conditions. Typically, contributing drainage to a Tree Well will be less than 5,000 sq-ft for a large tree.

Description

Tree Wells are intended both to support the growth of healthy tress and to retain stormwater runoff. Tree Wells retain stormwater runoff via interception and evaporation of direct precipitation, and infiltration and evapotranspiration of runoff. Tree Wells also provide additional benefits from increasing tree cover including energy conservation, air quality improvements, and aesthetic enhancement.

When properly designed, Tree Wells can retain stormwater runoff from up to 10 parts impervious surfaces for each unit of Tree Well soil surface area. Many design variations may be used in Tree Well BMPs including the use of structural soil mixes and proprietary load bearing suspended pavement cells. Tree Wells are often adjacent to a curb or driveway. As with all stormwater BMPs, stormwater must be allowed to enter and distribute through the system. In order to provide these functions, Tree Wells must include an inlet of some form and a surface distribution system to allow water to flow over the surface of the soil and infiltrate into soil pores. Tree Wells also must include permeable soils to support healthy vegetation and infiltration of runoff.

Note: Proprietary Biofiltration BMPs such as Filterra and Modular Wetlands Systems do not qualify as Tree Wells as described in this Fact Sheet. Approval requirements for Proprietary Biofiltration BMPs can be found in the SMR WQMP.

Types of Tree Wells

Tree Wells may be designed in a variety of ways. They will typically fall into one of the three general categories:

- **Open Top Tree Wells** are those that do not contain pavement above any portion of the tree well soil. The distribution and ponding layers for this type of Tree Well are comprised of a shallow depressed area at the soil surface. This is the simplest configuration. This allows water to soak into the tree well soil by ponding over the surface. The depressed area should extent over the limits of the tree well soils that is being claimed for stormwater benefits.
- **Structural Soil Tree Wells** are those that support pavement or sidewalks above tree well soil that consists of structural soils that also permit healthy root growth. Structural soils are specially-blended to provide structural support for overlying pavement while also being supportive of healthy vegetation. Both proprietary and non-proprietary structural

soils can be sourced from landscape and/or aggregate suppliers. The distribution and ponding layers for this type of Tree Well are provided by including a layer of open-graded gravel above the structural soil. This gravel layer permits rapid distribution of water over the surface of the structural soils and is also supportive of overlying pavement or sidewalks.

- **Suspended Pavement Tree Wells** are those that use structural cells to transfer the weight of overlying pavement to deeper soil layers, thereby permitting a volume of uncompacted soils to support healthy tree growth and infiltration of runoff. The distribution and ponding layer for this type of tree well may consist of either void space at the top of the structural cells or open-graded gravel located at the surface of the Tree Well soil below the top of the suspended pavement cell. Suspended pavement cells are typically proprietary systems.

Siting Considerations

Tree Wells work best when they are installed in relatively levels areas, but mildly sloped areas can be accommodated. Because Tree Wells are typically relatively small BMPs, they can be situated in many parts of a site, such as:

- ✓ Parking islands
- ✓ Medians
- ✓ Site entrances
- ✓ Rights-of-Way between roadway and sidewalks

Additionally, the use of Tree Wells as Self-Retaining Areas requires that the following siting guidelines be considered:

- Tree species must be appropriately chosen for the development. For public right-of-ways, local planning guidelines and zoning provisions for the permissible species and placement of trees should be consulted. Proper tree placement and species selection minimizes problems such as pavement damage by surface roots and poor growth.
- To reduce the potential for clogging of Tree Well soil, Tree Wells should generally not be designed to receive runoff from high sediment producing areas such as bare ground or high traffic roadways.
- Site grading must direct runoff from adjacent areas into Tree Wells if such areas are included as part of the Tree Well Self-Retaining Area.
- There must be adequate grade differential at the tree well inlet so that water can reliably enter the system during storm events.

Setbacks

Locations of trees planted along public streets must follow local requirements and guidelines. Vehicle and pedestrian line of sight must be considered in tree selection and placement. Unless exemption is granted by the Copermittee the following minimum tree separation distances (from the tree trunk) are required:

- 20 feet from traffic signal and/or stop sign
- 5 feet from underground utility lines (except sewer)
- 10 feet from sewer lines
- 10 feet from above ground utility structures (Transformers, Hydrants, Utility poles, etc.)
- 10 feet from driveways
- 25 feet from intersections (intersecting curb lines of two streets)

If overhead utilities are located near a Tree Well, applicable tree selection guidelines should be followed. Such guidelines may permit that only certain shorter trees are permitted when overhead utilities are present.

Pretreatment

Pretreatment is not required for Tree Well BMPs; however, areas draining to BMPs should not include significant sources of sediment, which can lead to clogging of tree well soil pore space and reduce the stormwater benefit provided by Tree Wells.

Overflow

Tree Wells should be designed such that flows exceeding the retention capacity would bypass a given Tree Well and flow along a curb or gutter to an eventual storm drain inlet or another stormwater BMP. Because Tree Wells are usually small distributed BMPs, they are not required to include internal bypass piping connected to storm drains.

Design Criteria

To qualify as Self-Retaining Areas, all Tree Wells must be designed and sized according to the following requirements.

For configurations receiving flow via an inlet, where a portion of the tree well soil is below adjacent sidewalks, etc. the following criteria apply:

- **Inlet(s)** must be sized such that the runoff from the entire Self-Retaining area may flow unimpeded into the Tree Well during the 85th percentile 24-storm event. For Tree Wells with curb cut inlets, the cuts should be at least 18 inches wide.
- **Inlet Ponding Area** is an open water ponded area at the inlet location. It must be at least 10% of the total surface area of Tree Well soil area and must be at least 4 inches deep. It may not contain any gravel. The Inlet Ponding Area is intended to permit water to enter the system and flow into the distribution layer without premature bypass.
- **Distribution Layer** must be designed to permit rapid flow of runoff from the Inlet Ponding Area across the entire surface of Tree Well soil. The Distribution Layer must cover at least 80% of the total Tree Well soil surface area and must be level across the Tree Well Soil to permit even distribution. Distribution Layer materials and depths must conform to one of the following requirements:
    - Gravel Distribution Layers must be at least 12 inches thick and be composed of open-graded gravel. This layer may not be constructed using structural soil.

Gravel Distribution Layers are most applicable to Structural Soil Tree Wells, but they may also be used in Suspended Pavement Tree Wells.

- If the distribution layer consists of open void space, this layer must be at least 4 inches thick above the Tree Well Soil. Void space Distribution Layers are used in Open Top Tree Wells and may be used in Suspended Pavement Tree Wells.

For all tree well configurations, the following criteria apply:

- **Extent of pooled water** must be at least 80 percent of the tree well soil claimed for stormwater benefits.
- **Tree Well Soil** must be at least 36 inches deep. Tree Well Soil should be reasonably permeable (target 2 in/hr) and should be Loamy Sand, Sandy Loam, Loam, or structural soil. Compaction of Tree Well Soil is only permitted for structural soils. The surface of the soil must be level.
- **Trees** should be planted close to the center of the Tree Well soil and should not be located on the edge of the Tree Well area.

Tree Wells may also include some of the following optional design elements:

- **Root Barriers** to prevent root growth near utilities, under pavement, or near other sensitive areas. At the discretion of [Insert Jurisdiction], Root Barriers may be required when Tree Wells are located next to specific types of infrastructure.
- **Surface Grates** to improve pedestrian access and prevent compaction of Open Top Tree Wells. Surface grates should not be used to support automobiles.
- **Underdrains** to help avoid prolonged saturation in cases where underlying soils have low permeability.

Sizing Criteria

To qualify as Self-Retaining Areas, the amount of area draining to the Tree Well may be no more than 10 times as large as the surface area of Tree Well Soil. This sizing has been developed to provide ponding and pore storage equal to 1.5 times the DCV as explained at the end of this fact sheet. Sizing factors may be limited to smaller allowable tributary areas at the discretion of the local jurisdiction.

Tree Selection

Trees that are planted in Tree Wells should be selected according to the following guidelines:

- **Local Climate:** Tree should be selected according to the local climate. Local landscaping requirements should be used to determine those trees that are appropriate. Trees should ideally be selected that require no irrigation except during initial establishment.
- **Mature Size:** Trees should be selected such that there are at least 2 cubic feet of Tree Well Soil for each square foot of mature tree canopy projection (at the drip line). This is the amount of soil that is required to support healthy trees. Smaller trees should be selected for smaller Tree Wells. If the minimum Tree Well Soil Depth of 36 inches is used, trees should be selected to have a mature canopy projection up to 1.5 times the surface area of Tree Well Soil.

Maintenance

When appropriately sited and designed, Tree Wells should require relatively limited maintenance. Inspection and maintenance activities may include the following:

- Tree Health: Routine tree maintenance actions as necessary (e.g., pruning, watering young trees)
- Dead or diseased tree: Remove dead or diseased tree. Replace per original plans.
- Standing water in tree well for longer than 24 hours following a storm event: Loosen or replace soils surrounding the tree to restore drainage.
- Presence of mosquitos/larvae: Disperse any standing water from the tree well to nearby landscaping. Loosen or replace soils surrounding the tree to restore drainage (and prevent standing water).
- Accumulation of sediment in Tree Well Surface Ponding Area should be periodically removed to prevent clogging and to promote healthy trees without excessive sediment build up near the base.
- Trash and debris build up inlet or surface ponding areas: remove trash and debris.
- Entrance / opening to the tree well is blocked such that storm water will not drain into the tree well (e.g., a curb inlet opening is blocked by debris or a grate is clogged causing runoff to flow around instead of into the tree well; or a surface depression is filled such that runoff drains away from the tree well): Make repairs as appropriate to restore drainage into the tree well.

Sizing and Design Justification

This section does not apply to WQMP development. This section is included to provide the technical basis for the simple sizing factor of 10:1.

The following calculations support simplified sizing and design criteria for Tree Wells to maximize retention of runoff:

Retained Runoff = V_{TW} x R_{SOIL} + Ponding = A_{TW} x (D_{TW} x R_{SOIL} + Ponding Depth) = A_{TW} x (36” x 0.3 in/in + 4”) = A_{TW} x 14.8”

Where:

- Retained runoff equals the approximate runoff volume retained in a Tree Well
- V_{TW} is the volume of Tree Well Soil
- A_{TW} is the surface area of Tree Well Soil
- D_{TW} is the depth of Tree Well Soil
- R_{SOIL} is the retention of runoff in Tree Well Soil, as a volume fraction. R_{SOIL} is intended to represent the amount of water that is temporarily held by soil during storm events but then subsequently lost to evapotranspiration or to infiltration into underlying soil. This would include all water held by soil between saturation and permanent wilting point. A

value of 0.3 is a conservative estimate assuming that Tree Well soil is Loam, Sandy Loam, or Loamy Sand texture.

The amount of runoff generated from a given impervious area during the worst-case 85th percentile 24-hour storm is calculated as:

Impervious Area Runoff = A_{IMP} x $D85_{Temecula}$ = A_{IMP} x 1.0"

Where:

- A_{IMP} is the impervious area of the Self-Retaining Area
- $D85_{Temecula}$ equals the 85th percentile 24-hour precipitation depth at Temecula. Temecula was selected for this analysis because it has the greatest 85th percentile 24-hour precipitation depth in the developed portions of the SMR region (only the higher terrain of the Eastern Slopes exceeds this value).

For an I:P ratio of 10:1, the total loading to the Tree Well is 10 inches over the area of the tree well.

The retention depth over the tree well is 14.8" providing a retention volume approximately 1.5 times larger volume than the DCV. This ensures that the design would generally retain the DCV (if soil conditions allow) or provide biofiltration of 150% of the DCV if underlying soils do not allow for full infiltration and an underdrain is used.

Design guidance for Tree Wells requires that the surface distribution depth be at least 4" of void space or 12" of open-graded gravel. These minimums are intended to promote dispersion of runoff across the entire Tree Well soil surface and to reduce the likelihood of Tree Well bypass during more intense storms. This also helps assure that runoff has time to infiltrate into the pores of the tree well soil.

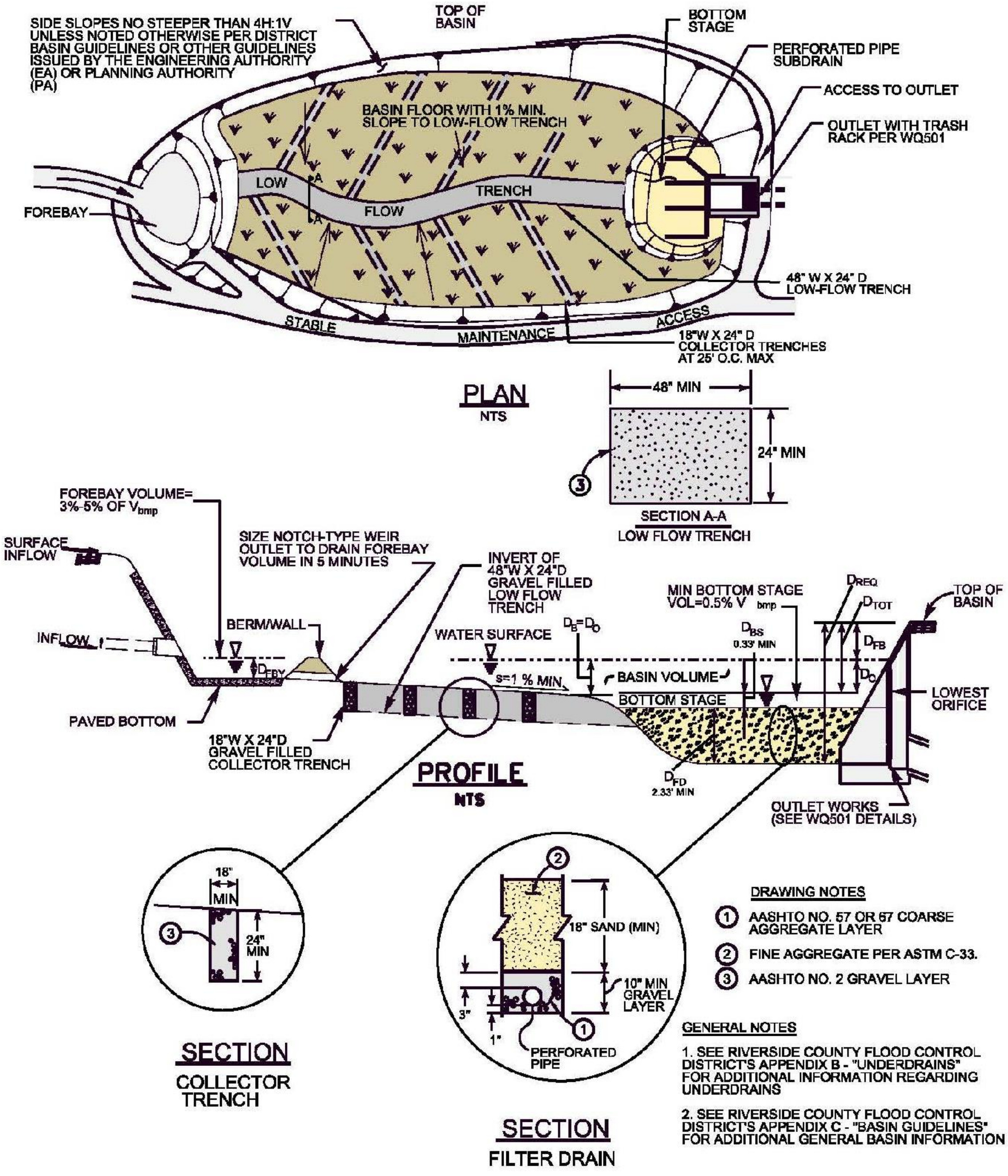
3.10 Extended Detention Basin

Type of BMP	Flow-Through Treatment
Priority Level	Priority 3 – Treatment Control
Treatment Mechanisms	Sedimentation, Infiltration, Evapotranspiration (when vegetated), Evaporation
Maximum Drainage Area	5 acres

Overview

The Extended Detention Basin (EDB) is designed to detain the design volume of stormwater, V_{BMP}, and maximize opportunities for volume losses through infiltration, evaporation, evapotranspiration and surface wetting. Additional pollutant removal is provided through sedimentation, in which pollutants can attach to sediment accumulated in the basin through the process of settling. Stormwater enters the EDB through a *forebay* where any trash, debris, and sediment accumulate for easy removal. Flows from the forebay enter the basin which is vegetated with native grasses that enhance infiltration and evapotranspiration, and which is interspersed with gravel-filled trenches that help further enhance infiltration. Water that does not get infiltrated or evapotranspired is conveyed to the *bottom stage* of the basin. At the bottom stage of the basin, low or incidental dry weather flows will be treated through a sand filter and collected in a subdrain structure. Any additional flows will be detained in the basin for an extended period by incorporating an outlet structure that is more restrictive than a traditional detention basin outlet. The restrictive outlet structure extends the drawdown time of the basin which further allows particles and associated pollutants to settle out before exiting the basin, while maximizing opportunities for additional incidental volume losses.

EXTENDED DETENTION BASIN BMP FACT SHEET



DRAWING NOTES

① AASHTO NO. 57 OR 67 COARSE AGGREGATE LAYER

② FINE AGGREGATE PER ASTM C-33.

③ AASHTO NO. 2 GRAVEL LAYER

GENERAL NOTES

1. SEE RIVERSIDE COUNTY FLOOD CONTROL DISTRICT'S APPENDIX B - "UNDERDRAINS" FOR ADDITIONAL INFORMATION REGARDING UNDERDRAINS

2. SEE RIVERSIDE COUNTY FLOOD CONTROL DISTRICT'S APPENDIX C - "BASIN GUIDELINES" FOR ADDITIONAL GENERAL BASIN INFORMATION

Figure 1 – Extended Detention Basin

Siting Considerations

Soils: EDBs can be used with almost all soils and geology. However, pollutant removal effectiveness is greatly improved when the underlying soil permits at least some infiltration.

Tributary Area: EDBs should only be used where the tributary drainage area is at least 5 acres, since meeting the draw-down requirements (discussed below) for smaller areas would result in very small outlet orifice diameters which would be prone to clogging.

Proximity to Receiving Waters: All site runoff must be treated to the MEP with appropriate BMPs *before* being discharged into Receiving Waters; as such the EDB cannot be constructed in-line within Receiving Waters.

Setbacks: Due to the infiltration characteristics incorporated into the EDB design, the lowest pervious point (beneath the filter drain) of the extended detention facility should be a minimum of 10' above the seasonal high groundwater table. All other setbacks shall be in accordance with applicable standards of the "Basin Guidelines" (Appendix C) or other guidelines issued by the Engineering Authority (EA).

Basin Guidelines: See Section 1 of the "Basin Guidelines" (Appendix C) for additional requirements (i.e., fencing, maintenance access, etc.) that may be required by the Engineering Authority (EA).

Landscaping Requirements

Basin vegetation provides erosion protection, enhances evapotranspiration and infiltration, and improves pollutant removal. The upper stage basin surface, berms and side slopes shall be planted with native grasses. Proper landscape management is also required to ensure that the vegetation does not contribute to water pollution through the use of pesticides, herbicides, or fertilizers. Landscaping shall be in accordance with applicable standards of the "Basin Guidelines" (Appendix C) or other guidelines issued by the EA.

Maintenance Guidelines

Schedule	Inspection and Maintenance Activity
During every scheduled maintenance check (per below), and *as needed* at other times	• Maintain vegetation as needed. Use of fertilizers, pesticides and herbicides should be strongly avoided to ensure they don't contribute to water pollution. If appropriate native plant selections and other IPM methods are used, such products shouldn't be needed. If such projects are used: ○ Care should be taken to avoid contact with the low-flow or other trenches, and the media filter in the bottom stage. ○ Products shall be applied in accordance with their labeling, especially in relation to application to water, and in areas subjected to flooding. ○ Fertilizers should not be applied within 15 days before, after, or during the rainy season. • No ponded water should be present for more than 72 hours to avoid nuisance or vector problems. No algae formation should be visible. Correct problems as needed.
Annually. If possible, schedule these inspections before the beginning of the rain season to allow for any repairs to occur before rains occur.	• Remove debris and litter from the entire basin • Inspect hydraulic and structural facilities. Examine the outlet for clogging, the embankment and spillway integrity, as well as damage to any structural element. • Check for erosion, slumping and overgrowth. Repair as needed. • Inspect sand media at the filter drain to verify it is allowing acceptable infiltration. **Scarify top 3 inches by raking the filter drain's sand surface annually.** • Check the media filter underdrains (via the cleanout) for damage or clogging. Repair as needed. • Remove accumulated sediment and debris from the forebay, and ensure that the notch weir is clear and will allow proper drainage. • Check gravel filled low flow and collector trenches for sediment buildup and repair as needed.
Every 5 years or sooner (depending on whether observed drain times to empty the basin are less than 72 hours).	• Remove the top 3 inches of sand from the filter drain and backfill with 3 inches of new sand to return the sand layer to its original depth. When scarification or removal of the top 3 inches of sand is no longer effective, remove and replace sand filter layer.
Whenever substantial sediment accumulation has occurred.	• Remove accumulated sediment from the bottom of the basin. Removal should extend to original basin depth.

EXTENDED DETENTION BASIN BMP FACT SHEET

Design Summary

Design Parameter	Extended Detention Basin
Drawdown time (total)	72 hours [2,3]
Minimum drawdown time for 50% V_{BMP}	24 hours [2]
Minimum tributary area	5 acres [2]
Outlet erosion control	Energy dissipaters to reduce velocities[1]
Forebay volume	3 to 5 % of V_{BMP}[3]
Basin Invert Longitudinal Slope (min.)	1%
Basin Invert Transverse (cross) Slope (min)	1%
Low-flow trench width (min.)	48 inches
Low-flow trench depth (min.)	24 inches
Slope of low-flow trench along bottom excavated Surface (max.)	1%
Slope of gravel collector trenches along bottom excavated surface (max.)	1 %
Length to width ratio (min.)	1.5:1
Basin depth (min.)	1 foot [3]
Bottom stage volume	0.5 % of V_{BMP} [3]
Bottom stage depth (min)	0.33 feet [3]
Filter drain depth (min)	2.33 feet [3]

1. **Ventura County's Technical Guidance Manual for Stormwater Quality Control Measures**
2. **CA Stormwater BMP Handbook for New Development and Significant Redevelopment**
3. **Denver, Colorado's UDFCD Drainage Criteria Manual, Volume 3**

Note: The information contained in this BMP Factsheet is intended to be a summary of design considerations and requirements. Additional information which applies to all detention basins may be found in the "Basin Guidelines" (Appendix C). In addition, information herein may be superseded by other guidelines issued by the Engineering Authority.

Design Procedure

These steps correspond to and provide a description of the information required in the EDB Design Worksheet.

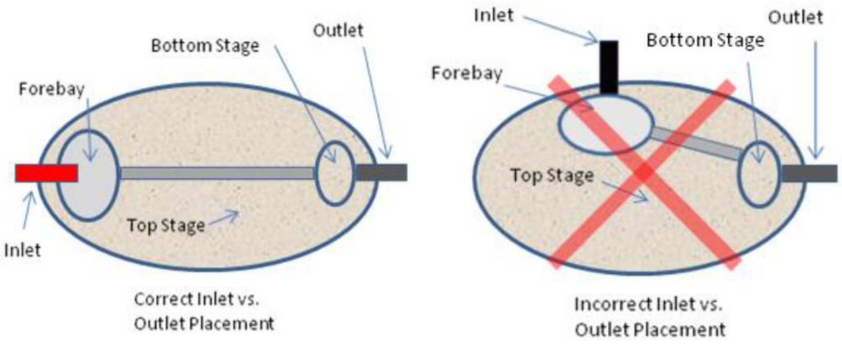
1. Find the Design Volume, V_{BMP}.

a) Enter the tributary area, A_T to the BMP. The minimum tributary area is 5 acres.

b) Enter the Design Volume, V_{BMP}, determined from Section 2.1 of this Handbook.

2. Basin Footprint

a) Enter the length and width of the EDB. The length shall be measured between the inlet to the basin and the outlet structure; and the width shall be measured at the widest point of the basin invert. The length to width ratio should be 1.5:1 or longer to prevent short-circuiting and increase the overall effectiveness of the BMP.



b) Enter the internal basin side slopes. See the "Basin Guidelines" (Appendix C) for side slope requirements. If variable internal side-slopes are used, enter the steepest slope that will be used.

c) Using Figure 1 as a guide, enter the proposed basin depth, D_B, and the freeboard depth, D_{FB}. Based on the information provided, the spreadsheet will calculate the minimum total depth required, D_{REQ}, for this BMP. D_{REQ} is the depth from the bottom of the underdrain layer in the bottom stage (see step 5c), to the top of the freeboard. This calculated minimum required depth can be used to determine if enough elevation difference is available within the design topography to allow for use of this BMP.

d) Additionally, the basin depth D_B is equal to D_O, which is the depth from the design pond water surface elevation to the lowest orifice in the outlet structure. D_O is confirmed by the spreadsheet and is used in the Basin Outlet Design described in step 6 below. It should be noted that this lowest orifice is a critical elevation in the design of this BMP. The Volume of the Basin V_{Basin} described in step 3d) is the volume of water above this lowest orifice. This lowest-orifice also represents the dry weather ponded water surface discussed in step 5c below. Below this elevation there must be a minimum of a 4-inch drop down to the surface of the Sand Filter in the bottom stage.

3. Basin Design

a) The Total Basin Depth, D_{TOT}, is calculated automatically, and is the sum of the basin depth D_B plus the freeboard depth D_{FB}.

b) Enter the longitudinal slope of the basin invert. This slope must be at least 1% and is measured along the low flow trench between the forebay and the bottom stage. Note that the surface of the sand layer in the bottom stage must be level (see Figure 1).

c) Enter the transverse slope of the basin invert. This transverse (cross sectional) slope must be at least 1% sloped toward the low flow trench.

d) Enter the Volume of the Basin, V_{Basin}. This volume must be the actual volume of water held within the basin as substantiated by modeling or appropriate volumetric calculations, and must be equal to or greater than V_{BMP}. This volume must be held above the lowest orifice in the Basin Outlet Design described in step 6 below.

4. Forebay Design

All flows must enter the basin through the forebay. The forebay provides a location for the settlement and collection of larger particles, and any other trash or debris. A relatively smooth and level concrete bottom surface should be provided to facilitate mechanical removal of any accumulated sediment, trash and debris.

