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C I T Y O F S T O C K T O N & C O U N T Y O F S A N J O A Q U I N

Final
Stormwater Quality Control Criteria Plan

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SECTION 1
INTRODUCTION

1.1 PURPOSE & GOALS

The *2009 Stormwater Quality Control Criteria Plan (2009 SWQCCP)* for the City of Stockton (City) and County of San Joaquin (County) is an update to the City's 2005 SWQCCP and the County's 2003 SWQCCP. The 2009 SWQCCP brings together these two documents and reflects new municipal stormwater National Pollutant Discharge Elimination System (NPDES) permit requirements (see Section 1.2) with a special emphasis on the implementation of low impact development (LID) strategies.

The 2009 SWQCCP was prepared to accomplish the following goals:

- Protect the waters of the City of Stockton and County of San Joaquin from the adverse impacts of urban stormwater runoff;
- Ensure that the implementation of the measures in the 2009 SWQCCP is consistent with NPDES permit and other State requirements;
- Provide clear development standards for developers, design engineers, agency engineers, and planners to use in the selection and implementation of appropriate stormwater control measures;
- Integrate LID strategies; and
- Provide maintenance procedures to ensure that the selected control measures will be maintained to provide effective, long-term pollution control.

1.2 BACKGROUND

In 1972, the Federal Clean Water Act (CWA) was amended to prohibit the discharge of pollutants to waters of the United States from any point source, unless the discharge is in compliance with an NPDES permit. In 1987, further amendments to the CWA added Section 402(p), which established a framework for regulating municipal and industrial stormwater discharges under the NPDES program through a two-phase implementation plan:

- Phase I regulations, promulgated in 1990, required metropolitan areas with a population greater than one hundred thousand and specific categories of industrial facilities, to obtain an NPDES permit for stormwater discharges.
- Phase II regulations, promulgated in 1999, require all small municipal separate storm sewer systems (MS4s) located within an urbanized area to obtain a NPDES permit for stormwater discharges.

In 2002, the City and urbanized portions of the County received a Phase I municipal NPDES permit (Order No. R5-2002-0181) issued by the Central Valley Regional Water Quality Control Board (RWQCB) for stormwater discharges from the Stockton Urbanized Area. The Stockton Urbanized Area[1] encompasses the stormwater drainage system operated by the City, the

[1] Portions of the County of San Joaquin outside of the Stockton Urbanized Area are covered by the NPDES Phase II regulations. Development projects located outside of the Stockton Urbanized Area may not fall under the provisions

urbanized areas of the County that are enclosed within the City, and the urbanized areas of the County that surround the City.

The 2002 NPDES permit required the City and the County to develop, administer, implement, and enforce a Planning and Land Development Program to reduce pollutants in runoff from new development and redevelopment to the maximum extent practicable (MEP). To address this requirement, the City and the County developed separate SWQCCPs in 2003. The City's SWQCCP was revised in 2005 and again in 2008.

1.3 THIRD TERM PERMIT REQUIREMENTS

In December 2007, the RWQCB issued the third term NPDES Permit (Order No. R5-2007-0173) to the City and the County, which requires the submittal of a revised/functionally updated SWQCCP to the RWQCB. The third term permit requires that new development and significant redevelopment integrate LID strategies and use a combination of stormwater control measures. As a result, the 2009 SWQCCP identifies how new development and significant redevelopment can meet these requirements by using a Volume Reduction Requirement. The Volume Reduction Requirement must be met through implementation of a combination of Volume Reduction Measures (such as rain barrels) and LID Treatment Controls (such as bioretention areas) to maintain the runoff volume from the proposed project site for a specified design storm depth at or below pre-project runoff volumes. The Volume Reduction Requirement is a separate and independent requirement from the Stormwater Quality Design Volume (SQDV) or Stormwater Quality Design Flow (SQDF), which are the primary required design criteria used to size Treatment Controls. Additional details on the Volume Reduction Requirement are presented in Sections 1.5, 2 and 5. Details regarding the SQDF or SQDV are presented in Section 6.

1.4 LOW IMPACT DEVELOPMENT STRATEGIES

Historically, stormwater management has consisted of a network of impervious surfaces (rooftops, driveways, roads, etc.) connected to a storm drain system that was designed to quickly convey stormwater off the site. Dozens of studies have documented the impacts of connected impervious cover on the natural hydrologic cycle (CWP, 2003). In a natural setting, the majority of rainfall is either infiltrated into the soil or is lost to evapotranspiration. However, with urbanization, pervious surfaces (such as forests and meadows) are converted into impervious cover and rainfall is converted into stormwater runoff. This leads to an increase in the volume and flow of runoff to water bodies (Figure 1-1). This increased stormwater runoff, if not managed correctly, may adversely impact local water bodies.

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of the 2009 SWQCCP. Development applicants should verify new development and redevelopment requirements with the County of San Joaquin Department of Public Works.

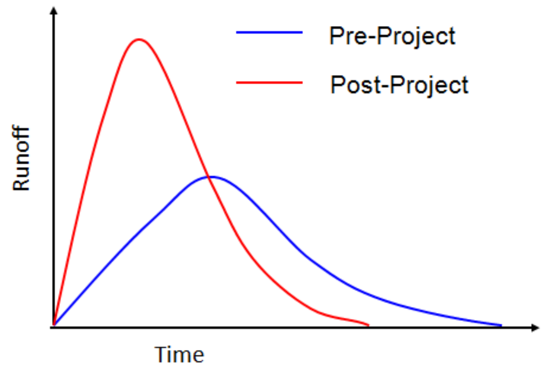


Figure 1-1. Pre vs. Post Project Hydrograph (Modified from: Haltiner, 2006)

To mitigate these impacts, conventional best management practices (BMPs) such as detention basins were implemented to temporarily detain stormwater runoff by releasing the flow over a period of time. However, detention basins have limited pollutant removal and groundwater recharge benefits (Figure 1-2).

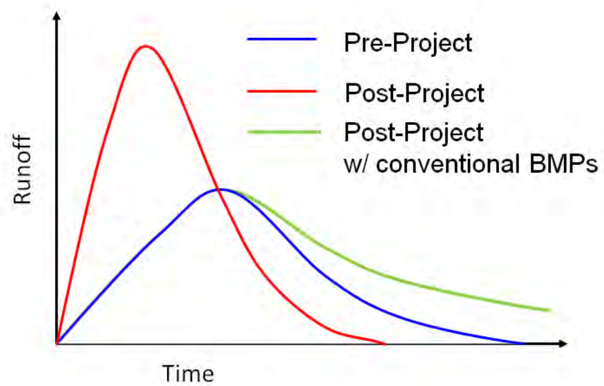


Figure 1-2. Hydrograph with Conventional BMPs (Modified from: Haltiner, 2006)

To improve pollutant removal and groundwater recharge benefits, improvements are being made beyond the conventional stormwater treatment controls through the use of LID strategies. LID, as required in the third term NPDES permit, is defined as, “a stormwater management strategy concerned with maintaining or restoring natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements. LID strategies employ a variety of natural and built features that reduce the rate of runoff, filter out its pollutants, and facilitate the infiltration of water into the ground.”

LID is a decentralized approach to stormwater management that works to mimic the natural hydrology of the site by retaining rainfall onsite. The idea is to eliminate the shaded areas as shown in Figure 1-3 by reducing the peak volume and duration of flow through the use of site design and volume reduction measures. The benefits of reduced stormwater volume include reduce pollutant loading and increased groundwater recharge and evapotranspiration rates.

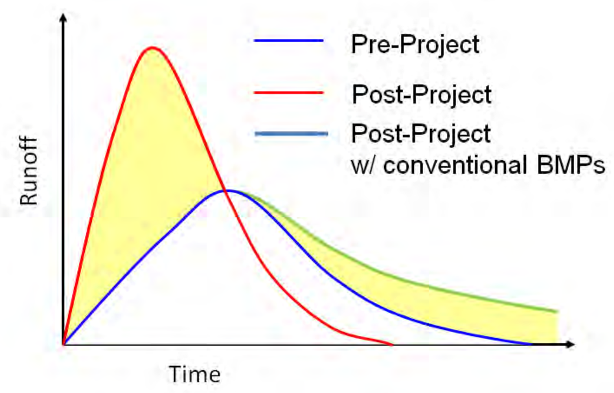


Figure 1-3. Goal of LID is to Mimic Pre-Project Hydrography through Reduction in Peak Runoff Volume and Flow (Modified from: Haltiner, 2006)

Additionally, LID strategies can reduce the cost associated with stormwater management and treatment. LID can reduce the amount of materials needed for pavement, reduce the need for curbs and gutters, and by reducing stormwater volume, can also reduce the size and cost of flood-control structures.
A recent study conducted by the US Environmental Protection Agency (2007) examined seventeen case studies to compare the projected or known costs of LID strategies with those of conventional development practices. The study found that the majority of projects realized significant savings due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping.

1.5 UPDATES TO THE SWQCCP: KEY CONCEPTS

The primary difference between the 2009 SWQCCP and the previous versions of the City and County SWQCCPs is the integration of the Volume Reduction Requirement and increased emphasis on LID strategies. The Volume Reduction Requirement was developed to provide a design criterion for achievement of LID at a proposed development project. The Volume Reduction Requirement allows developers and plan reviewers to determine when LID has been achieved and what constitutes adequate implementation of a combination of stormwater control measures.