Figure 2: Forebay filled with storm water

a) Enter the Forebay Volume VFB. This volume must be from 3 to 5 percent of V_{BMP}.

b) A rock or concrete berm must be constructed to detain water before it drains into the basin. The top of the berm shall be set no higher than the invert of the inlet conveyance. Enter the Forebay Depth, D_{FBY}.

c) The spreadsheet will calculate the minimum surface area of the forebay, A_{FB}, based on the provided Forebay Volume and Depth. Ensure that the plans provide for a forbay area at least this large.

d) Although the forebay will be well submerged in the design event, a full height rectangular notch-type weir shall be constructed through the berm to prevent permanent ponding in the forebay, and allow water to slowly and fully drain to the main body of the basin. This notch should be offset from the inflow streamline to prevent low-flows from short circuiting. Enter the width, W, of this rectangular notch weir. The width shall not be less than 1.5 inches to prevent clogging. Additionally, immediately outside the notch construct a minimum 1-foot by 1-foot gravel pad to prevent vegetative growth within the basin invert from blocking the notch.

5. Dry Weather and Low-Flow Management

The basin shall have both a low-flow gravel trench and a network of gravel collector trenches across the invert of the basin, as well as a bottom stage sand filter to treat low flows and dry weather flows (see Figure 1).

a) Low Flow Trench: The low-flow gravel trench conveys flow from the forebay to the bottom stage, while allowing for maximum incidental infiltration and volume loss. The trench shall be a minimum of 48 inches wide by 24 inches deep. This trench shall be unlined and backfilled with AASHTO No. 2 gravel (or similar) to the finished surface of the basin invert, and shall not use underdrains. The bottom excavated surface of the low-flow trench shall be 1 percent or flatter to promote infiltration.

Figure 3: Gravel filled low-flow trench

b) Collector Trenches: Gravel collector trenches beneath the top stage shall be arranged as illustrated in Figure 1 of Appendix C with minimal slope (1% maximum) along their bottom excavated surface to promote infiltration, and must extend from the low-flow trench to the toe of the basin side slopes. They shall be a minimum of 18-inches wide by 24-inches deep, unlined and backfilled with AASHTO No. 2 gravel (or similar) to the finished basin invert surface. The gravel collector trenches shall not use underdrains and shall be constructed with a maximum spacing of 25 feet, center to center. See Figure 1 of Appendix C.

c) Bottom Stage: A depressed sand filter drain area, referred to as the bottom stage, must be constructed adjacent to the outlet structure to treat any dry weather flows. To ensure that dry weather flows are treated through the sand filter and not discharged through the orifice plate, the top surface of the sand filter must be depressed at least 4 inches below the lowest orifice in the outlet structure. This depressed area will create a micro pool of water that is then filtered down through the sand filter and out through underdrains. Based on the minimum dimensions described below, the minimum depth of excavation below the lowest orifice in the outlet structure is 2.33 feet.

   i. Enter the Depth of the bottom stage, D_{BS}. As mentioned above, this depth must be at least 4 inches, and extend down below the lowest orifice in the outlet structure.

   ii. Enter the area of the bottom stage, A_{BS}.

iii. Based on the D_{BS} and A_{BS} entered, the spreadsheet will calculate V_{BS}. This volume is the volume of ponded water that will be held below the lowest orifice in the outlet structure, and above the surface of the sand filter. This volume must be at least 0.5% of V_{BMP}.

iv. Enter the thickness of the ASTM C-33 sand layer that will be provided, D_S. A minimum thickness of 18 inches is required.

v. Below the sand layer, a minimum 10-inch thick layer of gravel shall be installed with underdrains to drain the water that has been treated through the sand filter. The underdrains shall connect into the outlet structure. See Appendix B for standard underdrain construction. Enter the diameter of the underdrain pipe (minimum 6" dia.), and the spacing of the underdrains. The maximum spacing of the underdrains is 20 feet on center, however where the area of the bottom stage is particularly small (less than 500 square feet), the underdrain pipes shall be placed at no more than a 10-foot separation on center.

6. Basin Outlet Design

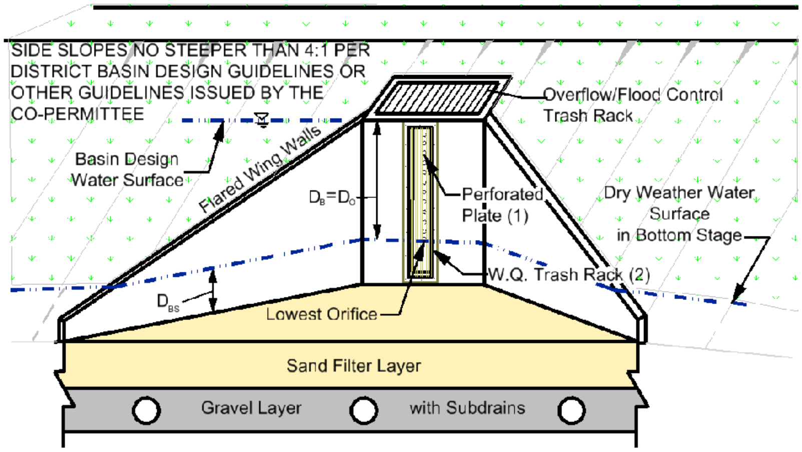


Figure 4: Basin Outlet Structure with Bottom Stage Shown

Outlet structures for publicly maintained basins shall conform to District Standard Drawings WQ501 unless approved in advance by the local Engineering Authority (EA). This standardization is to provide for efficient maintenance. The basin outlet should be sized to release the design volume, VBMP, within a 72-hour period but 50 percent of VBMP within 24 hours. This is an iterative design process where an appropriate control orifice can be selected using the following steps:

a. Develop a Stage vs. Discharge Curve for the Outlet Structure

Estimate the orifice size and outlet plate configuration (number per row, etc.). Based on D_O provided in the Basin Footprint section, the spreadsheet will automatically generate the stage vs. discharge relationship for this outlet:

$$Q = C*A*[2*g*(H-H_o)]^{0.5}$$

Where:

Q = discharge (ft^3/s)	g = gravitational constant (32.2 ft2/s)
C = orifice coefficient	H = water surface elevation (ft)
A = area of the orifice (ft)	H_o = orifice elevation (ft)

The lowest orifice shall be located with its centerline at the top of the bottom stage; at least 4 inches above the surface of the sand filter drain. To help avoid clogging, the minimum orifice diameter is limited to 3/8 inch. Since the 1/4 inch thickness of the orifice plate will be less than the orifice diameter, a value for C of 0.66 may be used. If another value for C is used, justification may be required.

b. Develop a Discharge/Volume vs. Stage Table for the Basin

Based on the shape and size of the basin, develop a relationship between the stage and the volume of water in the basin. Since the orifice spacing is 4 inches on center for the standard orifice plate, the stage intervals must also be 4 inches. Enter the basin volume at each interval starting at the centerline of the lowest orifice.

c. Route the Design Volume through the Basin

The spreadsheet assumes that the Design Volume, $V_{BMP,}$ enters the basin instantaneously and as such, no inflow/outflow hydrograph is necessary. The drawdown time for each stage becomes:

$$\Delta t = V_i/Q$$

Where:

Δt = drawdown time for each stage

V_i = the volume at each stage

Q = the flow rate corresponding to the headwater elevation at each stage.

The spreadsheet automatically determines the drawdown time from the sum of the Δt values for each stage. If the orifice size and plate configuration estimate meets the hydraulic retention time requirements (50% of the volume empties in not less than 24 hours, 100% of the volume empties in no more than 72 hours), the outlet is correctly sized. If these requirements are not met, select a new orifice size or configuration and repeat the process starting at Step 6a.

7. Outlet Protection

To prevent the orifices from clogging, trash racks are required where perforated vertical outlet control plates are used. This allows for easier access to outlet orifices for inspection and cleaning. Trash racks shall be sized to prevent clogging of the primary water quality outlet without restricting the hydraulic capacity of the outlet control orifices. The orifice plate shall be protected with a trash rack conforming to Standard Drawing WQ501 (at end of this section) with at least six square feet of open surface area or 25 times the total orifice area, whichever is greater. The rack shall be adequately secured to prevent it from being removed or opened when maintenance is not occurring.

Overflow Structure Similar to Standard Drawing Number WQ 501
(Photo courtesy of Colorado Association of Stormwater Floodplain Managers)

Trash rack with screen

8. Overflow Outlet

Overflow outlets for publicly maintained basins shall conform to Standard Drawing WQ501 (at end of this section) unless approved in advance by the Engineering Authority (EA).

9. Embankment

Embankments shall be designed in accordance with applicable standards of Riverside County Flood Control District's "Basin Guidelines" (Appendix C) or other guidelines issued by the Engineering Authority (EA). Where applicable, embankment designs must additionally conform to the requirements of the State of California Division of Safety of Dams.

10. Spillway and Overflow Structures

Spillway and overflow structures should be designed in accordance with applicable standards of the "Basin Guidelines" (Appendix C) or other guidelines issued by the Engineering Authority (EA).

Extended Detention Basin Design Procedure	BMP Subarea No.	Legend:	Required Entries Calculated Cells

Company Name: Date:

Designed by: County/City Case No.:

Design Volume

Tributary Area (BMP Subarea) A_T = acres

Enter V_{BMP}, determined from Section 2.1 of this Handbook V_{BMP}= ft^3

Basin Footprint

Overall Geometry

Length at Basin Bottom Surface Length = ft

Width at Basin Bottom Surface Width = ft

Meets 1.5 : 1 requirement?

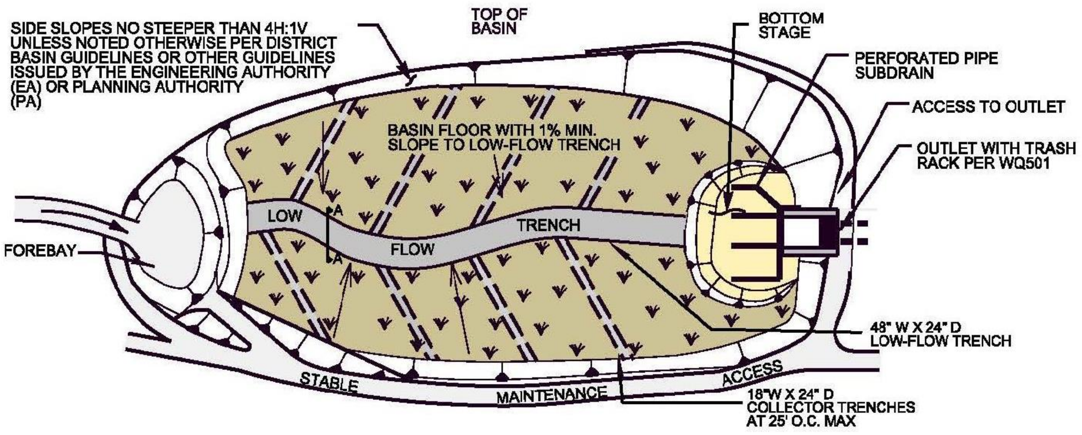
Side Slopes per "Basin Guidelines", Sect. 1.2 z = :1

Proposed Basin Depth (with no freeboard) D_B = ft

Depth of freeboard (if used) D_{FB} = ft

Minimum Required Allowance for Total Depth (including proposed basin depth, freeboard, minimum depth of bottom stage (D_{BS}=0.33') and minimum filter depth (D_{FD}=2.33')) D_{REQ} = ft

Depth from design water surface elevation to lowest orifice D_O = ft



Basin Design

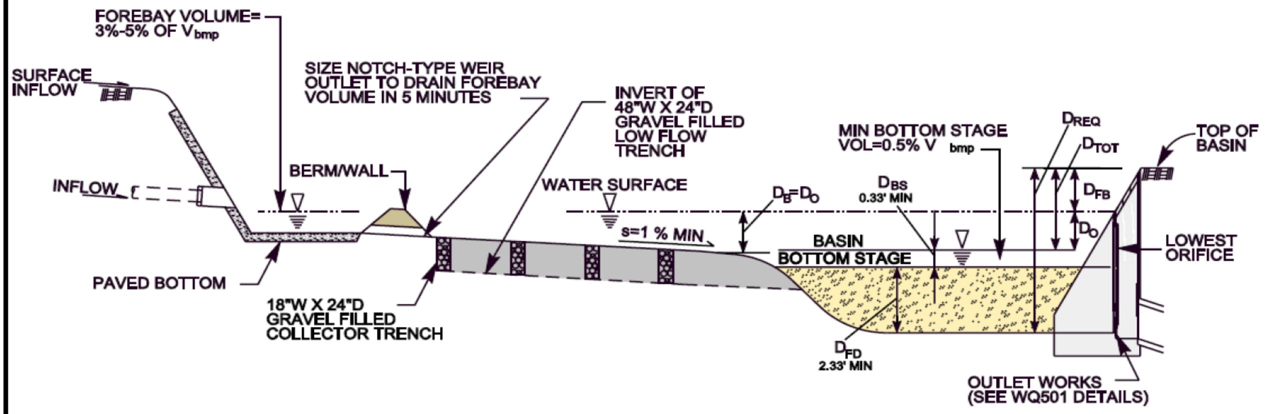
Basin Design

Proposed Total Basin Depth (proposed depth plus freeboard) D_{TOT} = ft

Basin Invert Longitudinal Slope Slope = %

Basin Invert Transverse Slope (1% min) Slope = %

Basin Volume V_{Basin} = ft^3



Forebay Design

Forebay Volume (3 - 5% V_{BMP}) V_{FB} = ft^3

Forebay Depth (height of berm) D_{FBY} = ft

Minimum Forebay Surface Area A_{FB} = ft^2

Rectangular weir (notch) W = in

Dry Weather and Low-Flow Management

Low-Flow Trench (see graphic below)

Depth (24 inches minimum, gravel filled) Depth = inches

Width (48 inches minimum) Width = inches

Trench Invert Longitudinal Slope Slope = %

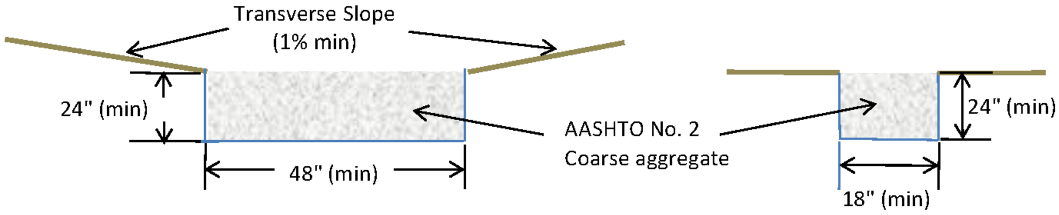
Collector Trenches (see graphic below)

Depth (24 inches minimum) Depth = inches

Width (18 inches minimum) Width = inches

Trench Invert Longitudinal Slope Slope = %

Spacing (25 feet on center maximum) S = feet



Low-Flow Trench

Collector Trench

Bottom Stage (Sand Filter) Design

Depth of the Bottom Stage (4" minimum ponding) D_{BS} = in

Surface Area of Bottom Stage A_{BS} = ft^2

Dry Weather Ponded Volume (above sand layer) V_{BS} = ft^3

Is V_{BS} no less than 0.5% V_{BMP}? Enter Depth and Surface Area

Depth of ASTM-C33 sand (18 inch minimum)

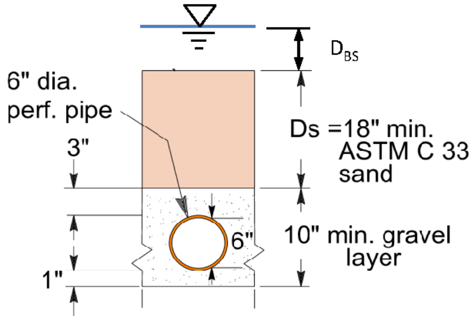
Ds = inches

Diameter of Subdrains

ϕ = in

Subdrain Spacing

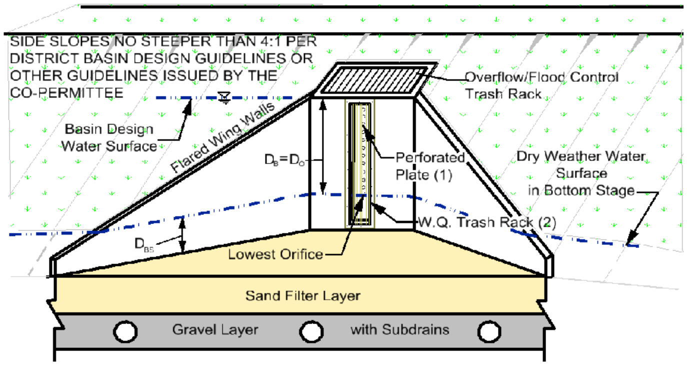
s = ft. on center



Basin Outlet Design

Outlet Design

Assume an orifice area. Based on the information provided above, the spreadsheet provides discharge vs. stage data. Enter the volume vs. stage data for each interval. This information is used to route the volume through the basin. The size of the orifice is acceptable when the data shows that less than 50% of V_{BMP} has drained in 24 hours, and that 100% drawdown occurs within 72 hours.



All values on this worksheet must be filled out to use this calculator

Flow Rate, Q (cfs)

$$Q=CA[2g(H-H_o)]^{0.5}$$

Discharge Coefficient,

Default, C = 0.66

Other, C =

Orifice Area (ft^2)

Orifice Diameter, d; number of orifices per row, n; and number of orifice rows, N (from the bottom up).

d = inches

n = per row

N = rows

Aeff = 0.000 ft^2 per row

or

Aeff = 0.000 in^2 per row

From outflow hydrograph, the time where 50% of V_{BMP} has drained from the basin (24 hour minimum):

Time (50%) = **Error *** hrs

From outflow hydrograph, the time where 100% V_{BMP} has drained from the basin(within 72 hours):

Time (100 %) = **Error *** hrs

Headwater Elev. / Stage (ft)	Discharge (cfs)	Volume (acre-ft)	Δt (hrs.)
0	0.0000	0.0000	
0.33			
0.67			
1.00			
1.33			
1.67			
2.00			
2.33			
2.67			
3.00			
3.33			
3.67			
4.00			
4.33			
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5.33			
5.67			
6.00			
6.33			
6.67			
7.00			
7.33			
7.67			
8.00			
8.33			
8.67			
9.00			
9.33			
9.67			
10.00			
		∑ =	0.00

3.11 Sand Filter Basin

Type of BMP	Flow-Through Treatment
Priority Level	Priority 3 – Treatment Control BMP
Treatment Mechanisms	Filtration
Maximum Drainage Area	25 acres

Description

The Sand Filter Basin (SFB) is a basin where the entire invert is constructed as a stormwater filter, using a sand bed above an underdrain system. Stormwater enters the SFB at its forebay where trash and sediment accumulate or through overland sheet flow. Overland sheet flow into the Sand Filter Basin is biofiltered through the vegetated side slopes or other pre-treatment. Flows pass into the sand filter surcharge zone and are gradually filtered through the underlying sand bed. The underdrain gradually dewaters the sand bed and discharges the filtered runoff to a nearby channel, swale, or storm drain.

Sand Filter (no forebay) -
Photo courtesy of Colorado UDFCD

The primary advantage of the SFB is its effectiveness in removing pollutants where infiltration into the underlying soil is not practical, and where site conditions preclude the use of a Bioretention Facility . The primary disadvantage is a potential for clogging if silts and clays are allowed to flow into the SFB. In addition, this BMP's performance relies heavily on its being regularly and properly maintained.

While this BMP is not currently considered an LID BMP, when designed in accordance with this manual, a Sand Filter Basin is considered to be a highly effective Treatment Control BMP.

Siting Considerations

SFBs should be avoided where onsite configurations include a base flow and/or where this BMP would be put into operation while construction, grading or major landscaping activities are taking place in the tributary catchment. **This BMP has a flat surface area**, so it may be challenging to incorporate into steeply sloping terrain. SFBs should be set away from areas that could discharge fine sediments into the basin such as at the bottom of a slope. **See Section 1 of Riverside County Flood Control and Water Conservation District's "Basin Guidelines" (Appendix C) for additional requirements** (i.e., fencing, maintenance access, etc.) or other guidelines issued by the Engineering Authority (EA)[1].

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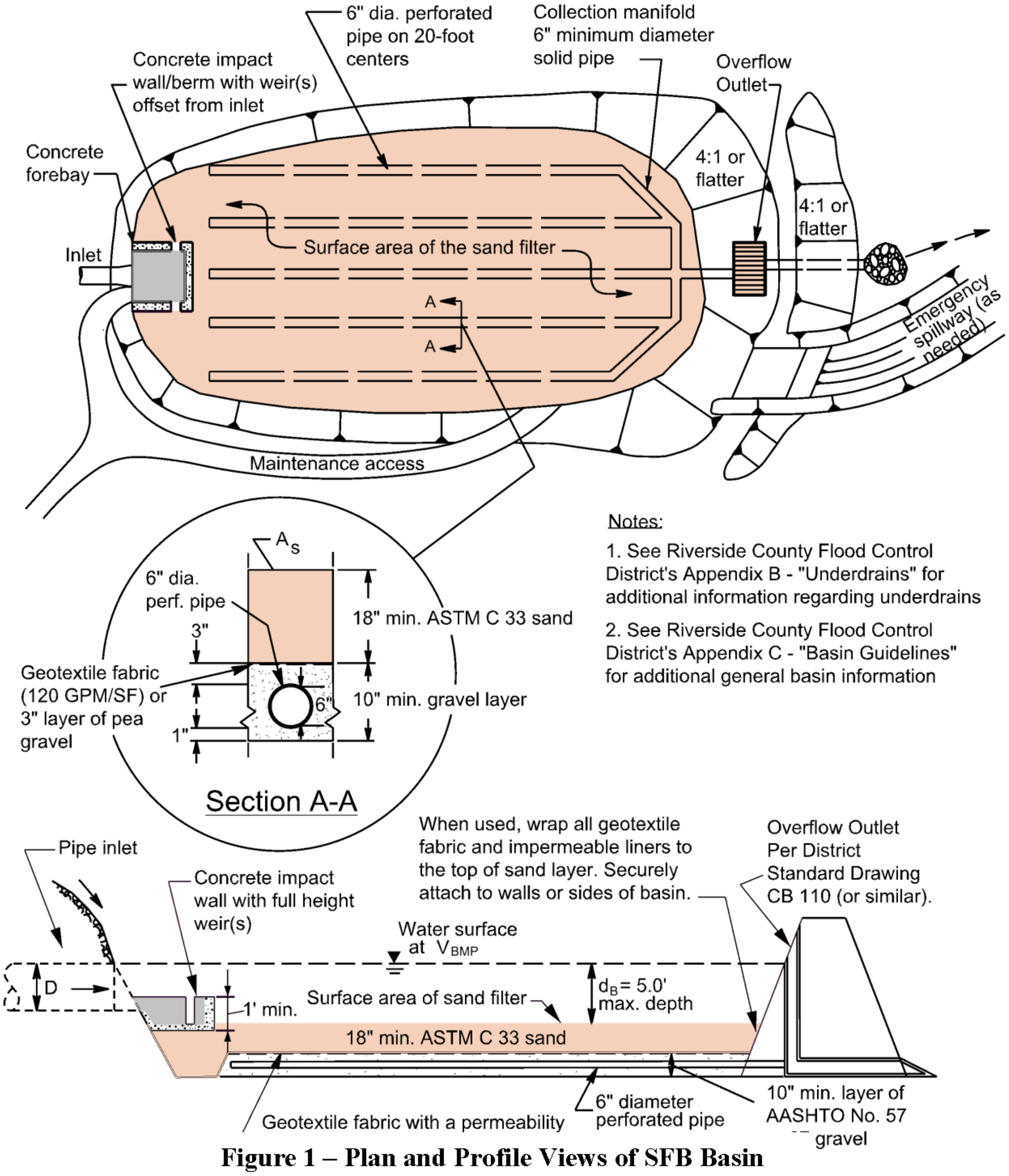
[1] The Engineering Authority (EA) may choose to alter these guidelines and may have different/additional requirements. These entities, along with the District, will be referred to as the EA

Setbacks

The bottom of the sand filter should remain above the seasonal high groundwater level. Always consult your geotechnical engineer for additional site-specific recommendations.



Notes:

1. See Riverside County Flood Control District's Appendix B - "Underdrains" for additional information regarding underdrains
2. See Riverside County Flood Control District's Appendix C - "Basin Guidelines" for additional general basin information

Figure 1 – Plan and Profile Views of SFB Basin

Forebay

A concrete forebay shall be provided to reduce sediment clogging and to reduce erosion. The forebay shall have a design volume of at least 0.5% V_{BMP} and a minimum 1 foot high concrete splashwall. Full height notch-type weir(s), offset from the line of flow from the basin inlet to prevent short circuiting shall be used to outlet the forebay. It is recommended that two weirs be used and that they be located on opposite sides of the forebay (see Figure 1).

Underdrains

Underdrain piping shall consist of a manifold (collector) pipe with perforated lateral branching. The lateral branching conveys the filtered water to the manifold where it is discharged into the outlet structure. See Appendix B for additional information.

Overflow Structure

An overflow must be provided to drain volume in excess of V_{BMP} or to help drain the system if clogging were to occur. Overflows shall flow to an acceptable discharge point such as a downstream conveyance system. Overflows must be placed above the water quality capture volume and near the outlet of the system. The overflow structure shall be similar to the District's Standard Drawing CB 110.

Recommended Maintenance

Table 1 - Recommended Inspection and Maintenance Activities for SFBs

Schedule	Inspection and Maintenance Activity
Semi-monthly including just before the annual storm season and following rainfall events.	• Routine maintenance and inspection. • Remove debris and litter from the entire basin to minimize filter clogging and to improve aesthetics. • Check for obvious problems especially filter clogging and signs of long term ponding. Repair as needed. Address odor, insects, and overgrowth issues associated with stagnant or standing water in the basin bottom. There should be no long-term ponding water. • Check for erosion and sediment laden areas in the basin. Repair as needed. Clean forebay if needed. • Revegetate side slopes where needed.
Annually. If possible, schedule these inspections within 72 hours after a significant rainfall.	• Inspection of hydraulic and structural facilities. Examine the overflow outlet for clogging, the embankment and spillway integrity, and damage to any structural element. • Check side slopes and embankments for erosion, slumping and overgrowth. • Inspect the sand media at the filter drain to verify it is allowing acceptable infiltration. **Scarify the top 3 inches by raking the filter drain's sand surface annually.** • Check the filter drain underdrains for damage or clogging. Repair as needed. • Repair basin inlets, outlets, forebays, and energy dissipaters whenever damage is discovered. • No water should be present 72 hours after an event. No long term standing water should be present at all. No algae formation should be visible. Correct problem as needed.
Every 5 years or sooner depending on the observed drain times (no more than 72 hours to empty the basin).	• Remove the top 3 inches of sand from the filter drain and backfill with 3 inches of new sand to return the sand layer to its original depth. When scarification or removal of the top 3 inches of sand is no longer effective, remove and replace sand filter layer.