Key concepts associated with the Volume Reduction Requirement include:

- All Priority New Development and Significant Redevelopment Projects must apply four categories of stormwater pollution controls measures: Site Design Controls (Section 3), Source Controls (Section 4), Volume Reduction Measures (Section 5), and Treatment Controls (Section 6).
- New Development Priority Projects must comply with the Volume Reduction Requirement. The Volume Reduction Requirement can be met through the application of Volume Reduction Measures (BMPs that reduce runoff volume as outlined in Section 5) and LID Treatment Controls (BMPs that provide Treatment Control and reduce runoff volume as outlined in Section 6).

- The Volume Reduction Requirement is determined by subtracting the pre-project runoff volume from the post-project runoff volumes for the 0.51-inch storm depth, which is the average 85th percentile/24-hour storm depth estimated for the Stockton area.
- Priority Significant Redevelopment Projects must also comply with the Volume Reduction Requirement; however credits may be applied based on the type of redevelopment. A credit of 0.05 inches from the 0.51 inch Volume Reduction Requirement may be applied to any of the following types of redevelopment. Credits are additive such that a maximum credit of 0.25 inch is possible for a project that meets all five criteria:
    - Significant Redevelopment (as defined in Section 2.1)
    - Brownfield redevelopment
    - High density (>7 units per acre)
    - Vertical Density, (Floor to Area Ratio (FAR) of 2 or >18 units per acre)
    - Mixed use and Transit Oriented Development (within ½ mile of public transit)
- The runoff coefficients used to calculate the Volume Reduction Requirement should be based on the specific land use elements of the development site (e.g., as opposed to a blanket coefficient for all medium density residential). The goal should be to reduce, or minimize, impervious areas, and thus runoff coefficients, through site design strategies such as using the minimum allowable roadway width. Lower runoff coefficients will result in a smaller Volume Reduction Requirement. Fact Sheet G-4 in Section 3 suggests strategies to minimize impervious cover. Minimizing or eliminating the use of curb and gutter so that roadway runoff drains to swales and other Volume Reduction Measures or LID Treatment Controls is strongly encouraged where slope and density permit.
- To meet the Volume Reduction Requirement, projects must <u>first</u> apply Volume Reduction Measures. The Volume Reduction Measure fact sheets (Section 5) detail how volume reduction is calculated for each measure.
- Volume Reduction Measures also provide treatment benefits, which are recognized through tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the Stormwater Quality Design Volume (SQDV) or Stormwater Quality Design Flow (SQDF), which are the primary design criteria used to size Treatment Controls. The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of Volume Reduction Measures reduces effective impervious area and thereby the volume of water to be treated. The Volume Reduction Measure fact sheets (Section 5) detail how the tributary impervious area credit is calculated for each measure. The application of credits to determine effective area for design of Treatment Controls is described in Section 6.
- If a project does not fully meet the Volume Reduction Requirement through the application of Volume Reduction Measures, the project must use LID Treatment Controls to further reduce stormwater runoff volumes and treat the SQDF or SQDV. Calculation procedures for determining the volume reduction for LID Treatment Controls are provided within each fact sheet in Section 6.

  - Treatment Controls are categorized into two groups: LID Treatment Controls (structural BMPs that reduce runoff volume) and Conventional Treatment Controls (structural BMPs that typically do not reduce runoff volume).
  - If the Volume Reduction Requirement has been met through the use of Volume Reduction Measures, projects may utilize either LID Treatment Controls or Conventional Treatment Controls to treat the SQDV or SQDF.
  - Selection of Treatment Controls should be based on their ability to reduce runoff volumes and remove pollutants of concern (e.g., receiving water 303(d) listings). See Table 6-2 for pollutant removal efficiency of treatment controls.
- If the Volume Reduction Requirement is <u>not</u> entirely met through the combination of Volume Reduction Measures and LID Treatment Controls, the project must submit a Volume Reduction Requirement Waiver Form as described in Section 5.

1.6 ORGANIZATION OF THE SWQCCP

The SWQCCP is organized as follows:

Section 1	Provides an overview of the purpose of the SWQCCP, applicable regulations and an introduction to LID.
Section 2	Outlines a step-by-step process for meeting the standards outlined within the SWQCCP.
Section 3	Contains fact sheets on site design controls.
Section 4	Includes fact sheets on source controls.
Section 5	Provides fact sheets on volume reduction measures.
Section 6	Contains fact sheets on treatment controls.
Section 7	Details maintenance requirements for control measures.

SECTION 2
STORMWATER MANAGEMENT STANDARDS FOR NEW DEVELOPMENT AND SIGNIFICANT REDEVELOPMENT

This section provides an overview of the stormwater management standards for new development and significant redevelopment. This section contains information regarding development projects that are subject to the SWQCCP and outlines the process that must be used to effectively incorporate stormwater control measures and satisfying the requirements of the permitting agencies in the City of Stockton and County of San Joaquin.

The control measures, often termed Best Management Practices or BMPs, described in the 2009 SWQCCP were selected to optimize post-construction, on-site stormwater pollution control. All Priority New Development and Significant Redevelopment Projects must apply all four categories of stormwater pollution controls measures:

- Site Design Controls (Section 3)
- Source Controls (Section 4)
- Volume Reduction Measures (Section 5)
- Treatment Controls (Section 6)

2.1 PROCESS TO COMPLY WITH CITY AND COUNTY STANDARDS

A step-by-step process for incorporating these controls is illustrated in **Figure 2-1**. The applicability of specific controls outlined in Steps 3 – 6 should be confirmed with the local permitting agency.

In addition to the requirements prescribed within the 2009 SWQCCP, development projects must also adhere to applicable drainage standards as specified in the City of Stockton Standard Specifications and Plans or the County of San Joaquin Improvement Standards.

Step 1: Determine if Project is Subject to SWQCCP

The first step is to identify whether the project is considered a Priority Project. Priority Projects must implement the controls identified in the 2009 SWQCCP.

Projects that are not Priority Projects are still subject to City or County stormwater staff review. Stormwater controls may be required by the City or County for Non-Priority Projects, depending on the potential discharge of pollutants in stormwater runoff.

Priority Projects include the following:

1) **Significant redevelopment** - Significant redevelopment is defined as the creation or addition of at least 5,000 square feet of impervious surfaces on an already developed site. Significant redevelopment includes, but is not limited to, expansion of a building footprint or addition or replacement of a structure; structural development including an increase in gross floor area and/or exterior construction or remodeling; replacement of impervious surface that is not part of a routine maintenance activity; and land disturbing activities related with structural or impervious surfaces. Where significant redevelopment results in an increase of less than fifty

percent of the impervious surfaces of a previously existing development, and the existing development was not subject to the Development Standards, the numeric sizing criteria discussed below applies only to the addition, and not the entire development.

2) **Home subdivision of 10 housing units or more –** This category includes single-family homes, multi-family homes, condominiums, and apartments.

3) **Commercial developments greater than or equal to 5,000 square feet –** This category is defined as any development on private land that is not for heavy industrial or residential uses, where the land area for development is greater than or equal to 5,000 square feet of impervious area (not including the parking lot, see separate parking lot requirement below). The category includes but is not limited to hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, commercial retail nurseries, multi-apartment buildings, car wash facilities, mini-malls, and other business complexes, shopping malls, hotels, office buildings, public warehouses, and other industrial facilities.

4) **Automotive repair shops –** This category is defined as a facility that is categorized in any one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, or 7536-7539, where the total impervious area for development is greater than or equal to 5,000 square feet.

5) **Restaurants –** This category is defined as a facility that sells prepared foods and drinks for consumption, including stationary lunch counters and refreshment stands selling prepared foods and drinks for immediate consumption (SIC code 5812), where total impervious area for development is greater than or equal to 5,000 square feet.