Table 2 - Design and Sizing Criteria for SFBs

Design Parameter	Extended Detention Basin
Maximum tributary area	25 acres [2]
Basin design volume	100% of V_{BMP}
Maximum basin depth	5 feet
Forebay volume	0.5 % of V_{BMP}
Longitudinal Slope	0%
Transverse Slope (min.)	0%
Outlet erosion control	Energy dissipaters to reduce velocities[1]

1. **Ventura County's Technical Guidance Manual for Stormwater Quality Control Measures**
2. **CA Stormwater BMP Handbook for New Development and Significant Redevelopment**

Note: The information contained in this BMP Factsheet is intended to be a summary of design considerations and requirements. Additional information which applies to all detention basins may be found in the District's "Basin Guidelines" (Appendix C). In addition, information herein may be superseded by other guidelines issued by the EA.

Design Procedure

1. Enter the Tributary Area, A_{TRIB}
2. Enter the Design Capture Volume, V_{BMP}, determined from Section 2.1 of this Handbook
3. SFB Geometry

   Determine the minimum sand filter area required. The filtration bed surface shall be flat with the maximum depth for the reservoir design volume no greater than 5 feet*. The reservoir design volume does not include the volume of the sand filter. No credit is given for voids in the sand layer toward the reservoir volume since the sand is part of the water quality filter and not a reservoir layer. The design storage volume shall equal 100 percent of V_{BMP}. The minimum sand filter area (As) of the basin's bottom shall be determined using the equation:

   $$A_s = (V_{BMP}/ d_B)$$

   Where:

   V_{BMP} = Design Volume, ft^3
   d_B = proposed basin depth (5 feet maximum), ft

   Once the basin side slopes, proposed basin depth and depth of freeboard are entered, the spreadsheet will calculate the minimum total depth required to use this BMP. This is the depth from the top of the basin (including freeboard) down to the bottom of the underdrain gravel layer. This depth can be used to determine if enough vertical separation is available between the BMP and its outlet destination.

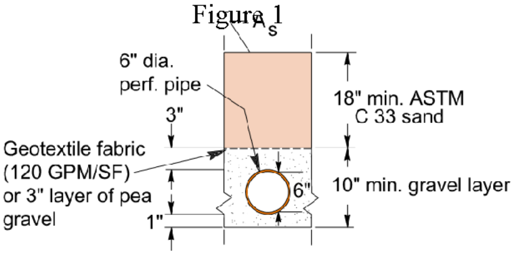
*Note: The 5 foot maximum depth equates to a minimum filter media infiltration rate of 0.83 inches per hour with a 72 hour drawdown time. Studies have shown that while initially most filter media will infiltrate at a much higher rate, it is not uncommon for that rate to decrease significantly over a very short period of time. (Urbonas, 1996)

4. Enter the proposed surface area of the basin.

5. Forebay

   Provide a concrete forebay. Its volume shall be at least 0.5% V_{BMP} with a minimum 1 foot high concrete splashwall. Full-height notch-type weir(s) shall be used to outlet the forebay. The weir(s) must be offset from the line of flow from the basin inlet. It is recommended that two weirs be used and that they be located on opposite sides of the forebay (see Figure 1). Notches shall not be less than 1.5 inches in width.

Figure 1



6. Filter Media

   Provide, as a minimum, an 18-inch layer of filter media (ASTM C-33 sand). Other filter media may be considered with sufficient supporting documentation. Where a medium level of removal efficiency is desired for nutrients, the depth of the sand layer must be increased to 36 inches.

5. Underdrains

   Underdrains shall be provided per the guidelines outlined in Appendix B.

Sand Filter Basin (SFB) - Design Procedure

BMP ID

Legend: Required Entries
Calculated Cells

Company Name:
Designed by:

Date:
County/City Case No.:

Design Volume

Total Tributary area A_{TRIB} = ac

Enter V_{BMP} determined from Section 2.1 of this Handbook V_{BMP}= ft^3

Basin Geometry

Basin side slopes (no steeper than 4:1) z = :1

Proposed basin depth (see Figure 1) d_B = ft

Depth of freeboard (if used) d_{fb} = ft

Minimum bottom surface area of basin ($As = V_{BMP}/d_B$) A_s = ft^2

Minimum total depth required (includes freeboard, filter media and subdrains) d_{req} = ft

Proposed Surface Area ft^2

Forebay

Forebay volume (minimum 0.5% V_{BMP}) Volume = ft^3

Forebay depth (height of berm/splashwall. 1 foot min.) Depth = ft

Forebay surface area (minimum) Area = ft^2

Full height notch-type weir Width (W) = in

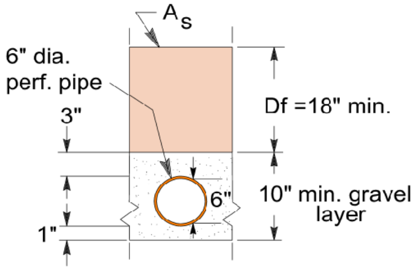
Filter Media

Description of filter media

Sand (ASTM C-33)

Other (Clarify in "Notes" below)

Media depth, df = inches



Underdrains

Diameter of perforated underdrain in

Spacing of underdrains (maximum 20 feet on center) OK ft

Notes:

3.12 Harvest and Use BMPs

Type of BMP	Site Design – Harvest and Use
Treatment Mechanisms	Volume Reduction
Infiltration Rate Range	Any infiltration rate, when applicable and feasible
Maximum Drainage Area	This BMP is generally limited by the cistern / detention storage volume

Description

Harvest and use BMPs include both above-ground and underground cisterns / vaults. Such BMPs collect and temporarily store runoff for later non-potable uses including the following:

- Irrigation
- Toilet flushing
- Other non-potable uses, such as industrial processes

Above-ground cisterns collect and temporarily store runoff from rooftops or other above-ground impervious surfaces. Underground cisterns include subsurface tanks, vaults and oversized pipes that temporarily store runoff for later use. These systems can include pipes that divert runoff to the cistern, an overflow system for when the cistern is full, a pump, and a distribution system to supply the intended uses.

Siting Considerations

- The primary feasibility consideration for harvest and use BMPs is the presence of a consistent and reliable demand that is sufficient to drain the BMPs between storms. When designing harvest and use systems for stormwater management, a reliable method of quickly regenerating storage capacity (through the use of the captured stormwater) must exist to ensure that there will be adequate storage capacity for subsequent storms in the wet season.
- Other feasibility considerations include potential conflicts with health and plumbing codes. Applicable health codes focus mainly on the potential impacts of long-term standing water in the BMP facility.
- For above-ground cisterns, the facilities should be installed on a level surface, either on consolidated and stable native soil, or on a concrete pad. A geotechnical analysis is required to ensure stability.
- For underground detention facilities, **pretreatment** must be provided where necessary or as directed by the Engineering Authority, to prevent accumulation of sediments within the BMP. These facilities should be installed on consolidated and stable native soil. A geotechnical analysis is required to ensure stability.

Key Design Elements

- All cisterns must:
    - Have provisions for mosquito prevention and abatement.
    - Have mechanisms to keep debris and animals from entering the cistern, and have a mechanism to easily clean any/all screens.
    - Have provisions for safe overflow of runoff when the cistern is full. Overflow shall be directed to an appropriate area as approved by the Engineering Authority. Dispersion within vegetated areas is preferred.
    - Have adequate access to maintain and/or replace the cistern and all associated equipment such as pumps. For underground cisterns / vaults, this includes access adequate to remove any/all accumulated sediment.
    - Be designed in a manner that allows for supplemental potable water to be used when there is insufficient harvested water to fully meet required demands.
    - Include measures acceptable to the local water supplier to prevent harvested storm water from being introduced into the potable water supply.

See the following figures for *examples* of common elements of above-ground and underground cisterns. The proposed design elements and configurations must be approved by the Engineering Authority.

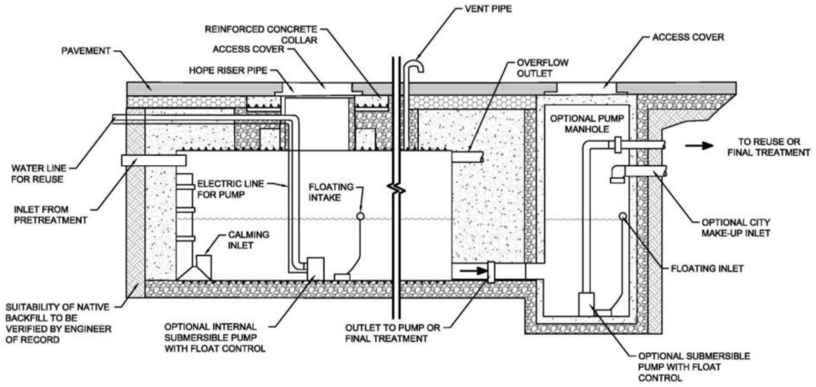


Figure 1 – Common Design Elements of Underground Cistern

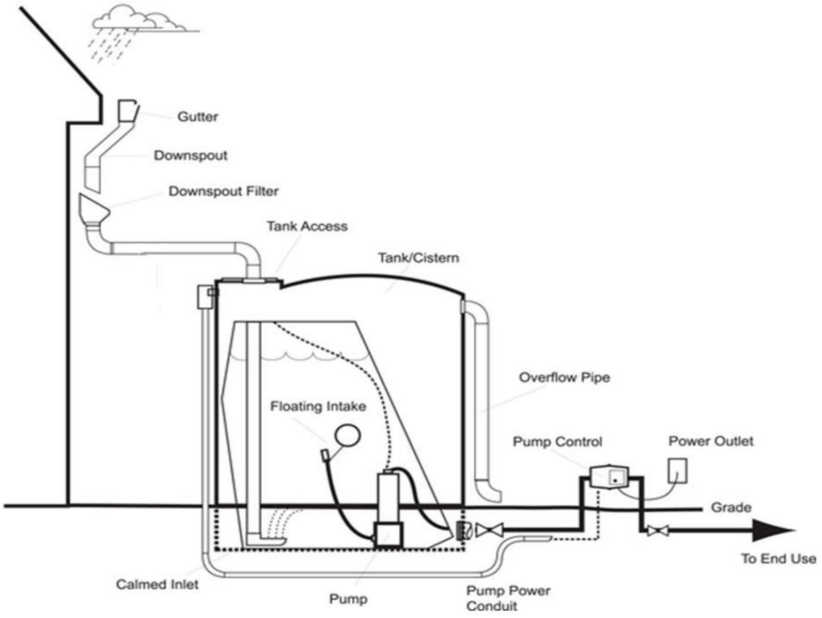


Figure 2 – Common Design Elements of Above-ground Cistern
Graphic courtesy of BRAE

HARVEST AND USE BMP FACT SHEET

Design and Sizing Criteria

1. Assess whether there is sufficient and reliable (year-round) demand for non-potable use of the runoff from the area tributary to the BMP. Consider seasonal variations in demand for harvested water, such as irrigation needs during the wet season, periodic facility closures (such as for schools), etc. Verify with the Engineering Authority (EA) and the Santa Margarita Region (SMR) Water Quality Management Plan (WQMP) for applicability requirements / restrictions for this BMP. The following potential on-site uses for harvested rainwater are typically assessed:

   a. Irrigation use
   b. Toilet use
   c. Other non-potable uses (i.e. industrial use)

2. If there is a sufficient on-site demand for harvested rainwater acceptable to the Engineering Authority, determine the Design Capture Volume, V_{BMP}, determined from Section 2.1 of this Handbook.

3. Size the cistern to hold and allow for the use of the Design Capture Volume, in accordance with any manufacturer specifications.

Inspection and Maintenance Schedule

Schedule	Activity
Annually before the wet season	• Check for debris and sediment on screens and overflow facilities and remove where observed. • Verify proper operation of all pumps. • Check integrity of downspout connections to harvest and use BMPs • Check locking mechanisms on facility entry covers • Check integrity of mosquito screens
After storm events	• Check for long-term standing water in the facility. If standing water is observed more than 72 hours after the last storm event, monitor water levels, and verify that the water is being drawn down through the intended use of the water. If water is not properly being drawn down ensure that all pumps distribution systems are functioning correctly. Under no circumstances shall water retained within a cistern be pumped or otherwise drained in a manner that could allow a discharge to a street or storm drain. • Remove debris and sediment from screens and overflow facilities

APPENDIX A

Infiltration Testing

APPENDIX A - INFILTRATION TESTING

Infiltration BMPs use the interaction of chemical, physical, and biological processes between soil and water to filter out sediments and constituents from stormwater. Infiltration BMPs require a maximum drawdown time to avoid nuisance issues. Since drawdown time is contingent on the infiltration rate of the underlying soil, tests are used to help establish the vertical infiltration rate of the soil below a proposed infiltration facility. The tests attempt to simulate the physical process that will occur when the facility is in operation.

Section 1 - General Requirements

1.1 - Summary of Requirements

The following is a brief summary of the requirements for all infiltration test reports submitted to the Engineering Authority (EA)[1] for the purpose of water quality BMP design. A checklist form is included at the end of this document.

1. Where infiltration testing is to be performed (as directed by the EA or in the WQMP), the measured infiltration rate of the underlying soil must be determined using either the single ring infiltrometer test (as described in ASTM D 5126, Section 4.1.2.1), the double ring infiltrometer test (ASTM D 3385), the well permeameter method (USBR 7300-89), or a percolation test per County of Riverside Department of Environmental Health (RCDEH) test procedures. A general explanation of these test methods can be found in Section 2 of this appendix. The minimum number of tests required can be found in Table 1 and is dependent upon the type of infiltration test performed.

2. Test pits and borings (ASTM D 1452) may be used to determine the USCS series and textural class (SM, CL, etc.) of the soil horizons, the thickness of soil and rock strata, and to estimate the historical high groundwater mark[2]. Test pits or boring logs must be of sufficient depth to establish that a minimum of 5 feet of permeable soil exists below the infiltration facility and that there is a minimum of 10 feet between the bottom of the infiltration facility and the historical high groundwater mark (Sections 1.7 and 2.5). The required number of test pits or borings are listed in Table 1.

3. A final report, prepared by a registered civil engineer, geotechnical engineer, certified engineering geologist or certified hydrogeologist shall be provided to the EA which demonstrates through infiltration testing and/or soil logs that the proposed facility location is suitable for the proposed infiltration facility and an infiltration rate shall be recommended. In addition, any requirements associated with impacts to a landslide, erosion or steep slope hazard area should also be addressed in the final report. (Section 1.7)

[1] *County Transportation, Coachella Valley Water District and the City Engineer for incorporated cities within the County may choose to alter these guidelines and may have different/additional requirements. These entities, along with the District, will be referred to as the Engineering Authority (EA).*

[2] *The "historical high groundwater mark" is defined as the groundwater elevation expected due to a normal wet season and shall be obtained by boring logs or test pits.*

4. Tests may be performed only by individuals trained and educated to perform, understand and evaluate the field conditions. The individual(s) supervising the field work must be named in the final report as described in Item 3. (Section 1.7)

5. Preliminary site grading plans shall be provided to the EA showing the proposed BMP locations along with section views through each BMP clearly identifying the extents of cut/fill relative to native soil. (See Section 1.1)

6. For sites where infiltration BMPs have been determined to be feasible and will be used, infiltration tests shall be performed within the boundaries of the proposed infiltration BMP and at the bottom elevation (infiltration surface) of the proposed infiltration BMP to confirm the suitability of infiltration. (See Photo 5)

A Note on “Infiltration Rate” vs. “Percolation Rate”

A common misunderstanding exists that the “percolation rate” obtained from a percolation test is equivalent to the “infiltration rate” obtained from a single or double ring infiltrometer test. While the percolation rate is related to the infiltration rate, percolation rates tend to overestimate infiltration rates and can be off by a factor of ten or more. However, as is discussed in Section 2.3, the percolation rate can be converted to a reasonable estimate of the infiltration rate using the Porchet Method.

1.2 Applicability of Infiltration BMPs

The WQMP guidance applicable to a project (based on the watershed location of the project), may include specific criteria for evaluating whether infiltration BMPs are feasible for a particular project. Where the WQMP requires that infiltration testing be performed as part of an infiltration feasibility evaluation, a testing method approved by the EA shall be used. The District requires the use of the methods described in Section 2 herein. The remainder of Section 1 herein describes requirements that must be implemented whenever an infiltration BMP is to be implemented.

1.3 - Grading Plans

Many projects require a significant amount of grading prior to their construction. It is important to determine if the BMP will be placed in cut or fill since this may affect the performance of the BMP or even the soil. As such, preliminary site grading plans showing the proposed BMP locations are required along with section views through each BMP clearly identifying the extents of cut or fill. In addition, since it is imperative that any testing be performed at the proper elevations and locations, it is highly recommended that the preliminary site grading plans be provided to the engineer/geologist prior to any tests being performed.

1.4 - Cut Condition

Where the proposed infiltration BMP is to be located in a cut condition, the infiltration surface level at the bottom of the BMP might be far below the existing grade. For example, if the infiltration surface of a proposed BMP is to be located at an elevation that is currently beneath 15 feet of cut, how can the proposed infiltration surface be tested?

In order to determine an infiltration rate where the proposed infiltration surface is in a cut condition, the following procedures may be used:

1. The USBR 7300-89, "Procedure for Performing Field Permeability Testing by the Well Permeameter Method" (Section 2.4). Note: the result must be converted to an infiltration rate.
2. The Percolation Test per RCDEH (Section 2.3) may be used. Note: the result must be converted to an infiltration rate.

Refer also to the WQMP guidance document applicable to the project, which may identify applicability criteria for infiltration BMPs in cut conditions.

1.5 - Fill Condition

If the bottom of a BMP (infiltration surface) is in a fill location, the infiltration surface may not exist prior to grading. How then can the infiltration rate be determined? For example, if a proposed infiltration BMP is to be located in 12 feet of fill, how could one reasonably establish an infiltration rate prior to the fill being placed?

Unfortunately, no reliable assumptions can be made about the in-situ properties of fill soil. As such, the bottom, or rather the infiltration surface of the BMP, must extend into natural soil. The natural soil shall be tested at the design elevation prior to the fill being placed.

In some cases, the extension of the BMP down to natural soil may prove infeasible. In that case, another BMP must be selected.

1.6 - Factors of Safety

Long term monitoring has shown that the performance of working full-scale infiltration facilities may be far lower than the rate measured by small-scale testing. There are several reasons for this:

- Over time, the surface of infiltration facilities can become plugged as sedimentary particles accumulate at the infiltration surface.
- Post-grading compaction of the site can destroy soil structure and seriously impact the facility's performance.

- Soils and soil strata are rarely homogenous, and variations across a site, and sometimes even within a BMP footprint, can cause tested infiltration rates to vary widely.
- Testing procedures in general are subject to natural variations and errors which can skew the results.

As such, to obtain an appropriate level of confidence in the final design infiltration rate, factors of safety shall be applied to the tested infiltration rate, I_t, in order to determine the design infiltration rate, I_d. These factors are based on such considerations as the type of tests used, the number of tests performed and whether testing is performed at all. Table 1 provides a complete matrix of testing requirements versus factors of safety.

1.7 - Infiltration Testing Requirements

Table 1 is a list of infiltration BMPs with test regime options and their corresponding design factors of safety. The options are summarized below:

Option 1- This test regime includes ring infiltrometer type tests, test pit or boring logs and a final report. The minimum required number of tests is as described in Table 1. The minimum required factor of safety for this option is FS=3.

Option 2- This test regime includes percolation type tests, test pit or boring logs and a final report. The minimum required number of tests is as described in Table 1. The minimum required factor of safety for this option is FS=3.

Option 3- This test regime includes test pit or boring logs only and a final report. The minimum required number of tests is as described in Table 1. An expected infiltration rate shall be included in the final report based on the specifics of the borings or test pits. The minimum required factor of safety for this option is FS=6. This option may be used for projects with a maximum tributary area of 5 acres only.

Option 4- This test regime includes a single test pit or boring log at any representative location on the project site. Plates E-6.1 and E-6.2 of the Riverside County Flood Control and Water Conservation District's (RCFCD) Hydrology Manual shall then be used to establish an approximate infiltration rate based on the appropriate Runoff Index and the Antecedent Moisture Content (AMC) as defined on page C-3 of the Hydrology Manual. The minimum required factor of safety for this option is FS=10.

Table 1 - Infiltration Testing Requirements							
Infiltration BMP	Testing Options	Ring Infiltrometer Tests(1)	Percolation Test(2)	Test Pits or Boring Logs(3)	Final Report(4)	Hydrology Manual(5)	Factor of Safety
Infiltration Trench	Option 1►	2 tests min. with at least 1 per trench	not used	1 boring or test pit per trench	Required	not used	FS = 3
	Option 2►	not used	4 tests min. with at least two per trench	1 boring or test pit per trench	Required	not used	FS = 3
	Option 3(7)►	not used	not used	1 boring or test pit per trench	Required	not used	FS = 6
	Option 4►	not used	not used	1 boring or test pit per site	not used	only	FS = 10
Infiltration Basin	Option 1►	2 tests min. with at least 1 per basin(6)	not used	1 boring or test pit per basin	Required	not used	FS = 3
	Option 2►	not used	4 tests min. with at least 2 per basin(6)	1 boring or test pit per trench	Required	not used	FS = 3
	Option 3(7)►	not used	not used	1 boring or test pit per basin	Required	not used	FS = 6
	Option 4►	not used	not used	1 boring or test pit per site	not used	only	FS = 10
Permeable Pavement	Option 1►	2 tests min. with at least 1 every 10,000 ft^2	not used	1 boring or test pit every 10,000 ft^2	Required	not used	FS = 3
	Option 2►	not used	4 tests min. with at least 2 every 10,000 ft^2	1 boring or test pit every 10,000 ft^2	Required	not used	FS = 3

Table Footnotes:

(1) Ring Infiltrometer tests per Section 2.2

(2) Percolation tests per Section 2.3 and Well Permeameter Test per Section 2.4

(3) Test pits or boring logs per Section 2.5

(4) Final Report per Section 1.7

(5) See Plate E-6.2 of the District's Hydrology Manual

(6) For basins in excess of 10,000 ft^2, provide one (1) ring infiltrometer test or two (2) percolation tests for each additional 10,000 ft^2

(7) This option may be used for projects with a maximum tributary area of 5 acres only.

1.8 - Final Report

Where a final report is required, a civil engineer, geotechnical engineer, certified engineering geologist or certified hydrogeologist shall establish whether the location is suitable for the proposed infiltration facility. At least 5 feet of permeable soil must be present below the infiltration facility and a minimum of 10 feet between the bottom of the infiltration facility and the historical high groundwater mark[1] is required. The signed/stamped report shall include discussion and records of the infiltration testing as well as boring log findings. Based on the results of these tests, the report shall provide an estimate of the infiltration rate found at the location of each proposed infiltration BMP in units of inches per hour. The factor of safety specified in Table 1 will be applied to the interpreted test results to determine the design infiltration rate for each infiltration BMP. Any requirements associated with impacts to an erosion hazard area, steep slope hazard area, or landslide hazard area should also be addressed in the report. In addition, the report shall include complete field records with the following information:

- Location of the test site.
- Dates of test, start and finish.
- Weather conditions, start to finish.
- Names(s) of technician(s).
- Description of test site, including assessment of boring profile and USCS soil classification.
- Depth to the water table and a description of the soils to a depth of at least 10 feet below proposed infiltration surface.
- Type of equipment used to construct the boreholes or test holes (such as backhoe, hollow stem auger, etc.)
- Areas of the rings (if used) or test hole diameter.
- Volume constants for graduated cylinder or Mariotte tube (if used).
- Complete field results in tabular format. Sample test data forms, as well as examples, have been provided following the description of each test in Section 2.
- A plot of the infiltration rate versus total elapsed time. An example is provided following the description of each test in Section 2.
- A labeled keymap showing test and boring locations.
- Confirmation that the soil was pre-saturated in accordance with the testing methods described herein.

Section 2 - Accepted Testing Methods

There is a wide range of different methods for measuring the infiltration rate of a given soil with varying degrees of accuracy and reliability. However, the District will accept only the following test methods:

1. Single Ring Infiltrometer (Per ASTM D 5126), Section 2.1.1
2. Double Ring Infiltrometer (Per ASTM D 3385), Section 2.1.2
3. Well Permeameter Method (USBR 7300-89), Section 2.4
4. Percolation Test (per County of Riverside Department of Environmental Health procedure), Section 2.3

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[1] The "historical high groundwater mark" is defined as the groundwater elevation expected due to a normal wet season and shall be obtained by boring logs or test pits.

The following pages of this document provide an overview of these tests. It is recommended that the original Standards be referenced.

2.1 - Constant Head vs. Falling Head Method

There are two operational techniques used with all four of the testing techniques herein: the *constant head method* and the *falling head method*. With the *constant head method*, water is consistently added to both the outer and inner rings (ring infiltrometers) or to the test hole (pecolation test and well permeameter) to maintain a constant level throughout the testing. The volume of water needed to maintain the fixed level of the inner ring is measured. Conversely, in the *falling head method*, the water level is allowed to fall and the time that the water level takes to decrease is measured.

2.2 - Overview of Ring Infiltrometer Test Methods

Ring infiltrometers measure the rate of infiltration at the soil surface. Infiltration is influenced by both saturated hydraulic conductivity as well as capillary effects. The term *capillary effects* refers to the ability of dry soil to pull, or wick away, water from a zone of saturation faster than would occur if the soil were uniformly saturated. The magnitude of the capillary effect is determined by initial moisture content at the time of testing, the pore size, soil properties (texture, structure) and a number of other factors. The effects of capillarity are short lived and can greatly skew test results. As such, it is critical to obtain steady-state infiltration so that capillary effects are minimized. (ASTM 5126)

The ***single ring infiltrometer*** and ***double ring infiltrometer*** methods both employ the use of metal cylinders driven to shallow depths into the test soil. The rings are filled with water and the rate at which the water moves into the soil is measured. This rate becomes constant when the saturated hydraulic conductivity for the particular soil has been reached. This is reflected by the flattening out of the curve generated by sample test data as shown in Figure 2, “Plot of Infiltration Rate vs. Time”. While we note that infiltration rate is not exactly the same as saturated hydraulic conductivity, for the purposes of this guidance document they are synonymous.

2.2.1 - Single Ring Infiltrometers

Single ring infiltrometer tests using a ring 40 inches or larger in diameter have been shown to closely match full-scale facility performance (Figures 1 and 2, Photo 1). The cylindrical ring is driven approximately 12 inches into the soil. Water is ponded within the ring above the soil surface. The upper surface of the ring is often covered to prevent evaporation. Using the constant head method, the volumetric rate of water added to the ring, sufficient to maintain a constant head within the ring is measured. The test is complete and the tested infiltration rate, I_t, is determined after the flow rate has stabilized. (ASTM D 5126)

Photo 1 – Simple Single Ring Infiltrometer

To help maintain a constant head, a variety of devices may be used. A hook gauge, steel tape or rule, length of steel, or plastic rod pointed on one end can be used for measuring and controlling the depth of liquid (head) in the infiltrometer ring. If available, a graduated Mariotte tube or automatic flow control system may also be used. Care should be taken when driving the ring into the ground as there can be a poor connection between the ring wall and the soil. This poor connection can cause a leakage of water along the ring wall and an overestimation of the infiltration rate.