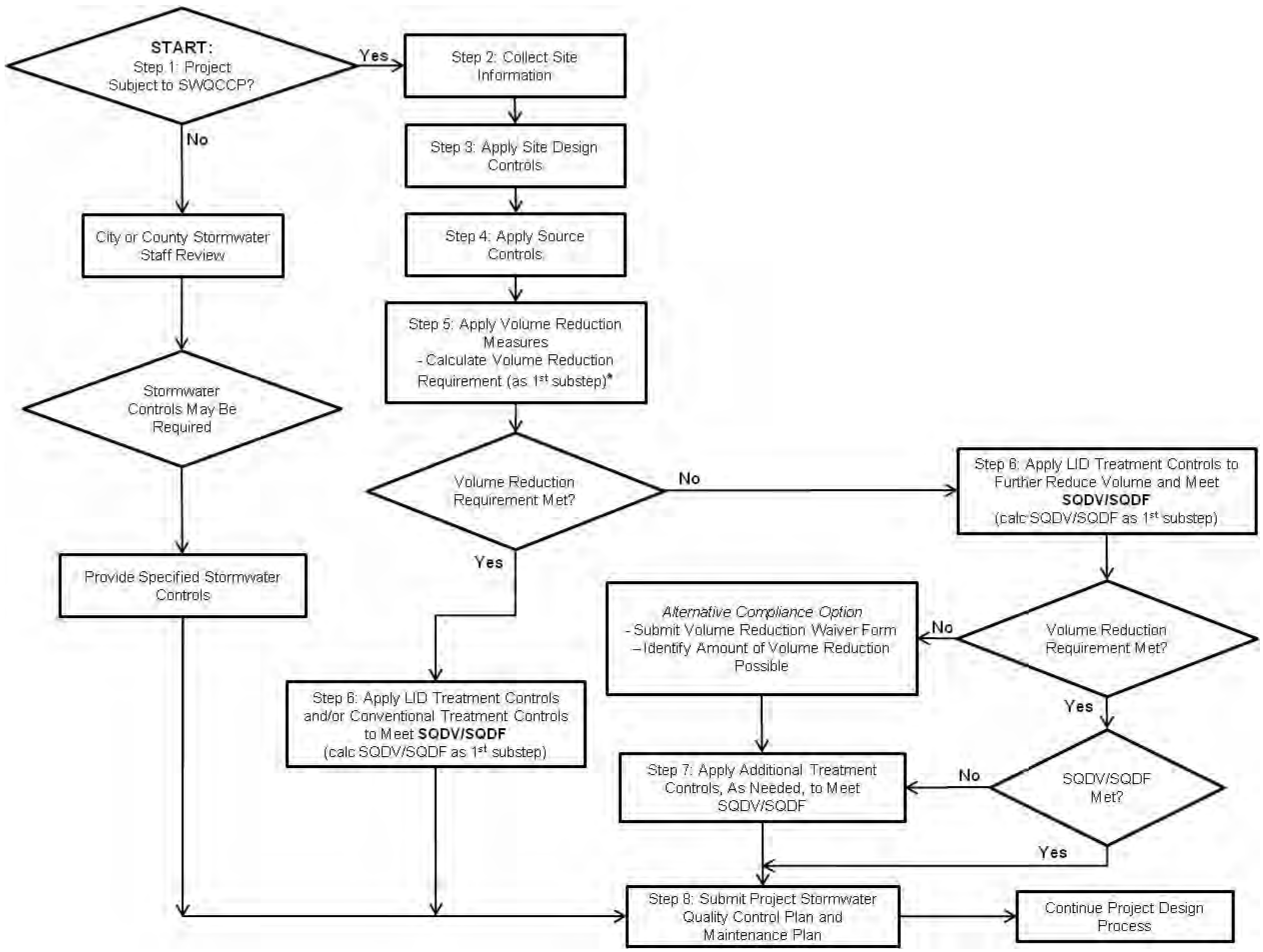
6) **Parking lots 5,000 square feet or more or with 25 or more parking spaces and potentially exposed to urban runoff –** Parking lot is defined as a land area or facility for the temporary parking or storage of motor vehicles used personally, for business, or for commerce.

7) **Street and roads –** This category includes any paved surface equal to or greater than one acre of impervious area used for the transportation of automobiles, trucks, motorcycles, and other vehicles.

8) **Retail Gasoline Outlets –** Retail Gasoline Outlet (RGO) is defined as any facility engaged in selling gasoline with 5,000 square feet or more of impervious surface area.

The standards set forth in the 2009 SWQCCP shall apply to all new developments and significant redevelopment projects falling under the priority project categories as specified above. Compliance with the SWQCCP should be discussed as early as possible in the site design process. The project engineer and other design professionals (including architects) should be involved during the City's Tentative Map stage or the County's Site or Use Permit Approvals.

In addition to the City and County requirements, owners/developers of some of the sites may also be subject to the State of California's general permit for stormwater discharge from industrial activities (Industrial General Permit) and general permit for stormwater from construction activities (Construction General Permit). The control measures provided in the 2009 SWQCCP may assist the owner/developer in meeting the requirements of the State's permits (http://www.waterboards.ca.gov/water_issues/programs/stormwater/). The City and County's stormwater staff are available to provide assistance regarding State permit requirements.



* Priority Significant Redevelopment Projects must also comply with the Volume Reduction Requirement; however credits may be applied (See Step 5 below)

Figure 2-1. Process for Meeting New Development & Significant Redevelopment Stormwater Standards

Step 2: Collect Site Information

The next step is to collect site information that is critical for the selection of appropriate stormwater controls. The following information should be documented and submitted to the City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division at the onset of the application process:

- Priority Project Category (see Step 1)
- Gross project area (acres)
- Drainage areas (acreage and location via site map)
- Impervious area (acreage and location via site map)
- Location of discharge (to the storm drain system or local receiving water)
- Watershed that the project will be located in (see Figure 2-2)
- Any pollutants for which receiving waters are listed as impaired under CWA Section 303(d) (also called pollutants of concern). The most current and up to date 303(d) list can be found at: www.swrcb.ca.gov/centralvalley/water_issues/tmdl/impaired_waters_list/
- Land use type and density of the development project and pollutants associated with that land use type (**Table 2-1**). Identify any additional pollutants expected to be present on site at concentrations that pose potential water quality concerns
- Activities expected to be on the site
- Site conditions: topography, hydraulic head, groundwater and soils (see **Appendix F** for more information on soils)

Table 2-1. New Development/Redevelopment Priority Project Categories and Associated Pollutants of Concern

New Development and Redevelopment Priority Project Category	Pollutant Category of Concern						
	Sediment	Nutrients	Metals	Trash and Debris	Oxygen Demand	Toxic Organics	Bacteria
Home Subdivisions (≥ 10 units)	X	X		X	X		X
Commercial Developments (≥ 5,000 SF)	x	x		X	x	x	x
Automotive Repair Shops			X	X		X	
Restaurants		x		X	X		X
Parking Lots (≥ 5,000 SF or 25 spaces)	x	x	X	X	x		
Street and Roads (≥ 1 ac paved surface)	X		X	X	x		
Retail Gasoline Outlets	X	x	X	X	x	X	

X = Pollutant likely to be present in stormwater runoff from project area
x = Pollutant may be present but is dependant on activities (e.g., landscaping) occurring at an individual development.

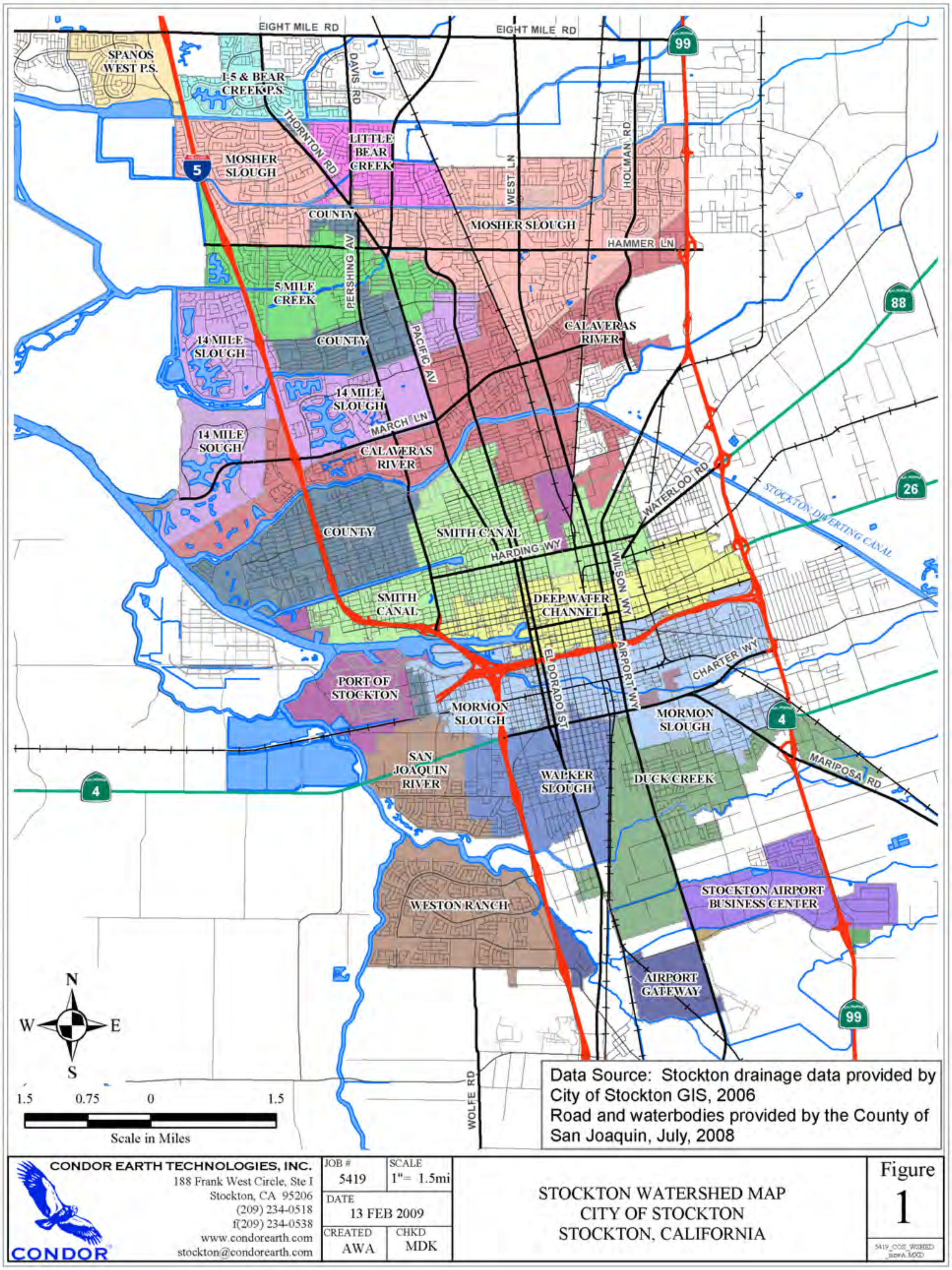


Figure 2-2. Stockton Watershed Map

Step 3: Apply Site Design Controls

The third step is to apply the required Site Design Controls as specified in **Table 2-2**. Site Design Controls protect sensitive environmental features such as riparian areas, wetlands and steep slopes. Development should be located on the least sensitive portion of the site. Additionally, the project should minimize impervious cover and soil compaction. These controls will help to reduce runoff volume and is the first step (and possibly the most inexpensive control measure) in meeting the Volume Reduction Requirement (see Step 5). Additional guidance on Site Design Controls can be found in Section 3. Minimizing or eliminating the use of curb and gutter so that roadway runoff drains to swales and other Volume Reduction Measures or LID Treatment Controls is strongly encouraged where the slope and density permit.

Step 4: Apply Source Controls

All Priority New Development and Significant Redevelopment projects must implement applicable Source Controls. Source Controls are operational practices that prevent pollution by reducing potential pollutants at the source. They typically do not require maintenance or significant construction. Any of the Priority Projects that has one or more of the following activities occurring onsite must implement the source control measures as specified in **Table 2-2**.

Step 5: Apply Volume Reduction Measures

All Priority New Development and Significant Redevelopment Projects must apply Volume Reduction Measures (**Table 2-2**). Volume Reduction Measures are generally considered to be BMPs that can direct, retain, reuse and/or infiltrate stormwater runoff (e.g., rain gardens and rain barrels). Additional guidance on Volume Reduction Measures is presented in Section 5. As the first substep to Step 5, projects must calculate their Volume Reduction Requirement.

The application of Volume Reduction Measures is driven by the **Volume Reduction Requirement**. The Volume Reduction Requirement is a new requirement developed in response to the recent NPDES Permit requirements specifying the explicit use of LID strategies and a combination of stormwater control measures.