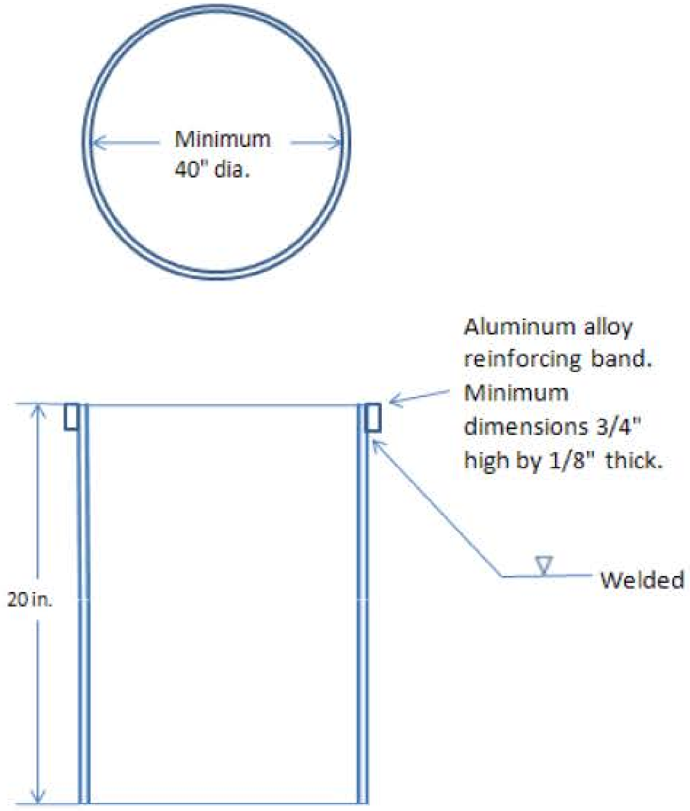
The volume of liquid used during each measured time interval may be converted into an incremental infiltration velocity (infiltration rate) using the following equation:

$$I_t = \Delta V/(A*\Delta t)$$

Where:

I_t = tested infiltration rate, in/hr
ΔV = volume of liquid used during time interval to maintain constant head in the ring, in^3
A = internal area of ring, in^2
Δt = time interval, hr.

Final Report - Ultimately, as discussed in Section 1.7, a final report shall be provided and, based on the test results, an infiltration rate shall be recommended.



Materials: 1/8" aluminum alloy sheet or material of similar strength

Figure 1- Single Ring Infiltrometer Construction

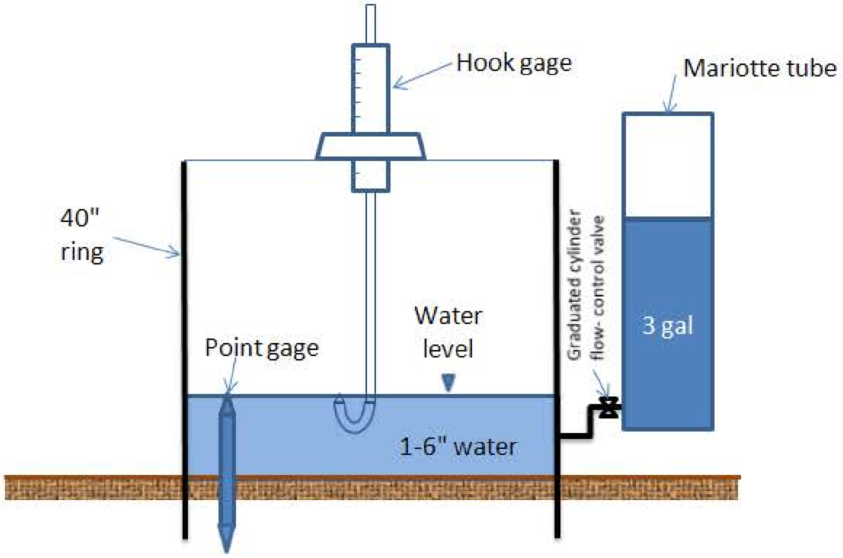
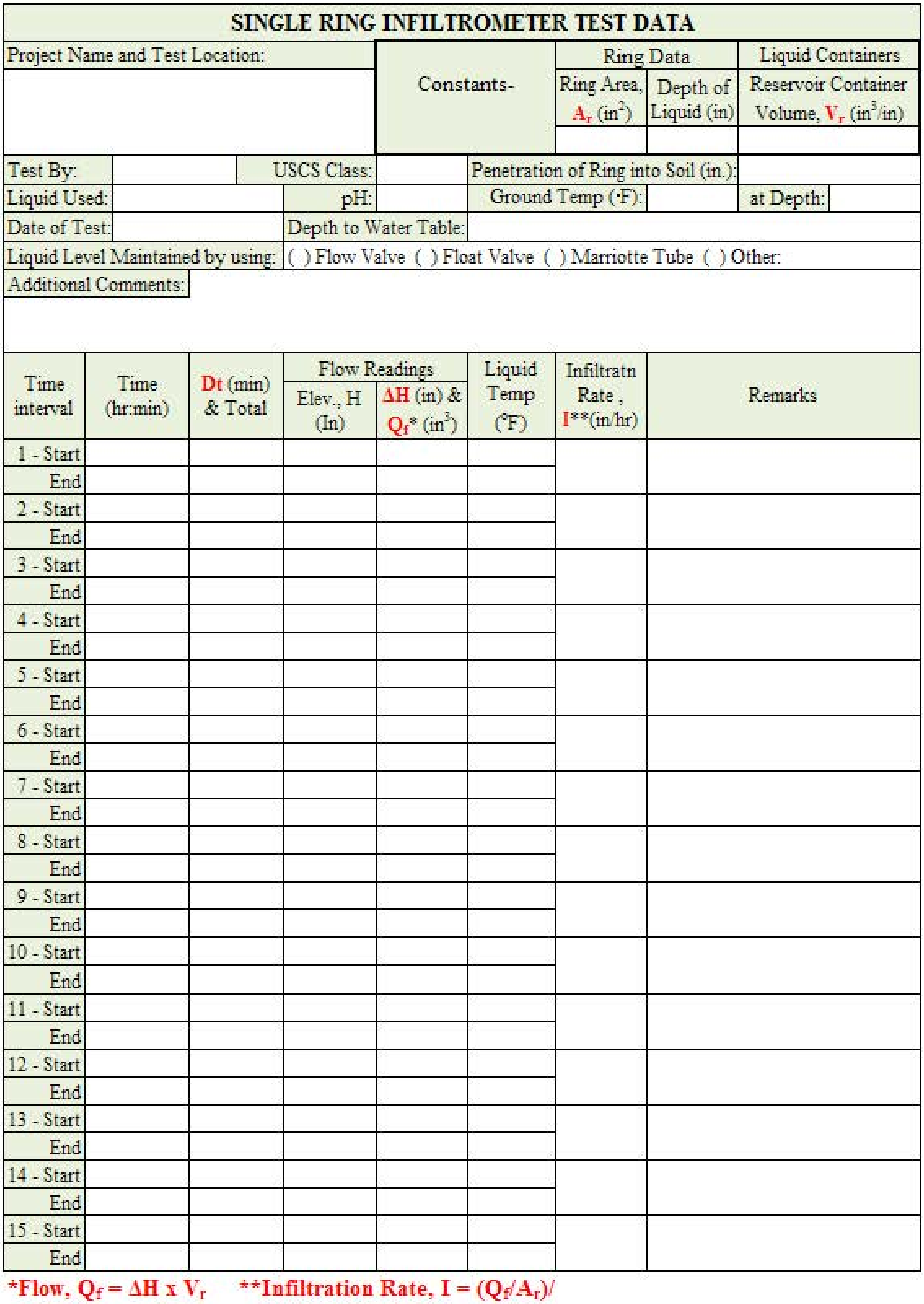


Figure 2- SIngle Ring Setup with Mariotte Tube



SINGLE RING INFILTROMETER TEST DATA

Project Name and Test Location:	Constants-	Ring Data		Liquid Containers
		Ring Area, A_r (in^2)	Depth of Liquid (in)	Reservoir Container Volume, V_r (in^3/in)

Test By: USCS Class: Penetration of Ring into Soil (in.):

Liquid Used: pH: Ground Temp (·F): at Depth:

Date of Test: Depth to Water Table:

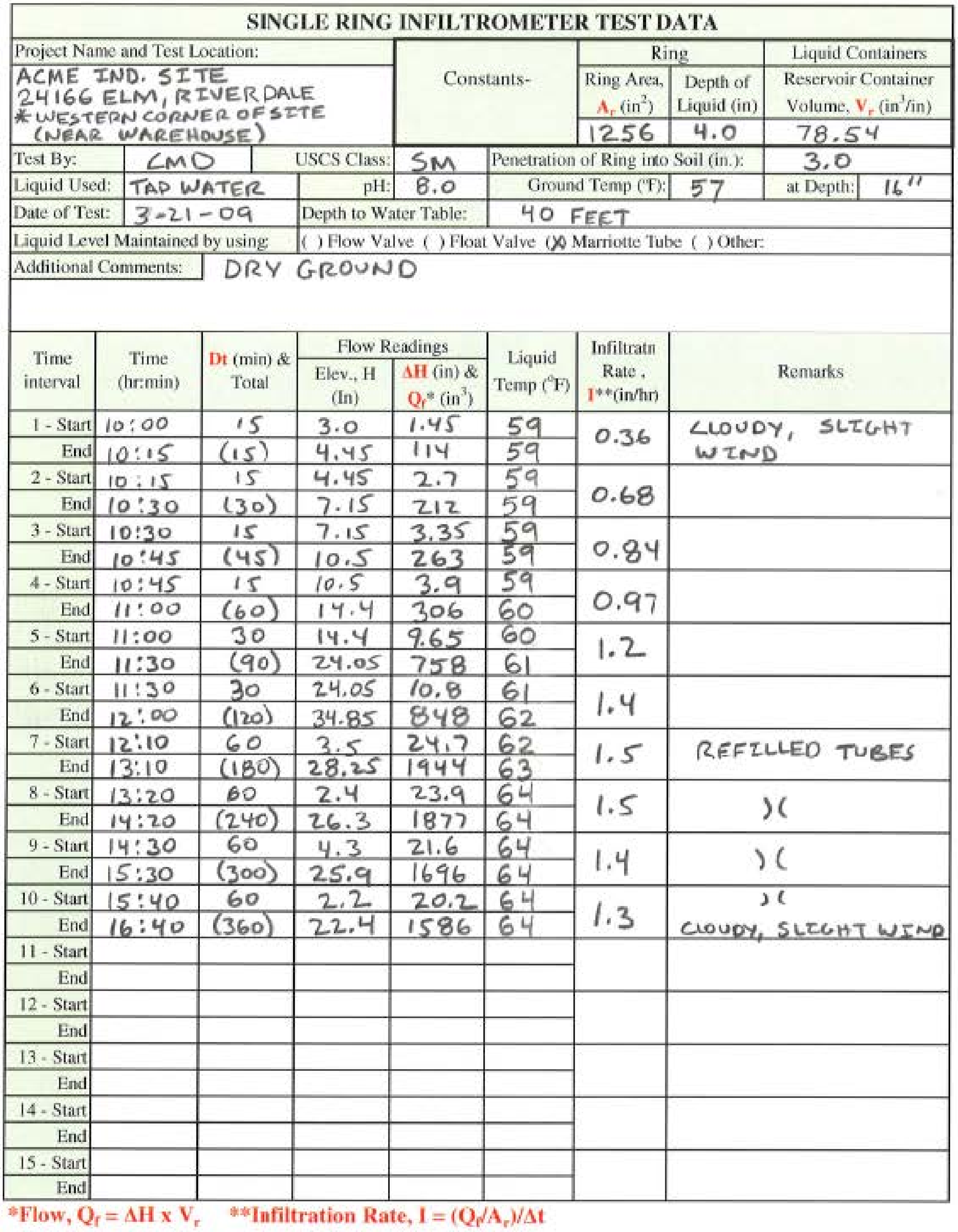
Liquid Level Maintained by using: ( ) Flow Valve ( ) Float Valve ( ) Marriotte Tube ( ) Other:

Additional Comments:

Time interval	Time (hr:min)	Dt (min) & Total	Flow Readings		Liquid Temp (°F)	Infiltratn Rate, I**(in/hr)	Remarks
			Elev., H (In)	ΔH (in) & Q_f* (in^3)			
1 - Start							
End							
2 - Start							
End							
3 - Start							
End							
4 - Start							
End							
5 - Start							
End							
6 - Start							
End							
7 - Start							
End							
8 - Start							
End							
9 - Start							
End							
10 - Start							
End							
11 - Start							
End							
12 - Start							
End							
13 - Start							
End							
14 - Start							
End							
15 - Start							
End							

***Flow, $Q_f = \Delta H \times V_r$** ****Infiltration Rate, $I = (Q_f/A_r)/$**

Table 2 – Sample Test Data Form for Single Ring Infiltrometer Test



SINGLE RING INFILTROMETER TEST DATA

Project Name and Test Location: ACME IND. SITE 24166 ELM, RIVERDALE *WESTERN CORNER OF SITE (NEAR WAREHOUSE)

Constants-

Ring		Liquid Containers
Ring Area, A_r (in^2)	Depth of Liquid (in)	Reservoir Container Volume, V_r (in^3/in)
1256	4.0	78.54

Test By: CMD　USCS Class: SM　Penetration of Ring into Soil (in.): 3.0

Liquid Used: TAP WATER　pH: 8.0　Ground Temp (°F): 57　at Depth: 16"

Date of Test: 3-21-09　Depth to Water Table: 40 FEET

Liquid Level Maintained by using: ( ) Flow Valve ( ) Float Valve (X) Marriotte Tube ( ) Other:

Additional Comments: DRY GROUND

Time interval	Time (hr:min)	Dt (min) & Total	Flow Readings		Liquid Temp (°F)	Infiltratn Rate, I**(in/hr)	Remarks
			Elev., H (In)	ΔH (in) & Q_f* (in^3)			
1 - Start	10:00	15	3.0	1.45	59	0.36	CLOUDY, SLIGHT WIND
End	10:15	(15)	4.45	114	59		
2 - Start	10:15	15	4.45	2.7	59	0.68	
End	10:30	(30)	7.15	212	59		
3 - Start	10:30	15	7.15	3.35	59	0.84	
End	10:45	(45)	10.5	263	59		
4 - Start	10:45	15	10.5	3.9	59	0.97	
End	11:00	(60)	14.4	306	60		
5 - Start	11:00	30	14.4	9.65	60	1.2	
End	11:30	(90)	24.05	758	61		
6 - Start	11:30	30	24.05	10.8	61	1.4	
End	12:00	(120)	34.85	848	62		
7 - Start	12:10	60	3.5	24.7	62	1.5	REFILLED TUBES
End	13:10	(180)	28.25	1944	63		
8 - Start	13:20	60	2.4	23.9	64	1.5	)(
End	14:20	(240)	26.3	1877	64		
9 - Start	14:30	60	4.3	21.6	64	1.4	)(
End	15:30	(300)	25.9	1696	64		
10 - Start	15:40	60	2.2	20.2	64	1.3	)(
End	16:40	(360)	22.4	1586	64		CLOUDY, SLIGHT WIND
11 - Start							
End							
12 - Start							
End							
13 - Start							
End							
14 - Start							
End							
15 - Start							
End							

*Flow, $Q_f = \Delta H \times V_r$　**Infiltration Rate, $I = (Q_f/A_r)/\Delta t$

FIGURE 3 – Sample Test Data

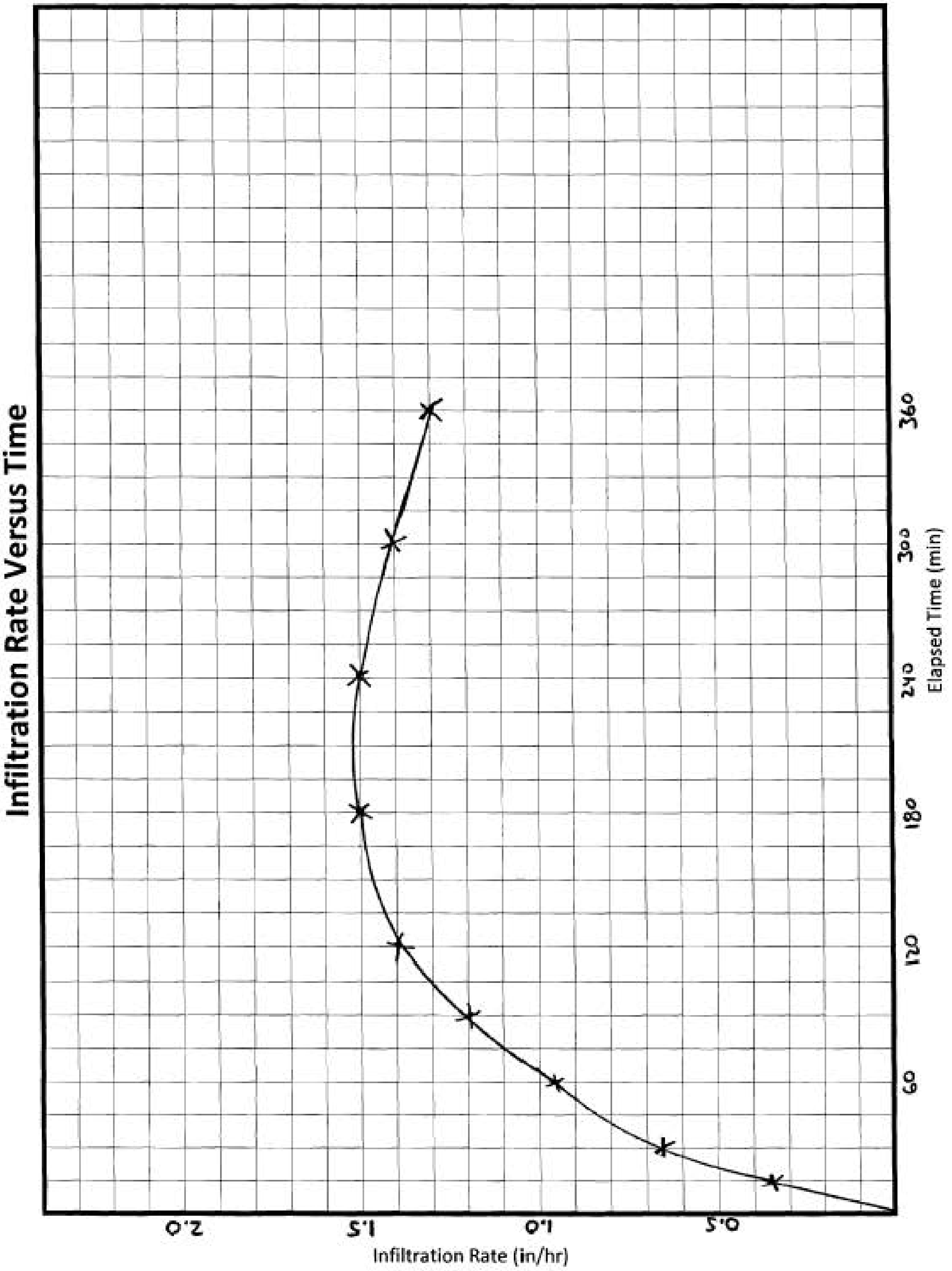


FIGURE 4 – Plot of Sample Test Data for Single Ring Infiltrometer Test

2.2.2 - Double Ring Infiltrometers

The ***double ring infiltrometer*** test (ASTM D 3385) is a well recognized and documented technique for directly measuring the soil infiltration rate of a site (see Figure 5, 6 and 7; Photos 2, 3, 4 and 5). Double ring infiltrometers were developed in response to the fact that smaller (less than 40 inch diameter) single ring infiltrometers tend to overestimate vertical infiltration rates. This has been attributed to the fact that the flow of water beneath the cylinder is not purely vertical and diverges laterally. Double ring infiltrometers minimize the error associated with the single-ring method because the water level in the outer ring forces vertical infiltration of water in the inner ring. Care should be taken when driving the rings into the ground as there can be a poor connection between the ring wall and the soil. This poor connection can cause a leakage of water along the ring wall and an overestimation of the infiltration rate. Another potential source of error is attributed to the size of the cylinders. As such, the use of cylinder sizes less than those prescribed in ASTM D 3385 is not recommended.

A typical double ring infiltrometer would consist of a 12 inch inner ring and a 24 inch outer ring. While there are two operational techniques used with the double-ring infiltrometer, the constant head method and the falling head method, ASTM D3385 mandates the use of the constant head method. With the constant head method, water is consistently added to both the outer and inner rings to maintain a constant level throughout the testing. The volume of water needed to maintain the fixed level of the inner ring is measured. To help maintain a constant head, a variety of devices may be used. A hook gauge, steel tape or rule, or length of steel or plastic rod pointed on one end, can be used for measuring and controlling the depth of liquid (head) in the infiltrometer ring. If available, a graduated Mariotte tube or automatic flow control system may also be used.

The volume of liquid used during each measured time interval may be converted into an incremental infiltration velocity (infiltration rate) using the following equation:

$$I_t = \Delta V/(A*\Delta t)$$

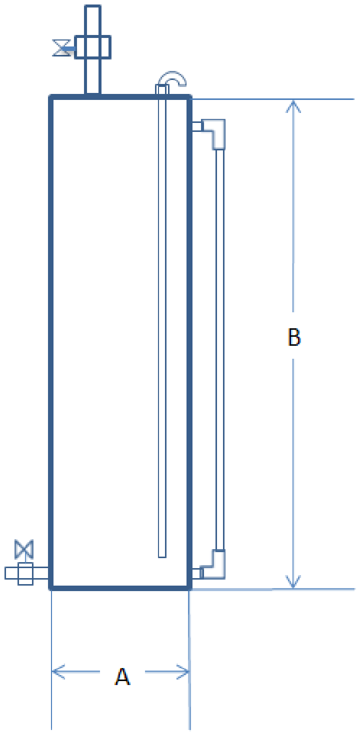
Where:

I_t = tested infiltration rate, in/hr
ΔV = volume of liquid used during time interval to maintain constant head in the inner ring, in^3
A = area of inner ring, in^2
Δt = time interval, hr.

Final Report - Ultimately, as discussed in Section 1.7, a final report shall be provided and, based on the test results, an infiltration rate shall be recommended.

Photo 2 – Simple Double Ring Infiltrometer

Photo 3 – Pre-fabricated Double Ring Infiltrometer
(Photo courtesy of Turf-Tec International)



Mariotte Tube
Useful Capacity

	1 gal	3 gal
A =	3 in.	6 in.
B =	18 in.	24 in.

Figure 5 - Mariotte Tube

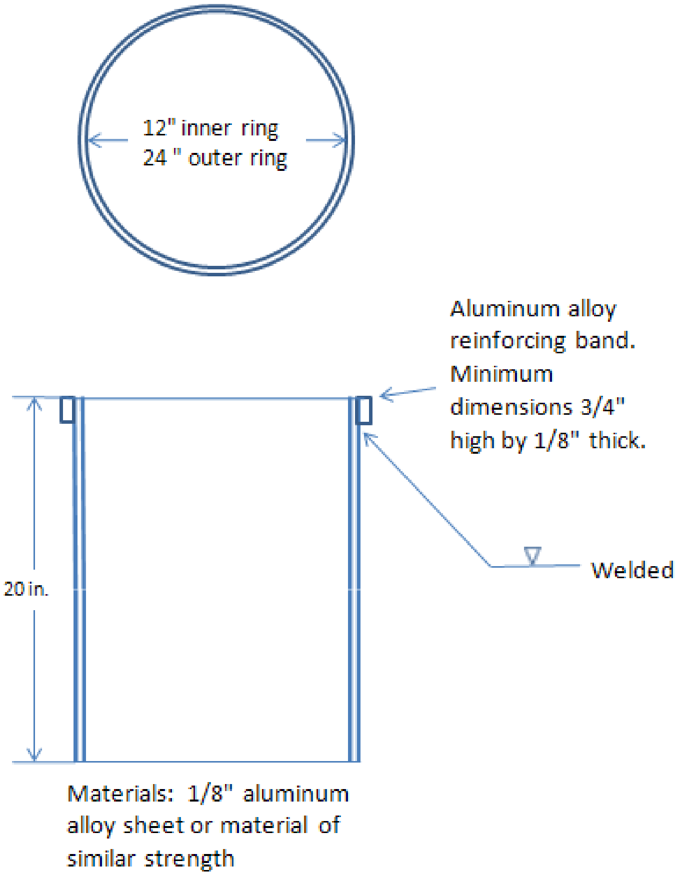


Figure 6- Double Ring Infiltrometer Construction

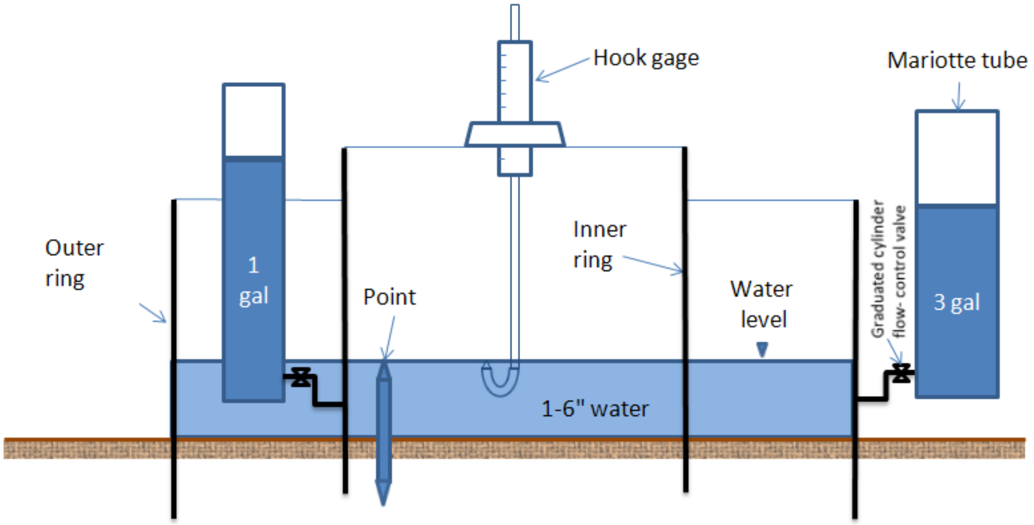
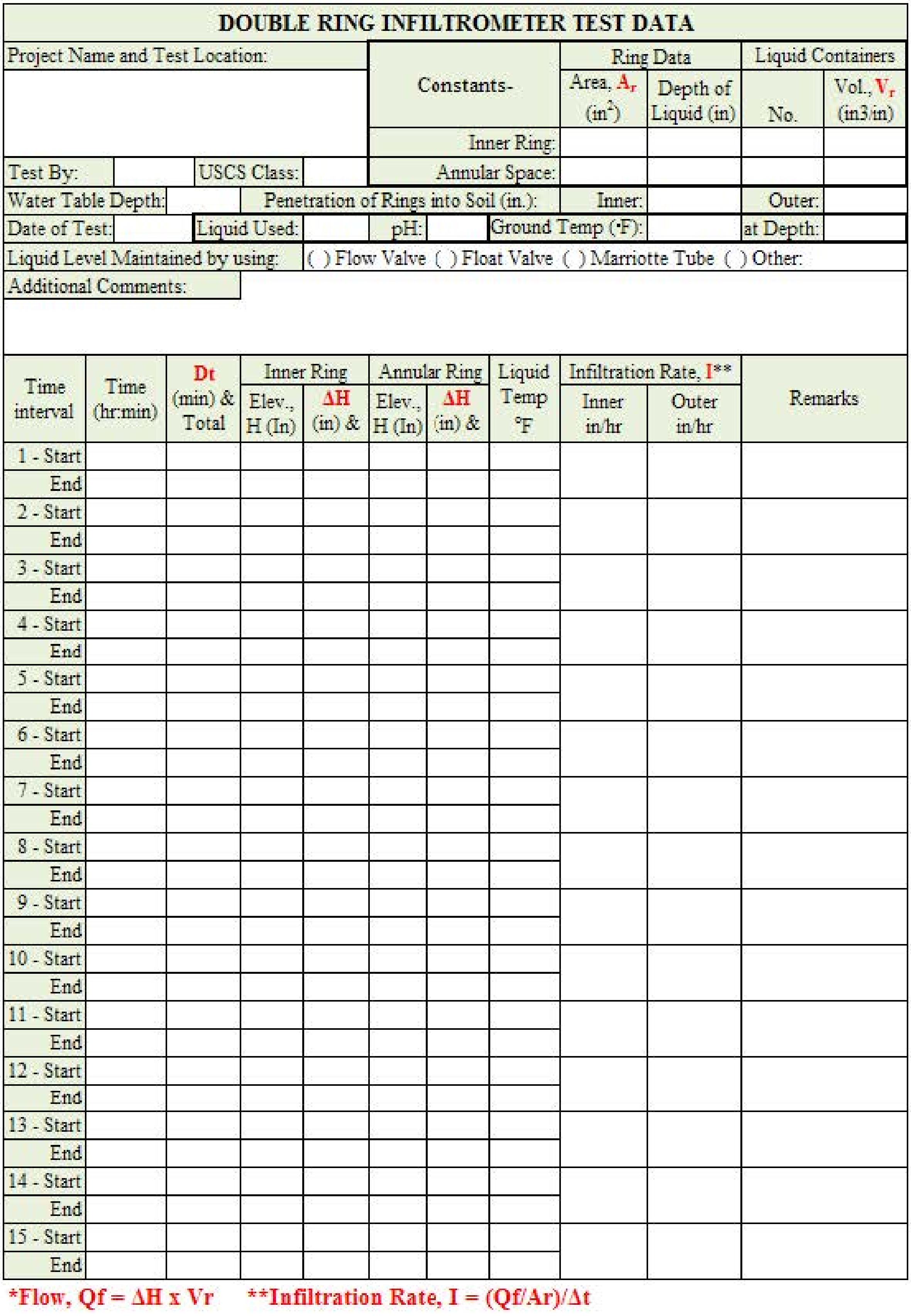


Figure 7- Double Ring Setup with Mariotte Tubes

Photo 4- Double Ring Infiltrometer Set-up with Mariotte Tubes (Photo courtesy of Turf-Tec International)

Photo 5 – Double Ring Infiltrometer Set-up for Test at Basin Surface Elevation (Photo courtesy of Turf-Tec International)



DOUBLE RING INFILTROMETER TEST DATA

Project Name and Test Location:

Constants-	Ring Data		Liquid Containers	
	Area, A_r (in^2)	Depth of Liquid (in)	No.	Vol., V_r (in3/in)
Inner Ring:				
Annular Space:				

Test By: USCS Class:

Water Table Depth: Penetration of Rings into Soil (in.): Inner: Outer:

Date of Test: Liquid Used: pH: Ground Temp (·F): at Depth:

Liquid Level Maintained by using: ( ) Flow Valve ( ) Float Valve ( ) Marriotte Tube ( ) Other:

Additional Comments:

Time interval	Time (hr:min)	Dt (min) & Total	Inner Ring		Annular Ring		Liquid Temp °F	Infiltration Rate, I**		Remarks
			Elev., H (In)	ΔH (in) &	Elev., H (In)	ΔH (in) &		Inner in/hr	Outer in/hr	
1 - Start										
End										
2 - Start										
End										
3 - Start										
End										
4 - Start										
End										
5 - Start										
End										
6 - Start										
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7 - Start										
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8 - Start										
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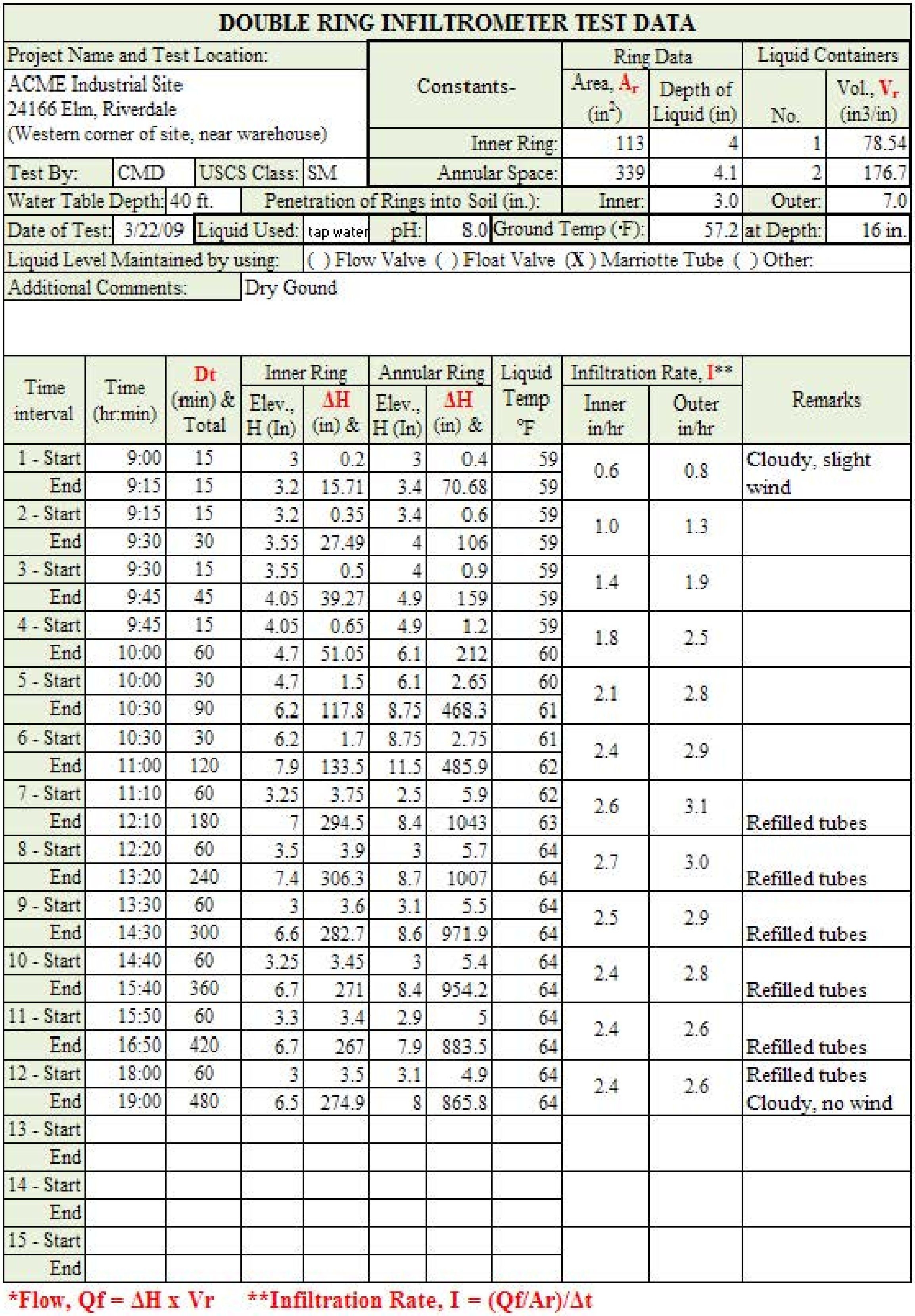
9 - Start										
End										
10 - Start										
End										
11 - Start										
End										
12 - Start										
End										
13 - Start										
End										
14 - Start										
End										
15 - Start										
End										

***Flow, Qf = ΔH x Vr** ****Infiltration Rate, I = (Qf/Ar)/Δt**

Table 3 – Sample Test Data Form for Double Ring Infiltrometer Test



DOUBLE RING INFILTROMETER TEST DATA

Project Name and Test Location:
ACME Industrial Site
24166 Elm, Riverdale
(Western corner of site, near warehouse)

Constants-	Ring Data: Area, A_r (in^2)	Ring Data: Depth of Liquid (in)	Liquid Containers: No.	Liquid Containers: Vol., V_r (in3/in)
Inner Ring:	113	4	1	78.54
Annular Space:	339	4.1	2	176.7

Test By: CMD USCS Class: SM

Water Table Depth: 40 ft. Penetration of Rings into Soil (in.): Inner: 3.0 Outer: 7.0

Date of Test: 3/22/09 Liquid Used: tap water pH: 8.0 Ground Temp (·F): 57.2 at Depth: 16 in.

Liquid Level Maintained by using: ( ) Flow Valve ( ) Float Valve (X) Marriotte Tube ( ) Other:

Additional Comments: Dry Gound

Time interval	Time (hr:min)	Dt (min) & Total	Inner Ring		Annular Ring		Liquid Temp °F	Infiltration Rate, I**		Remarks
			Elev., H (In)	ΔH (in) &	Elev., H (In)	ΔH (in) &		Inner in/hr	Outer in/hr	
1 - Start	9:00	15	3	0.2	3	0.4	59	0.6	0.8	Cloudy, slight wind
End	9:15	15	3.2	15.71	3.4	70.68	59			
2 - Start	9:15	15	3.2	0.35	3.4	0.6	59	1.0	1.3	
End	9:30	30	3.55	27.49	4	106	59			
3 - Start	9:30	15	3.55	0.5	4	0.9	59	1.4	1.9	
End	9:45	45	4.05	39.27	4.9	159	59			
4 - Start	9:45	15	4.05	0.65	4.9	1.2	59	1.8	2.5	
End	10:00	60	4.7	51.05	6.1	212	60			
5 - Start	10:00	30	4.7	1.5	6.1	2.65	60	2.1	2.8	
End	10:30	90	6.2	117.8	8.75	468.3	61			
6 - Start	10:30	30	6.2	1.7	8.75	2.75	61	2.4	2.9	
End	11:00	120	7.9	133.5	11.5	485.9	62			
7 - Start	11:10	60	3.25	3.75	2.5	5.9	62	2.6	3.1	
End	12:10	180	7	294.5	8.4	1043	63			Refilled tubes
8 - Start	12:20	60	3.5	3.9	3	5.7	64	2.7	3.0	
End	13:20	240	7.4	306.3	8.7	1007	64			Refilled tubes
9 - Start	13:30	60	3	3.6	3.1	5.5	64	2.5	2.9	
End	14:30	300	6.6	282.7	8.6	971.9	64			Refilled tubes
10 - Start	14:40	60	3.25	3.45	3	5.4	64	2.4	2.8	
End	15:40	360	6.7	271	8.4	954.2	64			Refilled tubes
11 - Start	15:50	60	3.3	3.4	2.9	5	64	2.4	2.6	
End	16:50	420	6.7	267	7.9	883.5	64			Refilled tubes
12 - Start	18:00	60	3	3.5	3.1	4.9	64	2.4	2.6	Refilled tubes
End	19:00	480	6.5	274.9	8	865.8	64			Cloudy, no wind
13 - Start										
End										
14 - Start										
End										
15 - Start										
End										

*Flow, Qf = ΔH x Vr **Infiltration Rate, I = (Qf/Ar)/Δt

Table 4 – Sample Test Data Form for Double Ring Infiltrometer Test

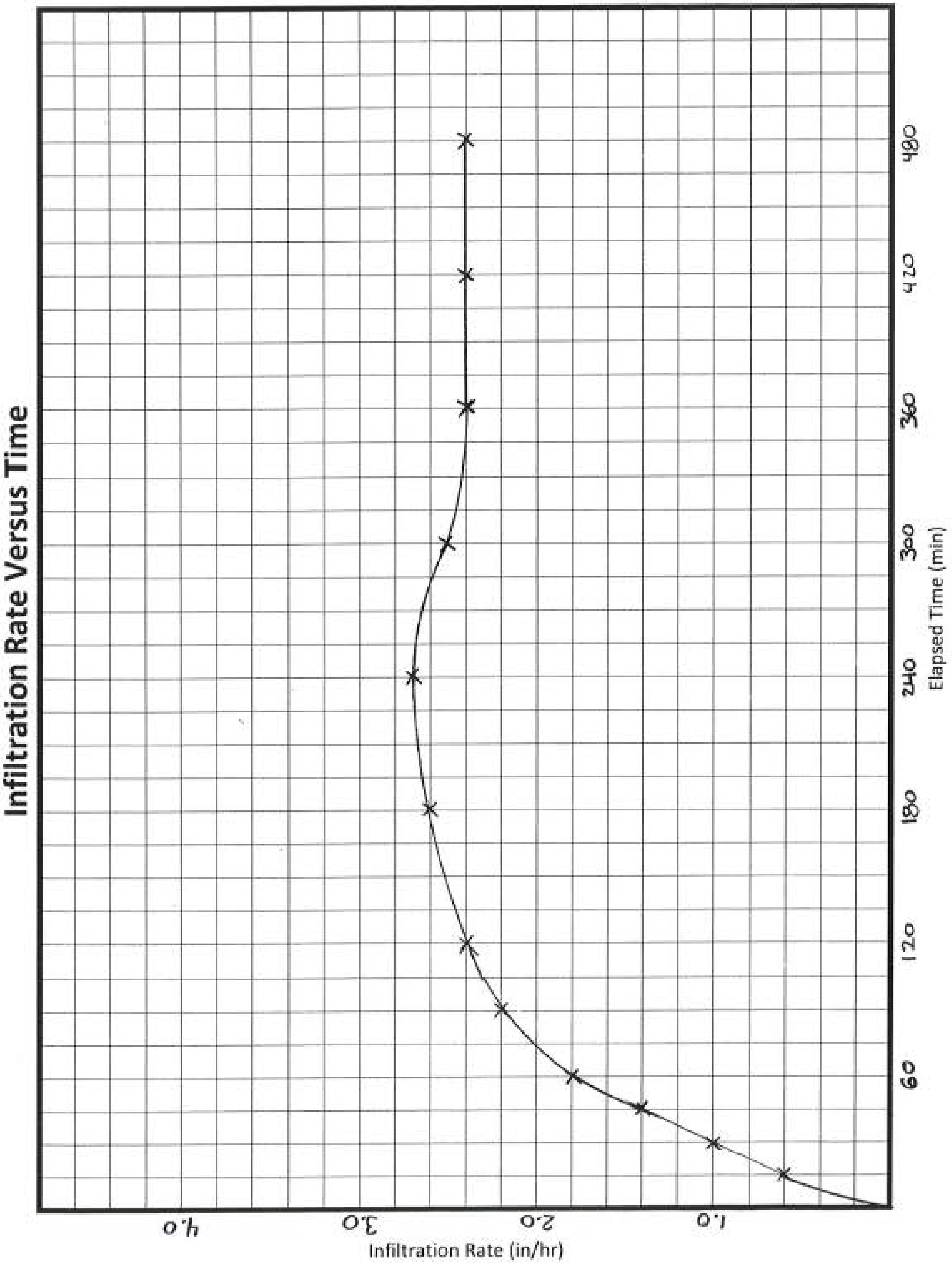


FIGURE 8 – Plot of Sample Test Data for Double Ring Infiltrometer Test

2.3 - Percolation Tests

The ***percolation test*** is widely used for assessing the suitability of a soil for onsite wastewater disposal. Depending on the required depth of testing, there are two versions of the percolation test. For shallow depth testing (less than 10 feet), the procedure would be as shown in Figure 8 (Photo 6). For deep testing (10 feet to 40 feet), the procedure is as shown in Figure 9. For deep testing, special care must be taken to ensure that caving of the sidewalls does not occur.

This test measures the length of time required for a quantity of water to infiltrate into the soil and is often called a "percolation rate". It should be noted that the percolation rate is related to, but not equal to, the infiltration rate. While an infiltration rate is a measure of the speed at which water progresses downward into the soil, the percolation rate measures not only the downward progression but the lateral progression through the soil as well. This reflects the fact that the surface area for infiltration testing would include only the horizontal surface while the percolation test includes both the bottom surface area and the sidewalls of the test hole. However, there is a relationship between the values obtained by a percolation test and infiltration rate. Based on the [1]"Porchet Method", the following equation may be used to convert percolation rates to the tested infiltration rate, I_t:

$$I_t = \frac{\Delta H \, \pi r^2 \, 60}{\Delta t(\pi r^2 + 2\pi r H_{avg})} = \frac{\Delta H \, 60 \, r}{\Delta t(r + 2H_{avg})}$$

Where:

I_t = tested infiltration rate, inches/hour
ΔH = change in head over the time interval, inches
Δt = time interval, minutes
$^*r$ = effective radius of test hole
H_{avg} = average head over the time interval, inches

An example of this procedure is provided on Page 26 based data form Table 5, *Sample Percolation Test Data*. Figure 11 provides a plot of the converted percolation test data.

*Where a rectangular test hole is used, an equivalent radius should be determined based on the actual area of the rectangular test hole. (i.e., $r = (A/\pi)^{0.5}$)

Note to the designer: The values obtained using this method may vary from those obtained from methods considered to be more accurate. The designer is encouraged to explore the derivation of these equations (Ritzema; Smedema)

Final Report - Ultimately, as discussed in Section 1.7, a final report shall be provided and, based on the test results, an infiltration rate shall be recommended.

---

[1] H.P. Ritzema, "Drainage Principles and Applications," International Institute for Land Reclamation and Improvement (ILRI), Publication 16, 2nd revised edition, 1994, Wageningen, The Netherlands.

Percolation Test Procedure

Only those individuals trained and educated to perform, understand and evaluate the field conditions and tests may perform these tests. This would include those who hold one of the following State of California credentials and registrations: Professional Civil and Geotechnical Engineers, Certified Engineering Geologist and Certified Hyrdrogeologist. The District will only approve the percolation test method described in this Chapter.

When the percolation testing has been completed, a 3 foot long surveyor's stake (lath) shall be flagged with highly visible banner tape and placed in the location of the test indicating date, test hole number as shown on the field data sheet, and firm performing the test. Field data shall be included in the Final Report as described in Section 1.7.

Shallow Percolation Test (less than 10 feet)

Test Preparation

1.) The test hole opening shall be between 8 and 12 inches in diameter or between 7 and 11 inches on each side if square.

2.) The bottom elevation of the test hole shall correspond to the bottom elevation of the proposed basin (infiltration surface). Keep in mind that this procedure will require the test hole to be filled with water to a depth of at least 5 times the hole's radius.

3.) The bottom of the test hole shall be covered with 2 inches of gravel.

4.) The sides of the hole shall remain undisturbed (not smeared) after drilling and any cobbles encountered left in place.

5.) **Pre-soaking** shall be used with this procedure. Invert a full 5 gallon bottle (more if necessary) of clear water supported over the hole so that the water flow into the hole holds constant at a level at least 5 times the hole's radius above the gravel at the bottom of the hole. Testing may commence after all of the water has percolated through the test hole or after 15 hours has elapsed since initiating the pre-soak. However, to assure saturated conditions, testing must commence no later than 26 hours after all pre-soak water has percolated through the test hole. The use of the "continuous pre-soak procedure" is no longer accepted. When sandy soils (as described below) are present, the test shall be run immediately.

Test Procedure

Test hole shall be carefully filled with water to a depth equal to at least 5 times the hole's radius (H/r>5) above the gravel at the bottom of the test hole prior to each test interval.

- In **sandy soils**, when 2 consecutive measurements show that 6 inches of water seeps away in less than 25 minutes, the test shall be run for an additional hour with measurements taken every 10 minutes. Measurements shall be taken with a precision of 0.25 inches or better. The drop that occurs during the final 10 minutes is used to calculate the percolation rate. Field data must show the two 25 minute readings and the six 10 minute readings.

- In **non-sandy soils**, obtain at least twelve measurements per hole over at least six hours with a precision of 0.25 inches or better. From a fixed reference point, measure the drop in water level over a 30 minute period for at least 6 hours, refilling after every 30 minute reading. The total depth of the hole must be measured at every reading to verify that collapse of the borehole has not occurred. The drop that occurs during the final reading is used to calculate the percolation rate.

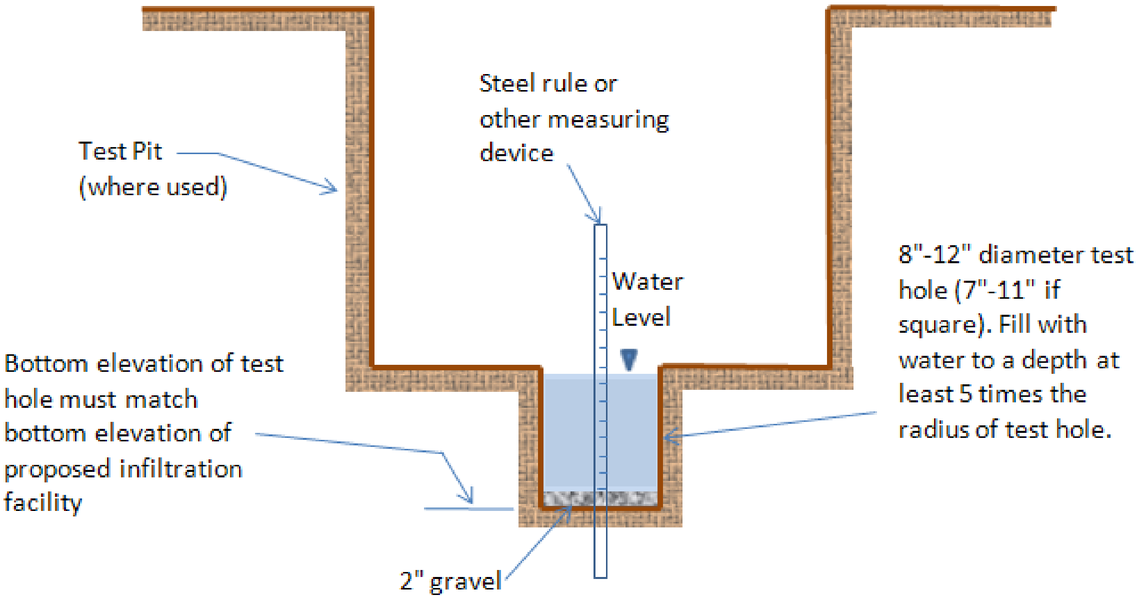


Figure 9- Test Pit for Shallow Percolation Test

Deep Percolation Test (Depths 10-40 feet)

Test Preparation

1.) Borehole diameter shall be either 6 inch or 8 inch only. No other diameter test holes will be accepted.

2.) The bottom elevation of the test hole shall correspond to the bottom elevation of the proposed basin (infiltration surface). Keep in mind that this procedure will require the test hole to be filled with water to a depth of at least 5 times the hole's radius.

3.) The bottom of the test hole shall be covered with 2 inches of gravel.

4.) The sides of the hole shall remain undisturbed (not smeared) after drilling and any cobbles encountered left in place. Special care should be taken to avoid cave-in.

5.) **Pre-soaking** shall be used with this procedure. Invert a full 5 gallon bottle of clear water supported over the hole so that the water flow into the hole holds constant at a maximum depth of 4 feet below the surface of the ground or if grading cuts are anticipated, to the approximate elevation of the **top** of the basin but at least 5 times the hole's radius (H/r>5). Pre-soaking shall be performed for 24 hours unless the site consists of sandy soils containing little or no clay. If sandy soils exist as described below, the tests may then be run after a 2 hour pre-soak. However, to assure saturated conditions, testing must commence no later than

26 hours after all pre-soak water has percolated through the test hole. The use of the "continuous pre-soak procedure" is no longer accepted. When sandy soils (as described below) are present, the test shall be run immediately.