> The **Volume Reduction Requirement** specifies that post-project runoff volumes must match pre-project runoff volumes for the 0.51-inch storm depth, which is the average 85th percentile/24-hour storm depth estimated for the Stockton area. In other words, the **Volume Reduction Requirement** is equal to the post-project runoff volume (without Volume Reduction Measures) minus pre-project runoff volume. New Development Priority Projects can apply a combination of Volume Reduction Measures and LID Treatment Controls (see Step 6) to meet the Volume Reduction Requirement. Additional information on the Volume Reduction Requirement is presented in Section 5.

Volume Reduction Measures also provide treatment benefits, which are recognized through tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the Stormwater Quality Design Volume (SQDV) or Stormwater Quality Design Flow (SQDF), which are the primary design criteria used to size Treatment Controls. The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of Volume Reduction Measures reduces the effective impervious area and, thereby, the volume of water to be treated.

The Volume Reduction Measure fact sheets (Section 5) detail how volume reduction and tributary impervious area credits are calculated for each measure. The application of credits to determine effective area for design of Treatment Controls is described in Section 6. **Appendix B** provides additional information on calculating and meeting the Volume Reduction Requirement.

Volume Reduction Requirement Credit for Significant Redevelopment

Priority Significant Redevelopment Projects must also comply with the Volume Reduction Requirement; however an incentive in the form of credits may be applied based on the type of redevelopment. A credit of 0.05 inches from the 0.51 inch Volume Reduction Requirement may be applied to any of the following types of redevelopment. Credits are additive such that a maximum credit of 0.25 inch is possible for a project that meets all five criteria:

- Significant Redevelopment (as defined in Step 1)
- Brownfield redevelopment
- High density (>7 units per acre)
- Vertical Density, (Floor to Area Ratio (FAR) of 2 or >18 units per acre)
- Mixed use and Transit Oriented Development (within ½ mile of public transit, such as a bus stop)

Step 6: Apply LID Treatment Controls

Treatment controls are required for all New Development and Significant Redevelopment Priority Projects (**Table 2-2**). Treatment controls are engineered technologies designed to remove pollutants from stormwater runoff and must be designed to treat the Stormwater Quality Design Flow (SQDF) or Stormwater Quality Design Volume (SQDV). Treatment Controls are designed to treat the runoff from the smaller storms and the first flush of large storms, which comprise 80 – 85% of annual runoff volumes. The volume or flow in excess of the design values is typically bypassed. Guidance on calculating the SQDF and SQDV is provided in Section 6. Selection of Treatment Controls should be based on their ability to reduce runoff volumes and remove pollutants of concern (e.g., receiving water 303(d) listings). See **Table 6-2** for pollutant removal efficiency of treatment controls.