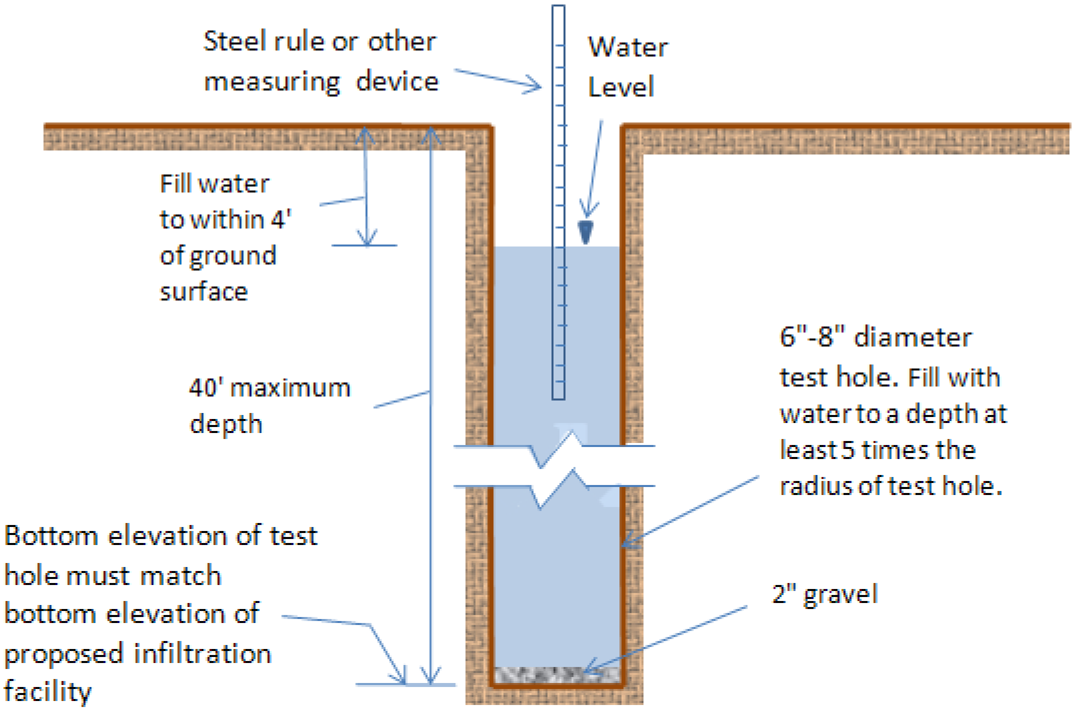


Figure 10- Test Pit for Deep Percolation Test

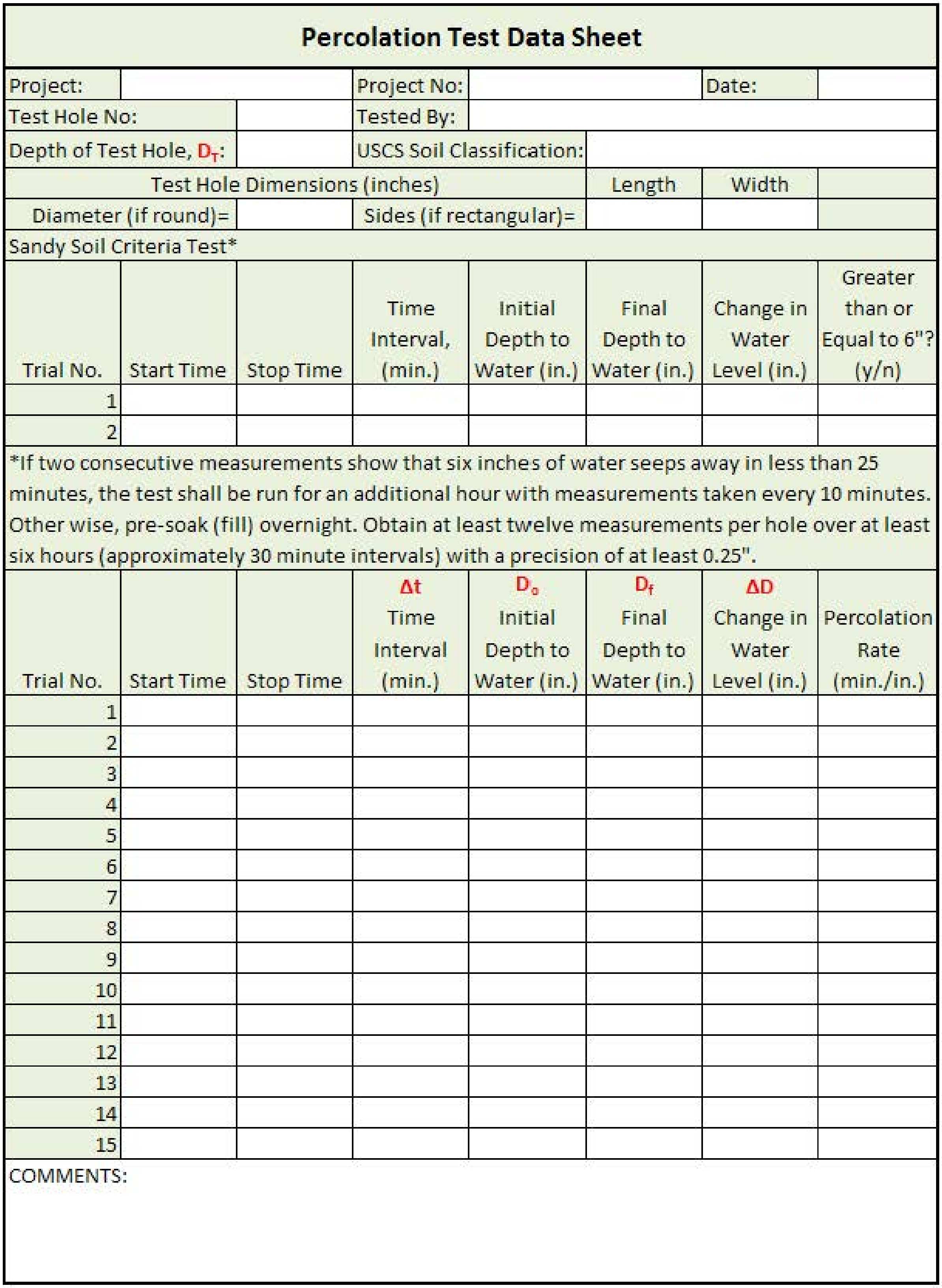
Test Procedure

Carefully fill the hole with clear water to a maximum depth of 4 feet below the surface of the ground or, if grading cuts are anticipated, to the approximate elevation of the **top** of the basin. However, at a minimum, the bore hole shall be filled with water to a depth equal to 5 times the hole's radius (H/r>5).

- In **sandy soils**, when 2 consecutive measurements show that 6 inches of water seeps away in less than 25 minutes, the test shall be run for an additional hour with measurements taken every 10 minutes. Measurements shall be taken with a precision of 0.25 inches or better. The drop that occurs during the final 10 minutes is used to calculate the percolation rate. Field data must show the two 25 minute readings and the six 10 minute readings.

- In **non-sandy soils**, the percolation rate measurement shall be made on the day following initiation of the pre-soak as described in Item #5 above. From a fixed reference point, measure the drop in water level over a 30 minute period for at least 6 hours, refilling after every 30 minute reading. Measurements shall be taken with a precision of 0.25 inches or better. The total depth of hole must be measured at every reading to verify that collapse of the borehole has not occurred. The drop that occurs during the final reading is used to calculate the percolation rate.

Photo 6 – Percolation Test Pit. Use of perforated PVC pipe is a variation.



Percolation Test Data Sheet

Project:			Project No:			Date:	
Test Hole No:			Tested By:				
Depth of Test Hole, D_T:			USCS Soil Classification:				
Test Hole Dimensions (inches)					Length	Width	
Diameter (if round)=			Sides (if rectangular)=				

Sandy Soil Criteria Test*

Trial No.	Start Time	Stop Time	Time Interval, (min.)	Initial Depth to Water (in.)	Final Depth to Water (in.)	Change in Water Level (in.)	Greater than or Equal to 6"? (y/n)
1							
2							

*If two consecutive measurements show that six inches of water seeps away in less than 25 minutes, the test shall be run for an additional hour with measurements taken every 10 minutes. Other wise, pre-soak (fill) overnight. Obtain at least twelve measurements per hole over at least six hours (approximately 30 minute intervals) with a precision of at least 0.25".

Trial No.	Start Time	Stop Time	Δt Time Interval (min.)	D_o Initial Depth to Water (in.)	D_f Final Depth to Water (in.)	ΔD Change in Water Level (in.)	Percolation Rate (min./in.)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

COMMENTS:

Table 5 – Sample Test Data Form for Percolation Test

Percolation Rate Conversion

Example:

The bottom of a proposed infiltration basin would be at 5.0 feet below natural grade. Percolation tests are performed within the boundaries of the proposed basin location with the depth of the test hole set at the infiltration surface level (bottom of the basin). The Percolation Test Data Sheet (Table 5) is prepared as the test is being performed. After the minimum required number of testing intervals, the test is complete. [1]**The data collected at the final interval is as follows:**

Time interval, Δt = 10 minutes
Final Depth to Water, D_f = 13.75 inches
[2]Test Hole Radius, r = 4 inches

Initial Depth to Water, D_0 = 12.25 inches
Total Depth of Test Hole, D_T = 60 inches

The conversion equation is used:

$$I_t = \frac{\Delta H\ 60\ r}{\Delta t(r+2H_{avg})}$$

"H_o" is the initial height of water at the selected time interval.

$H_o = D_T - D_0 = 60 – 12.25 =$ **47.75 inches**

"H_f" is the final height of water at the selected time interval.

$H_f = D_T - D_0 = 60 - 13.75 =$ **46.25 inches**

"ΔH" is the change in height over the time interval.

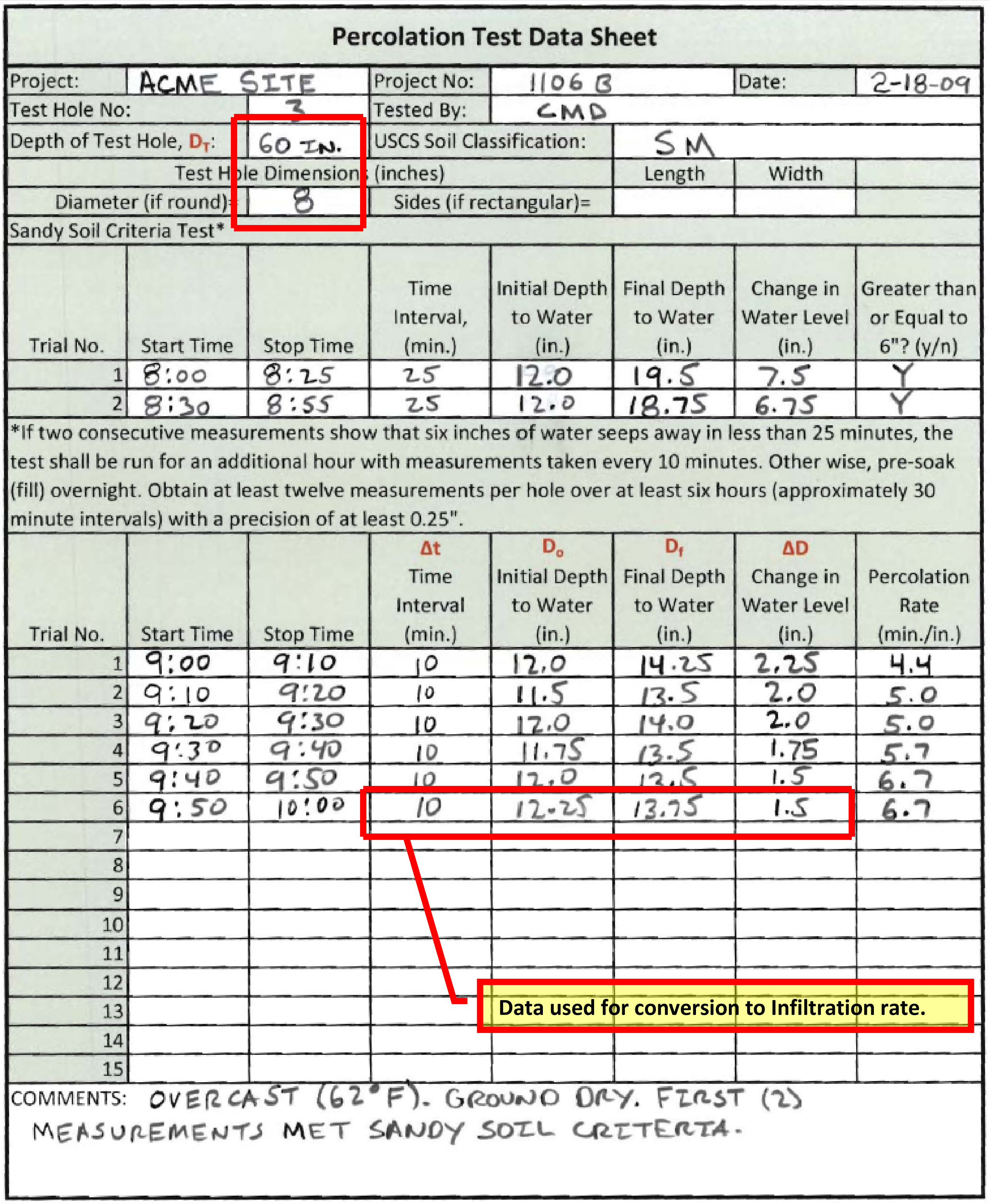
$\Delta H = \Delta D = H_o - H_f = 47.75 – 46.25 =$ **1.5 inches**

"H_{avg}" is the average head height over the time interval.

$H_{avg} = (H_o - H_f)/2 = (47.75 – 46.25)/2 =$ **47.0 inches**

"I_t" is the tested infiltration rate.

$$I_t = \frac{\Delta H\ 60\ r}{\Delta t(r+2H_{avg})} = \frac{(1.5\text{ in})(60\text{ min/hr})(4\text{ in})}{(10\text{ min})((4\text{ in}) + 2(47\text{ in}))} = \mathbf{0.37\ in/hr.}$$



Percolation Test Data Sheet

Project:	ACME SITE	Project No:	1106 B	Date:	2-18-09
Test Hole No:	3	Tested By:	CMD		
Depth of Test Hole, D_T:	60 IN.	USCS Soil Classification:	SM		
Test Hole Dimensions (inches)			Length	Width	
Diameter (if round)=	8	Sides (if rectangular)=			

Sandy Soil Criteria Test*

Trial No.	Start Time	Stop Time	Time Interval, (min.)	Initial Depth to Water (in.)	Final Depth to Water (in.)	Change in Water Level (in.)	Greater than or Equal to 6"? (y/n)
1	8:00	8:25	25	12.0	19.5	7.5	Y
2	8:30	8:55	25	12.0	18.75	6.75	Y

*If two consecutive measurements show that six inches of water seeps away in less than 25 minutes, the test shall be run for an additional hour with measurements taken every 10 minutes. Other wise, pre-soak (fill) overnight. Obtain at least twelve measurements per hole over at least six hours (approximately 30 minute intervals) with a precision of at least 0.25".

Trial No.	Start Time	Stop Time	Δt Time Interval (min.)	D_o Initial Depth to Water (in.)	D_f Final Depth to Water (in.)	ΔD Change in Water Level (in.)	Percolation Rate (min./in.)
1	9:00	9:10	10	12.0	14.25	2.25	4.4
2	9:10	9:20	10	11.5	13.5	2.0	5.0
3	9:20	9:30	10	12.0	14.0	2.0	5.0
4	9:30	9:40	10	11.75	13.5	1.75	5.7
5	9:40	9:50	10	12.0	13.5	1.5	6.7
6	9:50	10:00	10	12.25	13.75	1.5	6.7
7							
8							
9							
10							
11							
12							
13							
14							
15							

Data used for conversion to Infiltration rate.

COMMENTS: OVERCAST (62° F). GROUND DRY. FIRST (2) MEASUREMENTS MET SANDY SOIL CRITERIA.

Table 6 – Sample Percolation Test Data

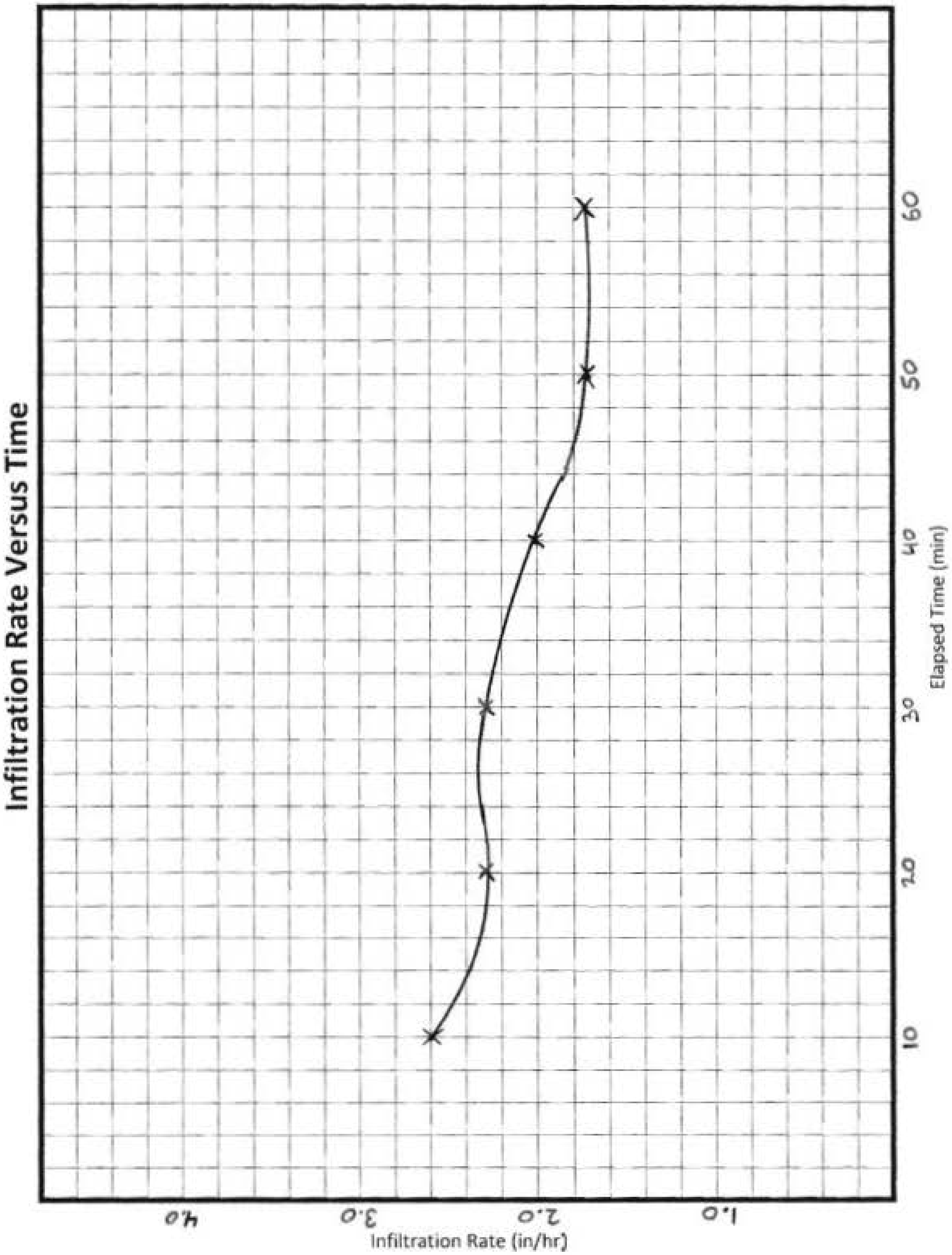


FIGURE 11 – PLOT OF CONVERTED PERCOLATION TEST DATA

2.4 - Field Permeability Test (Well Permeameter Method USBR 7300-89)

Similar to a constant-head version of the percolation test used for seepage pit design is the Well Permeameter Method of the United States Bureau of Reclamation. [1]USBR 7300-89 is an in-hole hydraulic conductivity test performed by drilling test wells with a 6-8 inch diameter auger to the desired depth. This test measures the rate at which water flows into the soil under constant-head flow conditions and is used to determine field-saturated hydraulic conductivity. As with the percolation test, the rate determined with this test is a "percolation rate" and is related, but not equal, to the infiltration rate. Infiltration rate is a measure of the speed at which water progresses downward into the soil. A percolation rate measures not only the downward progression but the lateral progression through the soil. However, this procedure uses the following equation(s) to establish an infiltration rate:

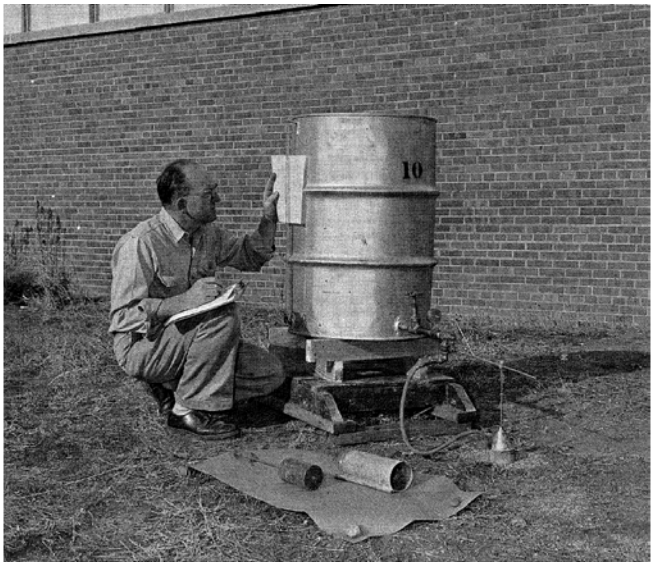


Photo 7 - Typical Well Permeamater Test Installation

Condition I: Typical condition (See Figure 12). The distance between the historical high water mark[2] and the water surface in the well is at least three (3) times the height of water in the well. In addition, there must be at least 10 feet from the bottom of the well to the historical high water table and at least 5 feet to impervious strata.

$$K_s = \frac{Q(\mu_T/\mu_{20})}{2\pi H^2}\left[\ln\left[\frac{H}{r}+\sqrt{\left(\frac{H}{r}\right)^2+1}\right]-\frac{\sqrt{1+\left(\frac{H}{r}\right)^2}}{\frac{H}{r}}+\frac{r}{H}\right]$$

Where:

K_s = saturated hydraulic conductivity (infiltration rate, inches/hour)
H = height of water in well (inches)
Q = percolation flow rate from selected time interval (cubic inches/hour)
r = effective radius of well (inches)
μ_T = viscosity of water at test temperature, T
μ_{20} = viscosity of water at 20°C

[1] A detailed description of this procedure along with a complete example using the associated equations can be found in the United States Bureau of Mines and Reclamation (USBR) document 7300-89.

[2] The "historical high groundwater mark" is defined as the groundwater elevation expected due to a normal wet season and shall be obtained by boring logs or test pits.

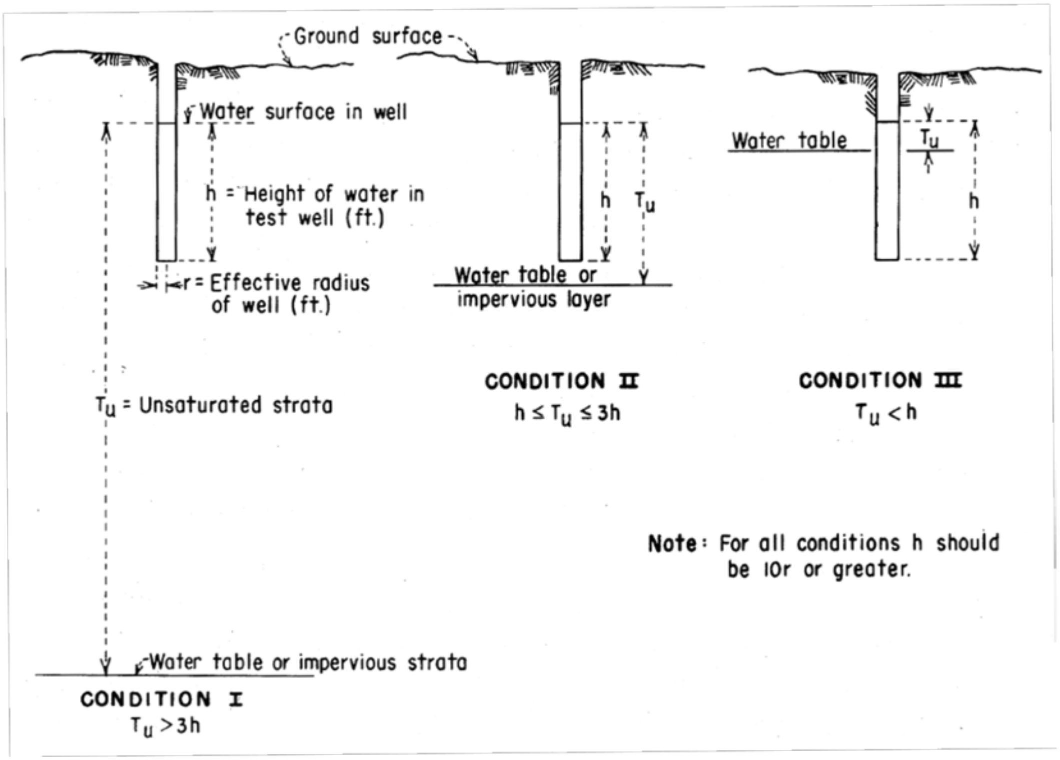


Figure 12 – Site Conditions Govern Procedure to be Used

Condition II: The distance between the historical high groundwater mark[1] and the water surface in the well is less than three (3) times, but at least equal to, the height of water in the well. In addition, there must be at least 10 feet from the bottom of the well to the historical high water mark[1] and at least 5 feet to impervious strata.

$$K_s = \frac{Q(\mu_{20}/\mu_T)}{2\pi H^2}\left[\frac{\ln\left(\frac{H}{r}\right)}{\frac{1}{6}+\frac{1}{3}\left(\frac{H}{T_u}\right)^{-1}}\right]$$

Where:

K_s = saturated hydraulic conductivity (infiltration rate, inches/hour)
H = height of water in well (inches)
Q = percolation flow rate from selected time interval (cubic inches/hour)
r = effective radius of well (inches)
μ_T = viscosity of water at water temperature, T
μ_{20} = viscosity of water at 20° C
T_u = unsaturated distance between the water surface and the water table or impervious strata

Condition III: Unacceptable location. The distance between the historical high groundwater mark and the water surface in the well is less than the height of water in well. As such, the base of the BMP would not be 10 feet above the historical high water mark or 5 feet from impervious strata.

Final Report - Ultimately, as discussed in Section 1.7, a final report shall be provided and, based on the test results, an infiltration rate shall be recommended.

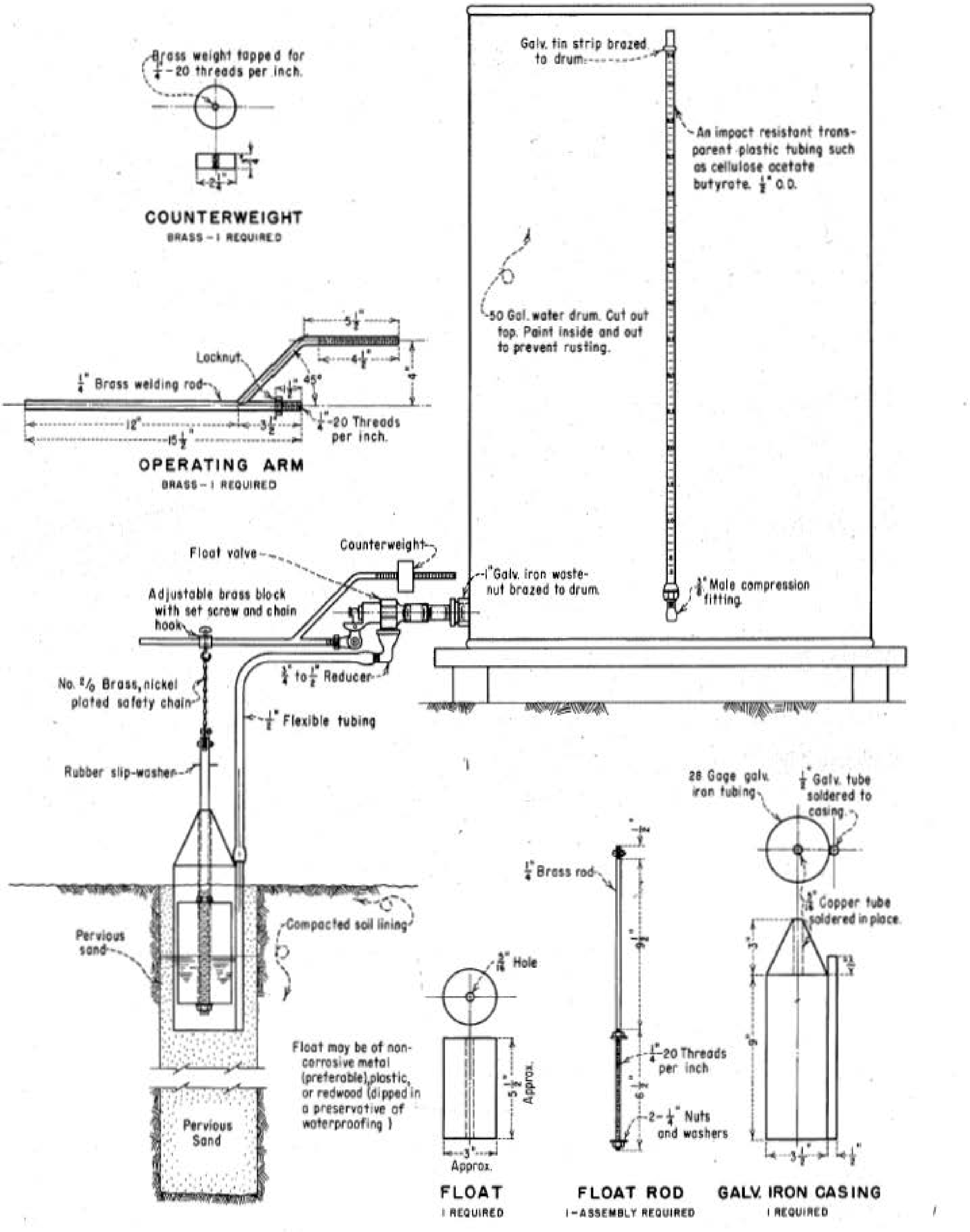


Figure 11 – Well Permeameter Test Equipment

2.5 - Borings and Test Pits

Borings and test pits are used to determine the thickness of soil and rock strata, estimate the depth to groundwater, obtain soil or rock specimens and perform field tests such as standard penetration tests (SPTs) or cone penetration tests (CPTs).

Test pits and trenches may be used to evaluate near-surface conditions up to about 15 feet deep but are often used for performing subsurface exploration at shallower depths. Test pits are often square in plan view and may be dug with shovels in less accessible areas. Trenches are long and narrow excavations usually made by a backhoe or bulldozer.

Borings (ASTM D 1452) are generally used to investigate deeper subsurface conditions. A cylindrical hole is drilled into the ground for the purpose of investigating subsurface conditions, performing field tests, and obtaining soil, rock, or underground specimens for testing. Borings can be excavated by hand (e.g., hand auger), although the usual procedure is to use mechanical equipment to excavate the borings.

Whatever method is used, testing shall be sufficient to establish USCS series and textural class (SM, CL, etc) of the soil beneath the infiltration surface of the BMP and of sufficient depth to establish that a minimum of 5 feet of permeable soil exists below the infiltration facility and that there is a minimum of 10 feet between the bottom of the infiltration facility and the historical high groundwater mark[1].

Photo 8- Auger Boring Rig

Photo 9 – Test Pit Excavation

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[1] The “historical high groundwater mark” is defined as the groundwater elevation expected due to a normal wet season and shall be obtained by boring logs or test pits.

Infiltration Test Requirement Checklist

___ Where infiltration testing is to be performed, the measured infiltration rate of the underlying soil must be determined using either the single ring infiltrometer test (as described in ASTM D 5126, Section 4.1.2.1), the double ring infiltrometer test (ASTM D 3385), the well permeameter method (USBR 7300-89), or a percolation test per County of Riverside Department of Environmental Health (RCDEH) test procedures. A general explanation of these test methods can be found in Section 2 of this appendix. The minimum number of tests required can be found in Table 1 and is dependent upon the type of infiltration test performed.

___ Test pits and borings (ASTM D 1452) may be used to determine the USCS series and textural class (SM, CL, etc.) of the soil horizons throughout the depth of boring log or pit, the thickness of soil and rock strata, and estimate the historical groundwater depth. Test pits or boring logs must be of sufficient depth to establish that a minimum of 5 feet of permeable soil exists below the infiltration facility and that there is a minimum of 10 feet between the bottom of the infiltration facility and the historical high groundwater mark[1] (Section 1.7 and 2.5). The required number of test pits or borings is listed in Table 1.

___ A final report, prepared by a registered civil engineer, geotechnical engineer, certified engineering geologist or certified hydrogeologist shall be provided to the District or other EA which demonstrates through infiltration testing and/or soil logs that the proposed facility location is suitable for the proposed infiltration facility and an infiltration rate shall be recommended. In addition, any requirements associated with impacts to a landslide, erosion or steep slope hazard area should also be addressed in the final report. (Section 1.7)

___ Tests may be performed only by individuals trained and educated to perform, understand and evaluate the field conditions. The individual(s) supervising this field work must be named along with their education or training background in the final report as described in Item 3. (Section 1.7)

___ Preliminary site grading plans shall be provided to the District or other EA showing the proposed BMP locations along with section views through each BMP clearly identifying the extents of cut/fill.

___ All infiltration tests shall be performed within the boundaries of the proposed infiltration BMP and at the bottom elevation (infiltration surface) of the proposed infiltration facility. (See Photo 5)

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[1] The "historical high groundwater mark" is defined as the groundwater elevation expected due to a normal wet season and shall be obtained by boring logs or test pits.

APPENDIX B

Underdrains

APPENDIX B – UNDERDRAINS

Where underdrains are specified, the following information provides guidance for underdrain requirements.

Underdrain Material Types

Underdrain pipe shall be 6-inch diameter ABS pipe or PVC pipe. ABS pipe shall meet the requirements of ASTM Designation D-2751, SDR 23.5, and PVC pipe shall meet the requirements of ASTM Designation D-2665. Perforations shall be as described in ASTM Designation C-700. It should be noted that placing the pipe such that the perforations are oriented upward may help to maximize infiltration in unlined BMP’s with underdrains. If the BMP is constructed with an impermeable liner, the perforations should be angled downward to maximize the volume of water that will be drained from the BMP.

Underdrain Connections

Pipe joints and storm drain structure connections must be adequately sealed to avoid piping conditions (water seeping through pipe or structure joints). Pipe sections shall be coupled using suitable connection rings and flanges. Field connections to storm drain structures and pipes shall be sealed with polymer grout material that is capable of adhering to surfaces. Underdrain pipe shall be capped (at structure) until completion of site construction. Underdrains connected directly to a storm drainage structure shall be non-perforated for an appropriate distance from the structure interface to avoid possible piping problems.

Underdrain Slope

Underdrains must "daylight" or connect to an existing drainage system to achieve positive flow. All underdrains must be placed with a minimum slope of 0.5% ($s = 0.005$ ft/ft).

Underdrains Layout and Spacing

Typically, there are two main layouts for underdrains. One is a non-perforated central collector pipe with perforated lateral feeder pipes, the other is simply a series of longitudinal perforated pipes. Both layouts connect to a non-perforated outlet pipe before “daylighting" or connecting to an existing drainage system. The minimum spacing is shown below.

BMP Type	Underdrains Center to Center Spacing
Sand Filter Basin	20’
Extended Detention Basins (Bottom stage 500 sq ft. or greater)	20’
Extended Detention Basins (Bottom stage < 500 sq ft.)	10’
Bioretention Facility	5’

Underdrain Gravel

Gravel bed materials should be used to protect an underdrain pipe and to reduce clogging potential. Placement of gravel over the underdrain must be done with care. Avoid dropping the gravel from excessive heights from a backhoe or front-end loader bucket. Spill directly over underdrain and spread manually.

Recommended construction specifications for gravel used to protect underdrains are as follows:

- AASHTO #57 stone preferred
- Geotextile fabrics should be avoided because tearing and/or plugging can dramatically affect performance. If the designer is concerned about the engineered soil media migrating into the underdrain, a 3-inch thick layer of "pea gravel" may be added to create a “choker” course.

Maintenance

Access for cleaning underdrains is required for each system. Clean-outs, with diameters equal to the underdrain, should extend 6 inches above the media and have a lockable screw cap for easy access. Cleanouts should be located for every 50 feet of lateral, at the collector drain line connection, and at any bends.

Underdrain Orifice Plate

When designing a BMP to meet Hydraulic Conditions of Concern (HCOC) criteria in addition to water quality criteria, it is sometimes necessary to install an orifice plate near the downstream end of the underdrain system. The orifice plate restricts the opening of the underdrain to mitigate flows to a specific lower flow threshold. Proper maintenance access should be provided to the orifice plate location to facilitate maintenance activities, specifically the removal of accumulated sediment and debris upstream of the orifice plate.

APPENDIX C

Basin Guidelines

APPENDIX C – BASIN GUIDELINES

This appendix is broken up into two sections. Section 1 presents guidelines and standards for the design and maintenance of water quality and increased runoff basins used within Riverside County. Applicable water quality basins include infiltration, sand filter and extended detention basins but do not include Bioretention BMPs. Section 2 is devoted to guidelines and standards for debris basins. Regional Basins are only loosely governed by this document and are largely considered on a case-by-case basis.

These guidelines are *intended* to be used on both private and public facilities throughout Riverside County and *shall* be adhered to for all facilities to be maintained by the Riverside County Flood Control and Water Conservation District (District). It is anticipated that County Transportation, Coachella Valley Water District and the City Engineer for incorporated cities within the County may choose to alter these guidelines and may have different/additional requirements. These entities, along with the District, will be referred to as the Engineering Authority (EA). Similarly, County or City Planning Departments, Parks Departments and Parks Districts may also have different/additional requirements. These entities will be referred to as the Planning Authority (PA). Both the EA and PA should be consulted regarding their specific requirements.

Section 1- Detention and Water Quality Basins

1.1 General Criteria

Off-line versus In-stream Mitigation – All water quality mitigation basins must be flow-through. In-stream mitigation is extremely difficult to accomplish unless the basin is designed to accommodate all upstream tributary area and to mitigate for all impacts due to upstream development. Therefore most EAs will not allow in-stream water quality mitigation basins. It shall be noted that while flow mitigation BMPs may be allowed to be constructed within “jurisdictional waters”, water quality mitigation BMPs will not be permitted.

Dam Safety Compliance – Basin designs that would be considered “jurisdictional” and fall under the Division of Safety of Dams (DSoD) review are not recommended.

Standard Details - Most EAs would prefer standardization of elements of outlet structures that are likely to wear (e.g., trash racks). Outflow control structures shall be designed in accordance with the EA's standards unless site-specific conditions preclude it. The District requires the use of Standard Drawing WQ501 for most basins. However a modified District CB110 overflow outlet is recommended for infiltration and sand filter basins. Minor modifications to provide supplemental hydraulic routing characteristics above the water quality storage volume are acceptable.

General Sizing Criteria – These guidelines relate to the basic features to be included in the various types of basins and the general geometrics of the basins design criteria. This appendix does not include the volumetric sizing of facilities. Follow the appropriate increased runoff guidelines or BMP fact sheet sizing.

Geotechnical Reports – A geotechnical report prepared by either a licensed geotechnical engineer, civil engineer or certified engineering geologist is required for all basins. The minimum content of the Geotechnical report shall include the following:

- Slope stability - Discussion shall include the affect the basin may have on the stability of adjacent slopes as a result of the basin's proposed location.

- Compaction, cut and fill - Issues due to soil compaction and/or cut and fill conditions with regards to the safety and effectives of the basin shall be discussed.

- Setbacks from buildings, slopes, wells - The report shall include recommendations for the minimum setback required from buildings, onsite walls, and slopes. In addition, the report shall determine the location of any pre-existing wells (onsite or offsite) and clarify that the minimum 100 foot horizontal setback has been maintained.

- Embankment design - For embankments over 5 feet in height, the geotechnical report shall include recommendations as to its construction and clarify that the embankment meets the requirements herein.

- Boring logs - Boring logs shall be provided within the report and a discussion of their findings included. Any subsurface conditions which may be pertinent to the safety and effectiveness of the basin shall be discussed.

- High Groundwater Level - The historic high groundwater level shall be determined. It shall be clarified that a minimum 10 foot vertical separation from the bottom of the basin to the top of the historic high groundwater level will be maintained.

In addition, where infiltration basins are to be utilized on the site the following topics shall be discussed:

- Existing Conditions (i.e., legacy pollutants) - Where existing soil contains unusually high levels of pollutants, the report shall clarify the extent of the pollution, mitigation efforts and the viability of using an infiltration BMP effectively as a result.

- Infiltration Testing - The use of infiltration BMPs may require an infiltration rate be established as described in Appendix A, "Infiltration Testing Guidelines". An infiltration testing report may be required and documented as described therein

Parking Lot Detention - Parking lots shall not be used to provide additional surface (above ground) storage for either water quality BMPs or to address HCOCs.

Seeps and Springs- Intermittent seeps along cut slopes are typically fed by a shallow groundwater source (interflow) flowing along a relatively impermeable soil stratum. These flows are precipitation driven and should discontinue after a few weeks of dry weather. No special provisions are needed when directing these flows through the basin. However, more continuous seeps and springs, which extend through longer dry periods, are likely from a deeper groundwater source. When continuous flows are intercepted and directed through basins, adjustments to the approved facility design may be required to account for the additional base flow (unless already considered in design).

Privately Owned Basins - All of the criteria herein apply to privately maintained basins except that retaining walls may be used for a portion of interior slopes. Privately owned basins are only acceptable for commercial projects, multi-family residential projects and single family residential communities with a viable maintenance mechanism. Retaining walls may not be used to support water impounding embankments. Retaining walls shall not exceed one third of the outside perimeter of the basin. Detailed structural design calculations must be submitted with every retaining wall proposal. A fence shall be provided along the top of the wall. **The use of retaining walls in a basin requires approval prior to tentative project approval.** The EA or PA may reject the proposed use of retaining walls due to aesthetic and maintenance concerns relating to nuisance and graffiti abatement.

1.2 - Basin Grading Parameters

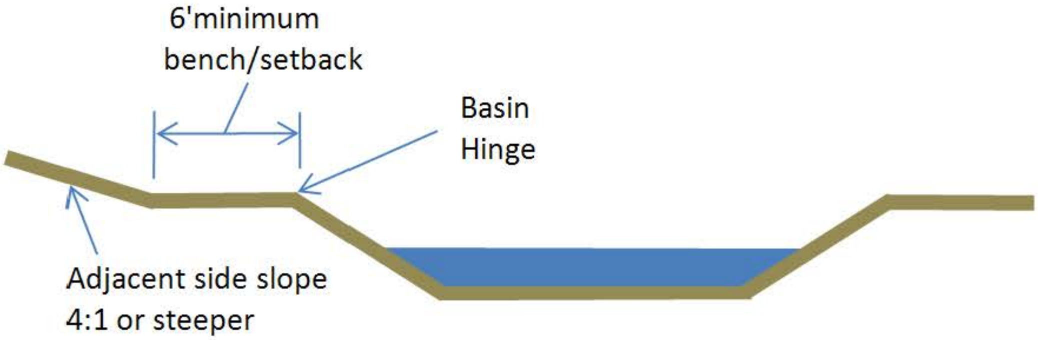
Basins must meet the following requirements for side slopes, fencing, and embankments:

Interior Side Slopes - At least 50 percent of the facility perimeter shall have interior sides no steeper than 4H:1V and in no case steeper than 2H:1V (even if fenced) to minimize safety risks. Side slopes shall be no steeper than 4H:1V whenever adjacent to down-gradient external property lines, roadways, sidewalks and trails.

Embankments - Embankment fill slopes (external and internal) may be no steeper than 4:1 with no exceptions. Basin embankment height will be based on the vertical distance from the design overflow water surface (typically the spillway invert elevation) to the lowest downstream toe of embankment fill. Basin embankments higher than 5 feet shall require design by a geotechnical engineer and shall have a top width not less than 20 feet. For embankments 5 feet or less in height, the minimum top width shall be 6 feet. Embankments for water quality basins may not exceed 3 feet in height.

Setbacks - All basin grading impacts shall be set back a minimum of 6 feet from down-gradient external property lines. This requirement applies to both the top of a cut-slope and the toe of any exterior slope embankment, along with rip-rap energy dissipaters relative to the property line (excluding road right of way). The cut-slope setback requirement is intended to avoid situations where future offsite grading/cut-slopes could turn an incised basin into an embankment-impounded reservoir. For all cases, depending on the amount of discharge and site characteristics, additional setback may be required unless appropriate easements are secured from the affected property owner(s).

There shall be a minimum 6 foot setback between a basin and an adjacent slope 4:1 or steeper measured horizontally from the basin hinge to the toe of the slope.



Forebay - A forebay shall be placed at each inlet to the basin to allow for the settlement and collection of larger particles. A relatively smooth concrete bottom surface should be provided to facilitate mechanical removal of accumulated sediment, trash and debris. A rock or concrete berm separates the forebay from the remainder of the basin. The forebay's design volume must be from 3 to 5% of the design volume, with the exception of infiltration and sand filter basins whose forebays should be 0.5% of the design volume. A full height notch-type weir shall be made through the berm to convey water to the main body of the basin. This notch shall be offset from the inflow streamline to prevent low-flows from short circuiting.

Basin Floor Slopes - Surface slopes should be kept at a minimum to allow for as much infiltration/groundwater recharge as is possible while still meeting vector concerns. All detention and extended detention basins shall have transverse and longitudinal bottom surface slopes of 1% minimum. For infiltration and sand filter basins, the basin floor should be level.

Gravel filled low-flow trench

Dry Weather Flow Management – All increased runoff or extended detention basins (**excluding** infiltration or sand filter basins) shall be designed to accommodate dry weather flows without impairing wet weather function or creating potential nuisance or maintenance issues. The basin shall have a network of gravel filled low-flow and collector trenches covering the entire basin floor area along with a sand filter drain adjacent to the outlet structure. See Figure 1 on following page.

A 48-inch wide by 24-inch deep low-flow trench conveys flow from the forebay to the filter drain. With a mild longitudinal slope of at least 1% to promote infiltration, the unlined low-flow trench shall be filled with 2" gravel (ASTM No. 2 or similar) to the finished surface and shall not use perforated subdrains.

Collector trenches beneath the top stage shall be arranged in accordance with Figure 1 with a maximum slope of 0.5% to promote infiltration and must extend from the low-flow channel to the toe of the basin side slopes. They shall be 18-inches wide by 24-inches deep and filled with 2" gravel (ASTM No. 2 or similar) to the finished surface. The collector trenches shall not have perforated subdrains and shall be constructed with a maximum spacing of 25 feet on center. See Figure 1 on following page.

A sand filter drain shall be constructed at the low point (or bottom-stage) of the basin adjacent to the outlet structure. To avoid clogging at the lowest orifice of the outlet structure, the top of the filter drain is offset below the lowest orifice of the outlet structure by 0.33 feet (4 inches). The sand filter drain shall include an 18 inch layer of sand (fine aggregate per

ASTM C-33) over a 10-inch gravel subdrain system and shall line the entire bottom stage. The total depth of the sand filter drain, $D_{FD,}$ shall therefore not be less than 2.33 feet. See Appendix B for standard subdrain construction. The filter drain's design volume must be a minimum of 0.5% of V_{BMP} and the minimum bottom stage area is $A_{BS}= V_{BMP}/ D_{BS}$.

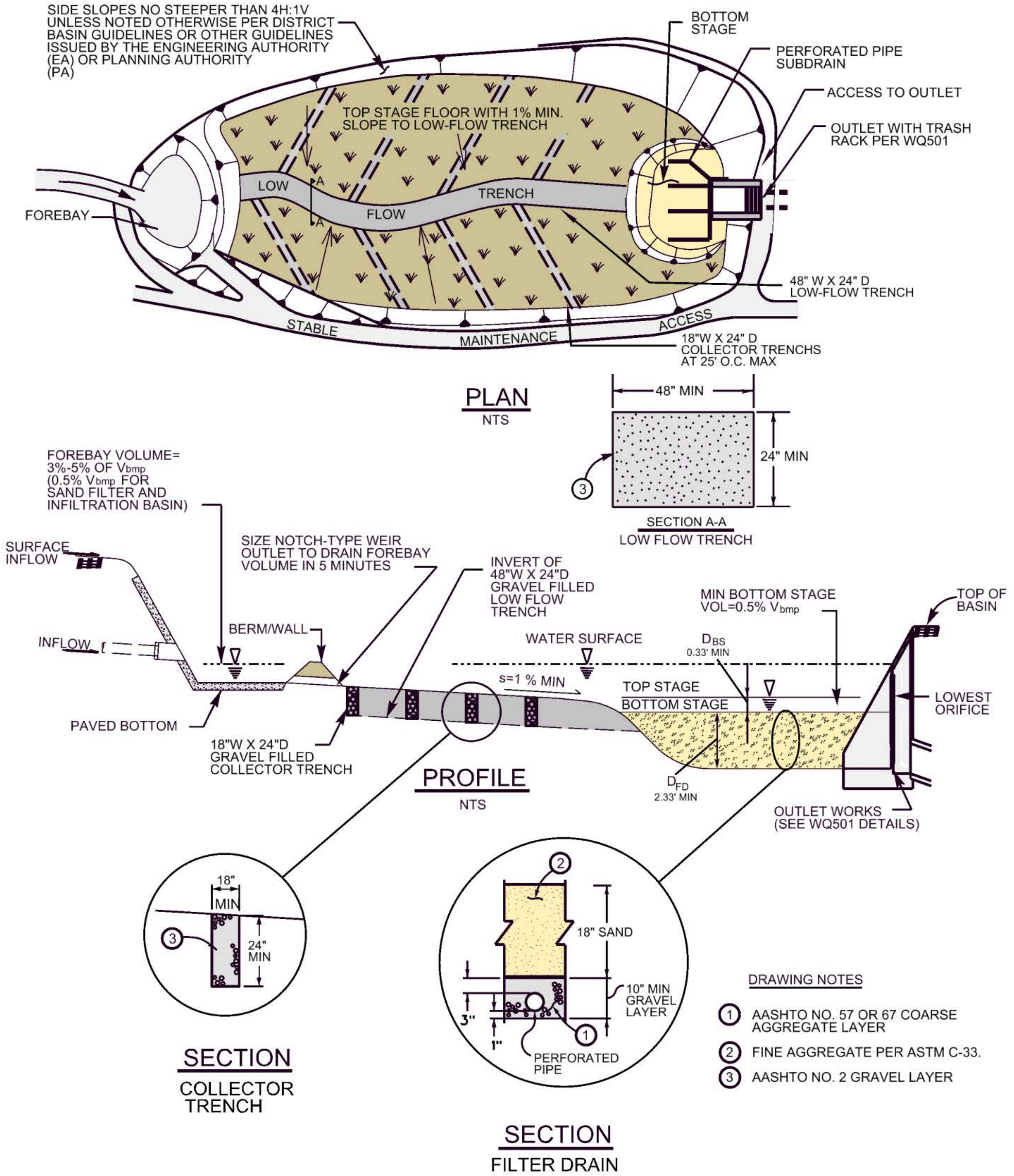
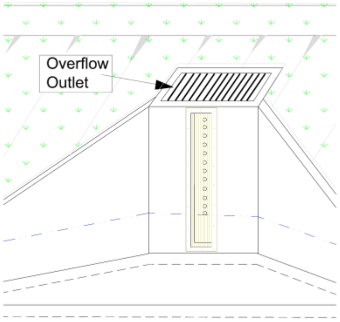


Figure 1 –Dry Weather Management Features

Outlet Structure and Spillway - Outlet structures shall conform to District Standard Drawing WQ501 unless approved in advance by the EA. This standardization is important in order to provide for efficient maintenance.

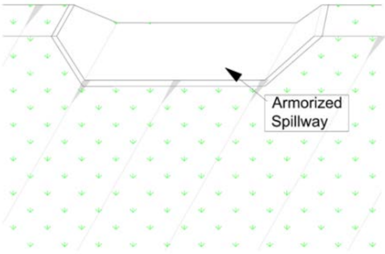
a. **Water Quality Outlet Trash Rack/Screen** - The outlet's orifice plate shall be protected with a conforming trash rack with at least six square feet of open surface area or 25 times the total orifice area, whichever is greater. The rack shall be adequately secured to prevent it from being removed or opened when maintenance is not occurring.

b. **Overflow Outlet** - In all basins, a primary overflow (usually integrated into the control structure) must be provided to pass flows greater than the design volume up to the 100-year event. The design must provide controlled discharge directly into the downstream conveyance system or an acceptable discharge point.



c. **Emergency Overflow** - In addition to the above overflow requirements, basins must have an emergency overflow escape path sized to safely pass the 100-year tributary developed peak flow in the event of total control structure failure (e.g., blockage of the control structure outlet pipe) or extreme inflows. Emergency overflow pathways are intended to control the location of basin overtopping and direct overflows back into the downstream conveyance system or other acceptable discharge point.

d. **Emergency Overflow Spillway -** Basins with constructed embankment over 3 feet in height and for BMP embankments of any height, or located on grades in excess of 5% must provide an emergency overflow spillway structure. The emergency overflow spillway must be designed to pass the 100-year developed peak flow, with a minimum 12 inches of freeboard, directly to the downstream conveyance system or an acceptable discharge point. The emergency overflow spillway shall be armored full width, beginning at a point midway across the berm embankment and extending downstream to an adequate outlet point. Design of emergency overflow spillways generally requires the analysis of a broad-crested trapezoidal weir.



Access Roads and Ramps - Maintenance access road(s) shall be provided to the top of the control structure and other drainage structures associated with the basin (e.g., inlet/forebay, emergency overflow or bypass structures). All basins shall have unobstructed access from a public street (see Section 1.4, "Right-of-Way") with commercial size curb cut-outs and driveway approaches. Flood control basins designed to attenuate the 100 year flood event shall have an access road around the entire basin. Manhole and catch basin lids should be within or at the edge of the access road and shall be at least three feet from a property line. Rims shall be set at the access road grade.

On large, deep basins (at least 1500 square feet bottom area, measured without the ramp, and over 4 feet deep), an access ramp must extend to the basin bottom at the forebay for removal of sediment with a trackhoe and truck. This is necessary so truck loading can be done in the basin bottom.

However, on small deep basins (less than 1500 square feet, but over 4 feet deep), the truck can remain on the ramp for loading. As such, the ramp may end at an elevation up to 4 feet above the basin bottom provided the basin side slopes are 4:1 or flatter.

On small shallow basins (less than 1500 square feet bottom area, and 4 feet deep or less), a ramp to the bottom is not required if the trackhoe can load a truck parked at the basin edge (trackhoes can negotiate mild interior basin side slopes).

No ramp is required for any basin 4-feet or less in depth if vehicular access is provided to the top of slope at the forebay and the side slopes are 4:1 or flatter. (Depth trigger for ramp is measured from top of slope adjacent to forebay invert.)

Design of access roads and ramps shall meet the following design criteria:

a. Maximum grade (measured along ramp centerline) shall be 15% for asphalt or concrete paving and 10% for soft surface or modular grid paving.
b. Inside turning radius shall be 35 feet, minimum.
c. Fence gates shall be located only on straight sections of road.
d. Access roads shall be constructed with an asphalt, concrete, 3-inch layer of compacted Class 2 aggregate road base material, decomposed granite or modular grid pavement.
e. Access roads and ramps shall be 15 feet in width on curves, 12 feet on straight sections. A paved apron shall be provided where access roads connect to paved public roadways.

1.3 - Landscaping

Landscaping will likely be required by the Planning Authority. Landscaping requirements shall be in accordance with Riverside County Ordinance 859 or equivalent agency ordinance. Care must be taken to ensure that landscaping does not hinder maintenance operations.

a. Facilities shall be designed so that they do not require mowing. Where mowing cannot be avoided, facilities shall be designed to require mowing no more than once or twice annually. A 6-foot minimum width must be provided to allow a mower to pass (see Figure 2).

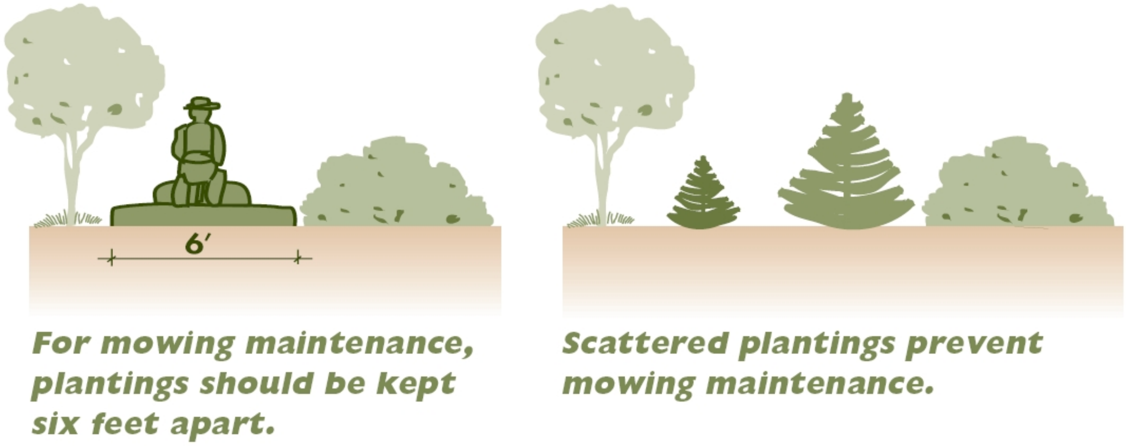
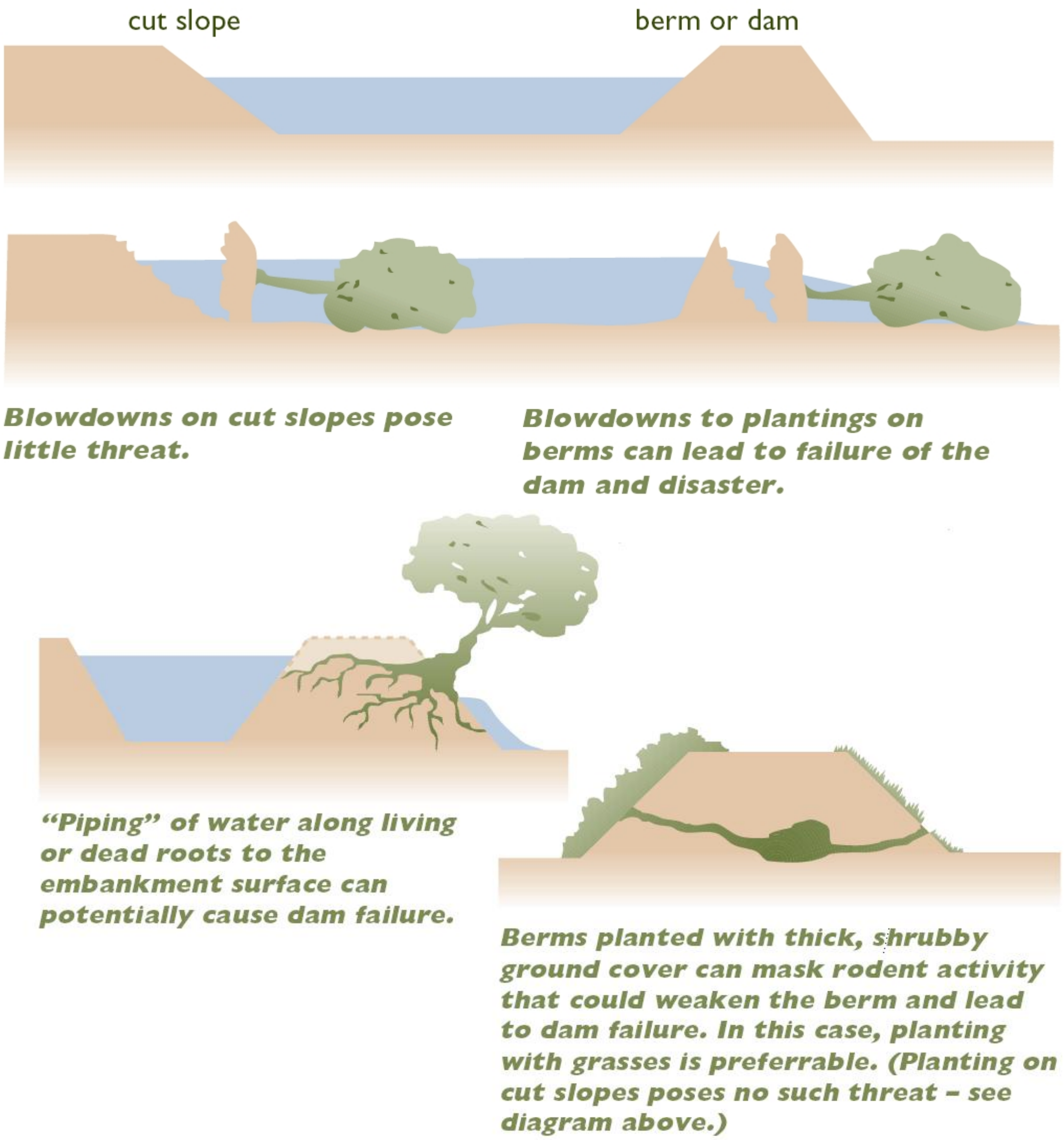


Figure 2- Landscaping setbacks (Source: King County WLR)

b. Turf and lawn areas are not allowed for publicly maintained basins unless an appropriate landscape maintenance entity is identified.

c. Planting is restricted on embankments that impound water either permanently or temporarily during storms (see figure 3). This reduces the likelihood of blown down trees, or the possibility of channeling or piping of water through the root system, which may contribute to dam failure on embankments that retain water.



Blowdowns on cut slopes pose little threat.

Blowdowns to plantings on berms can lead to failure of the dam and disaster.

"Piping" of water along living or dead roots to the embankment surface can potentially cause dam failure.

Berms planted with thick, shrubby ground cover can mask rodent activity that could weaken the berm and lead to dam failure. In this case, planting with grasses is preferrable. (Planting on cut slopes poses no such threat – see diagram above.)

Figure 3 - Hazardous Landscaping Practices (Source: King County WLR)

Note: *This restriction does not apply to cut slopes that form basin banks, only to embankments.*

d. No trees or shrubs may be planted within 10 feet of inlet or outlet pipes or from manmade drainage structures such as spillways or flow spreaders.

e. Trees with roots that seek water, such as willow or poplar, should be avoided within 50 feet of pipes or manmade structures.

f. Evergreen trees and others that produce relatively little leaf-fall (such as locust) are preferred in areas draining to the basin. Trees should be set back so branches do not extend over the outlet structure area of the basin (to help prevent clogging). Drought tolerant species are recommended.

g. Trees or shrubs may not be planted on portions of water-impounding embankments taller than four feet high. Only grasses may be planted on embankments taller than four feet.

1.4 - Additional Requirements

Fencing Criteria - The requirements for slopes and fencing are intended to discourage access to portions of a basin where steep side slopes (steeper than 4:1) increase the potential for slipping into the basin, and to allow easy egress for those who have fallen with slopes that are mild enough (flatter than 4:1 and unfenced) to allow for easy escape. If the basin will hold water deeper than 2 feet, a physical barrier as demarcation of the basin limits is required:

a. Where interior slopes are steeper than 4:1, the barrier shall be a fence 6 feet in height (see District Standard Drawing M-801 for chain link fence details). In joint use ventures where a special district or agency has agreed to maintain landscape facilities, tubular steel fencing such as that meeting Valley Wide Recreation and Parks District landscape standard LC-10 is also acceptable. Functionally equivalent designs may be acceptable on a case by case basis.

b. Where interior slopes are 4:1 or milder, the physical demarcation shall be (3-foot minimum height) vinyl or PVC rail fence, post-and-cable, masonry wall, or densely planted hedges. Functionally equivalent designs may be acceptable on a case by case basis.

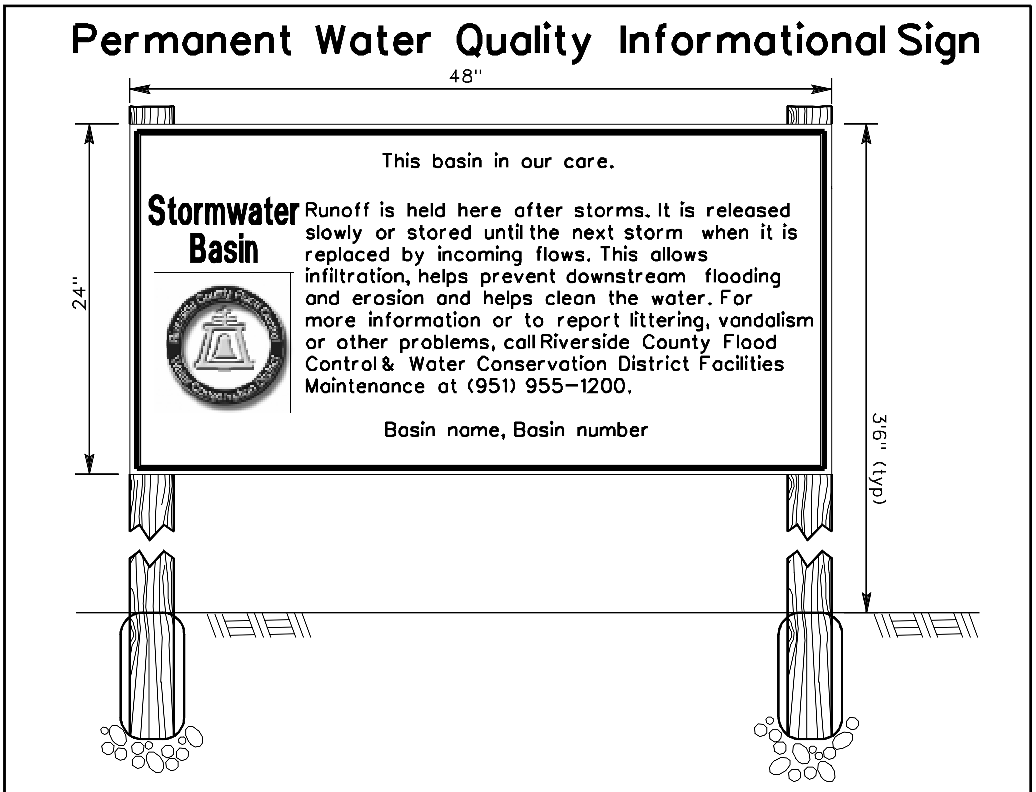
c. If the side slopes undulate, and segments of the slope are steeper than 4:1, the barrier standard from “b.” above may be used in place of the 6-foot fence for the short lengths of slope as specified here: The barriers described in “b.” may be used for sections of 2:1 slope not to exceed 20 lineal feet and sections of 3:1 slope not exceeding 50 lineal feet.

d. If required, fencing shall be placed at or above the overflow water surface. Side slope and attendant fencing requirements are not applicable to slopes above the overflow water surface.

Gates - Vehicular access shall be limited by a double-posted gate if a fence is required, or by bollards. Access road gates shall be 14 feet in width consisting of two swinging sections 7 feet in width (see the District’s Standard Drawing M-801 for details). Alternately, two fixed bollards on each side of the access road and two removable bollards equally located between the fixed bollards may be used. Additional vehicular access gates may be required as needed to facilitate maintenance access. Pedestrian access gates (if needed) shall be 4 feet in width.

Signage - All basins to be maintained by the District shall have a sign placed for maximum visibility from adjacent streets, sidewalks, and paths. The sign shall meet the design and installation requirements illustrated in Figure 4.

Right-of-Way - Basins shall not be located in a dedicated public road right-of-way. Publicly maintained basins shall be in a lot dedicated to the public. Any lot not abutting the public right-of-way will require a 16.5-foot wide extension of the lot to an acceptable access location.



This basin in our care.

Stormwater Basin

Runoff is held here after storms. It is released slowly or stored until the next storm when it is replaced by incoming flows. This allows infiltration, helps prevent downstream flooding and erosion and helps clean the water. For more information or to report littering, vandalism or other problems, call Riverside County Flood Control & Water Conservation District Facilities Maintenance at (951) 955-1200.

Basin name, Basin number

SPECIFICATIONS:

Size:	48 inches by 24 inches
Material:	0.125-gauge aluminum
Face:	Non-reflective vinyl or 3 coats outdoor enamel (sprayed).
Lettering:	Silk screen enamel where possible, or vinyl letters.
Colors:	Beige background, navy blue letters.
Type face:	Electrical condensed. Title: 3 inch; Sub-Title: 1 1/2-inch; Text: 1 inch; Outer border: 1/inch border distance from edge: 1/4-inch; all text 1 3/4-inch from border.
Posts:	Pressure treated, beveled tops, 1/2-inch higher than sign.
Installation:	Secure to fence if available. Otherwise, install two 4"x4" post, pressure treated, mounted atop a gravel bed, installed in 30-inch concrete filled post holes (8-inch minimum diameter), with the top of sign no higher than 42 inches from ground surface.
Placement:	Face sign in direction of primary visual or physical access. Do not block any access road. Do not place within 6 feet of structural facilities (e.g. manholes, spillways, pipe inlets).

Note: If the facility has a liner to restrict infiltration of stormwater, the following note must be added to the face of the sign: "This facility is lined to protect groundwater quality."

RIVERSIDE COUNTY FLOOD CONTROL

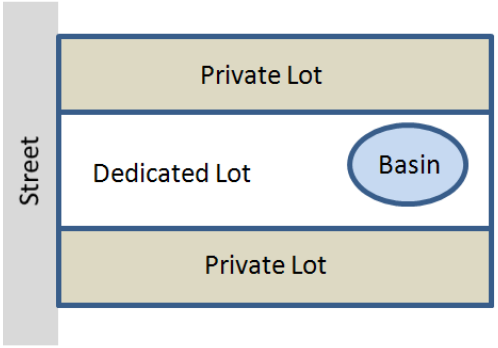
SUBJECT TO REVISION

CHIEF ENGINEER

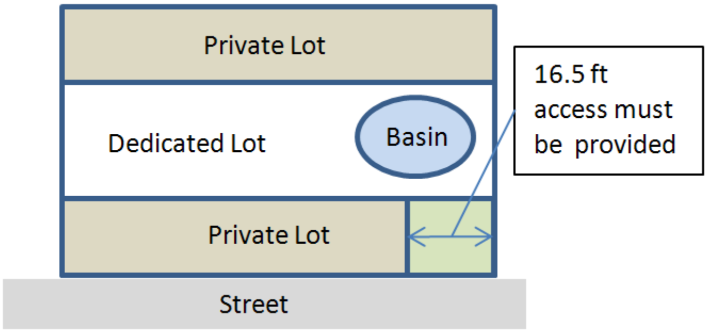
DATE:

STANDARD DRAWING NUMBER WQ502

Figure 4- Typical Basin Signage



Case 1 - Access available to public road right-of-way.



Case 2 - Access must be acquired through adjacent lot to public road right-of-way.

1.5 - Basins in Recreational Spaces

Any basin site with a bottom surface area larger than one acre will likely be required to incorporate active use area and shall be designed only after consultation with the PA to establish site-specific guidance which may increase the total facility footprint.

If multiple uses are being contemplated, consider the following:

- Place the active use areas such as ballparks, playing fields, and picnic areas above the water quality design volume (V_{BMP}) ponding limit.
- Use a multiple-stage detention basin to limit inundation of passive recreational areas to one or two occurrences a year.
- Side slopes shall not exceed 25% (4:1) unless they are existing, natural, and covered with vegetation.
- Locate the basin in a separate lot.
- Incorporate a bypass system or emergency overflow pathway that does not present a safety hazard or discharge into active recreation areas.
- The basin shall be landscaped in a manner to enhance passive recreational opportunities such as trails and aesthetic viewing. Inquire with the PA whether the basin can be compatible with the open space value and functions.

If the criteria above are met, projects may be able to receive some reduction in required onsite recreational space if approved in advance of tentative project approval by the PA.

Section 2 - Debris Basins

Debris basins differ from stormwater detention and water quality basins in that they are not intended to detain flows or to mitigate pollutants (other than debris). They are simply utilized to collect large debris from storm flows for later removal. The guidelines in this section apply to debris basins only.

Site access – Debris basins shall have unobstructed access from a public street (see Section 1.4, “Right-of-Way”) with commercial size curb cut-outs and driveway approaches.

Fencing – The entire facility shall be enclosed with 6-foot high chain link fencing and 14-foot high double drive gates. Where the perimeter fencing crosses a streambed, cable or barbed wire fencing across streambed will be provided.

Maintenance access - Maintenance access shall extend around the entire perimeter of the facility. Roads shall be a minimum of 15 feet wide (20 feet wide if on an embankment of 3 feet or higher). The minimum design turning radius shall be 35 feet. Ramps shall be a minimum of 15 feet wide with a maximum longitudinal slope of 10%. Both roads and ramps shall be surfaced (full width) with 3" of compacted Class 2 base material.

Basin Cut/Fill slopes – All basin slopes shall not be steeper than 3:1.

Stockpile/Staging Area – Shall be situated immediately adjacent to the basin. The minimum acreage shall be sufficient to temporarily store 20% of volume of debris accumulated in the 100-yr-frequency design event. Surface acreage shall be calculated assuming a stockpile of 10 feet high with 2:1 fill slopes. A minimum 15-foot wide access road with a 35-foot wide turning radius shall be provided to accommodate equipment access. In addition, a 70-foot long by 15-foot wide strip is required for equipment loading and unloading within an area of sufficient size to maneuver heavy construction equipment.

Minimum Basin Floor Surface Area – Basin floors 1,400 square or greater must be provided with a minimum width of 30 feet.

Outlet Structure – A tower-type outlet is not permitted. Use outlet structure design similar to that used in designs for Tahquitz Creek and Oak Street Debris Basins (slotted/slanted grate). All structures and ramps to structures shall include safety rails/belly bars at all stairways and wherever appropriate. A minimum of two (2) visible depth (paddle) gauges shall be provided.

APPENDIX D

BMP Pollutant Removal Effectiveness

APPENDIX D

BMP POLLUTANT REMOVAL EFFECTIVENESS

BMP Pollutant Removal Effectiveness(1)

Pollutant of Concern	Harvest and Use (9)	Infiltration BMPs(3)	Bioretention	Biofiltration with Partial Infiltration	Biofiltration with No Infiltration	Extended Detention Basins (2)	Sand Filter Basin(8)
Sediment	H	H	H	H	H	M	H
Nutrients	H	H	H	H/M(5)	M/L(6)	M/L(4)	M
Trash	H	H	H	H	H	H	H
Metals	H	H	H	H	H	M	M(7)
Bacteria	H	H	H	H	M	L	M
Oil & Grease	H	H	H	H	H	M	H
Organic Compounds	H	H	H	M	M	L	H
Pesticides and Herbicides	H	H	H	M	M	L	M

Abbreviations:

L: Low removal efficiency M: Medium removal efficiency H: High removal efficiency U: Unknown

Notes:

(1) Periodic performance assessment and updating of this table has occurred based on updated information from studies from the District, CASQA, Caltrans, the International BMP Database, and others. These effectiveness ratings are bases on the specific BMP designs incorporated into this manual. Effectiveness ratings assume operation of a given BMP in isolation. If BMPs are used in series the overall pollutant removal effectiveness may be increased. Where direct data are not available to describe the performance rating of a certain BMP/pollutant combination, professional judgement was applied based on evaluation of unit operations and processes of BMPs and the associated unit operations and processes that are effective for pollutant removal.

(2) Effectiveness based upon total 72-hour drawdown time.

(3) Includes infiltration basins, infiltration trenches, and permeable pavements without underdrains.

(4) Medium for Phosphorous, Low for Nitrogen.

(5) Nutrient removal is High if Bioretention Soil Media is formulated according to requirements in Fact Sheet 3.8 Bioretention Soil Media. Otherwise nutrient removal efficiency is Medium.

(6) Nutrient removal efficiency is Medium if Bioretention Soil Media is formulated according to requirements in Fact Sheet 3.8 Bioretention Soil Media. Otherwise nutrient removal efficiency is Low. Medium if the standard Bioretention Soil Media is used. If a nutrient sensitive Bioretention Soil Media is used, removal efficiency is High.

(7) High if specialized media targeting metals is used.

(8) Considered to be a Treatment Control BMP. See the WQMP to determine if this BMP can be used.

(9) Cisterns, when associated with an adequate and reliable (year-round) demand for non-potable use of captured storm water (see the applicable WQMP for any specific requirements), have a High effectiveness at removing all pollutants from stormwater runoff. If there is inadequate demand to reliably drain the cistern through non-potable use throughout the year, pollutant removal effectiveness will be low.

References:

Technical Guidance Document (TGD) for the Preparation of Conceptual/Preliminary and/or Project Water Quality Management Plans (WQMPs) in South Orange County. (2017)

International Stormwater Best Management Practices (BMP) Database 2014 Performance Summaries. http://www.bmpdatabase.org/Docs/2014%20Water%20Quality%20Analysis%20Addendum/BMP%20Database%20Categorical_StatisticalSummaryReport_December2014.pdf

International Stormwater Best Management Practices (BMP) Database 2016 Performance Summaries. http://www.bmpdatabase.org/Docs/03-SW-1COh%20BMP%20Database%202016%20Summary%20Stats.pdf

Strecker, E.W., W.C Huber, J.P. Heaney, D. Bodine, J.J. Sansalone, M.M. Quigley, D. Pankani, M. Leisenring, and P. Thayumanavan, "Critical Assessment of Stormwater Treatment and Control Selection Issues." Water Environment Research Federation, Report No. 02-SW-1. ISBN 1-84339-741-2. 290pp

Oil and grease, Organics, and Trash and Debris based on review of unit operations and processes; comprehensive dataset not generally available. BMP must include design elements
to address pollutants of concern.

APPENDIX E

Worksheets for calculating V_{BMP} and Q_{BMP}

Santa Margarita Watershed

V_{BMP} and Q_{BMP} worksheets

These worksheets are to be used to determine the required

Design Capture Volume (V_{BMP})
or the
Design Flow Rate (Q_{BMP})

for BMPs in the Santa Margarita Watershed

To verify which watershed your project is located within, visit

www.rcflood.org/npdes

and use the 'Locate my Watershed' tool

If your project is not located in the Santa Margarita Watershed,

Do not use these worksheets! Instead visit

www.rcflood.org/npdes/developers.aspx

To access worksheets applicable to your watershed

Use the tabs across the bottom
to access the worksheets for the Santa Margarita Watershed

Santa Margarita Watershed

BMP Design Volume, V_{BMP} (Rev. 03-2012)

Legend: 🟦 Required Entries
▨ Calculated Cells

(Note this worksheet shall **only** be used in conjunction with BMP designs from the **LID BMP Design Handbook**)

Company Name

Date

Designed by

County/City Case No

Company Project Number/Name

Drainage Area Number/Name

Enter the Area Tributary to this Feature $A_T =$ acres

85th Percentile, 24-hour Rainfall Depth, from the Isohyetal Map in Handbook Appendix E

Site Location

Township

Range

Section

Enter the 85th Percentile, 24-hour Rainfall Depth $D_{85} =$

Determine the Effective Impervious Fraction

Type of post-development surface cover
(use pull down menu)

Roofs

Effective Impervious Fraction $I_f =$

Calculate the composite Runoff Coefficient, C for the BMP Tributary Area

Use the following equation based on the WEF/ASCE Method

$C = 0.858I_f^3 - 0.78I_f^2 + 0.774I_f + 0.04$

$C =$

Determine Design Storage Volume, V_{BMP}

Calculate V_U, the 85% Unit Storage Volume $V_U = D_{85} \times C$

$V_u =$ (in*ac)/ac

Calculate the design storage volume of the BMP, V_{BMP}.

$$V_{BMP}\ (ft^3) = \frac{V_U\ (in\text{-}ac/ac) \times A_T\ (ac) \times 43{,}560\ (ft^2/ac)}{12\ (in/ft)}$$

$V_{BMP} =$ ft^3

Notes:

Santa Margarita Watershed

BMP Design Flow Rate, Q_{BMP} (Rev. 03-2012)

Legend: Required Entries; Calculated Cells

Company Name

Date

Designed by

County/City Case No

Company Project Number/Name

Drainage Area Number/Name

Enter the Area Tributary to this Feature $A_T =$ acres

Determine the Effective Impervious Fraction

Type of post-development surface cover (use pull down menu) Roofs

Effective Impervious Fraction $I_f =$

Calculate the composite Runoff Coefficient, C for the BMP Tributary Area

Use the following equation based on the WEF/ASCE Method

$C = 0.858I_f^3 - 0.78I_f^2 + 0.774I_f + 0.04$ $C =$

BMP Design Flow Rate

$Q_{BMP} = C \times I \times A_T$ $Q_{BMP} =$ ft^3/s

Notes:

Effective Impervious Fraction

Developed Cover Types	Effective Impervious Fraction
Roofs	1.00
Concrete or Asphalt	1.00
Grouted or Gapless Paving Blocks	1.00
Compacted Soil (e.g. unpaved parking)	0.40
Decomposed Granite	0.40
Permeable Paving Blocks w/ Sand Filled Gap	0.25
Class 2 Base	0.30
Gravel or Class 2 Permeable Base	0.10
Pervious Concrete / Porous Asphalt	0.10
Open and Porous Pavers	0.10
Turf block	0.10
Ornamental Landscaping	0.10
Natural (A Soil)	0.03
Natural (B Soil)	0.15
Natural (C Soil)	0.30
Natural (D Soil)	0.40
Mixed Surface Types	

Use this table to determine the effective impervious fraction for the V_{BMP} and Q_{BMP} calculation sheets