As indicated in Step 5, Priority New Development must meet the Volume Reduction Requirement. If the Volume Reduction Requirement has not been met through the use of Volume Reduction Measures, LID Treatment Controls must be used to further reduce runoff volume to meet the Requirement. If the Volume Reduction Requirement has been fully met through the use of Volume Reduction Measures, then a treatment control may be chosen from the lists of LID Treatment Controls or Conventional Treatment Controls.

If the Volume Reduction Requirement cannot be fully met due to site constraints, see “Alternative Compliance Option” in Section 5. Priority New Development and Significant Redevelopment Projects that cannot fully meet the Volume Reduction Requirement and are located in a watershed with a 303d listed waterbody, must select Treatment Controls with a medium to high removal efficiency for the pollutant of concern (see Table 6-2).

Guidance on Volume Reduction is provided in **Appendix B** and throughout the Fact Sheets provided in Sections 5 and 6.

Step 7: Select Additional Treatment Controls as Needed to Meet Treatment Requirement

If the Treatment Requirement is not entirely met through a combination of Volume Reduction Measures and LID Treatment Controls, the project must apply Conventional Treatment Controls to meet the requirement. Guidance on selection and design of Conventional Treatment Controls is provided in Section 6.

Regional Stormwater Facilities

New Development and Significant Redevelopment Projects that discharge stormwater runoff to City or County-approved, regional stormwater treatment control facilities that comply with the SQDV/SQDF requirements of the 2009 SWQCCP are not required to provide separate treatment controls. However, such projects are required to meet the Volume Reduction Requirement and provide site design, source, and volume reduction measures in accordance with the 2009 SWQCCP.

Step 8: Submit Project Stormwater Quality Control Plan and Maintenance Plan

Projects that are subject to the requirements of the 2009 SWQCCP, as defined in Step 1, are required to submit a Project Stormwater Quality Control Plan that adequately demonstrates that the proposed new development or redevelopment project will conform to all requirements of the 2009 SWQCCP.

The Project Stormwater Quality Control Plan (SWQCP) must be approved by the City of Stockton Department of Municipal Utilities or the San Joaquin County Department of Public Works, Community Infrastructure Division, whichever agency has jurisdiction over the project, before building permits or use permits will be issued for the project. The SWQCP must be submitted in addition to the Stormwater Pollution Prevention Plan (SWPPP) required for all construction projects. Project SWQCPs should conform to the content and format requirements indicated in **Appendix E** of this document. Flow charts depicting the City and County's project SWQCP review and approval process are provided in **Figures 2-3** and **2-4**, respectively.

The City and the County also require the submittal of a Maintenance Plan and execution of a Maintenance Agreement with the owner/operator of stormwater controls prior to the final acceptance of a private project for projects using any of the Structural Source Controls that require maintenance (Section 4), Volume Reduction Measures (Section 5) and Treatment Controls (Section 6). Maintenance Plans must include guidelines for how and when inspection and maintenance should occur for each control. Section 7 and **Appendices D and E** provide additional information and guidance on compliance with maintenance requirements.

Table 2-2. Control Measure Selection Matrix for New Development and Significant Redevelopment Project Categories

Project Category	Site Design Controls				Source Controls							Volume Reduction Measures	Treatment Controls
	Conserve Natural Areas (G-1)	Protect Slopes and Channels (G-2)	Minimize Soil Compaction (G-3)	Minimize Impervious Area (G-4)	Storm Drain Message and Signage (S-1)	Outdoor Storage Area Design (S-2)	Trash Storage Area Design (S-3)	Loading/ Unloading Dock Area Design (S-4)	Repair/ Maintenance Bay Design (S-5)	Vehicle/ Equipment/ Accessory Washing Area Design (S-6)	Fueling Area Design (S-7)	Rain Garden (V-1) Rain Barrel/Cistern (V-2) Vegetated Roof (V-3) Interception Trees (V-4) Grassy Channel (V-5) Vegetated Buffer Strip (V-6)	<u>LID Treatment Controls</u> Bioretention (L-1) Stormwater Planter (L-2) Tree-well Filter (L-3) Infiltration Basin (L-4) Infiltration Trench/Dry Well (L-5) Porous Pavement Filter (L-6) Vegetated (Dry) Swale (L-7) Grassy Swale (L-8) Grassy Filter Strip (L-9) <u>Conventional Treatment Controls</u> Constructed Wetland (C-1) Extended Detention Basin (C-2) Wet Pond (C-3) Proprietary Control Device (C-4)
Significant Redevelopment	R	R	R	R	R	R^1	R^1	R^1	R^1	R^1	R^1	S	S
Home Subdivisions (≥ 10 units)	R	R	R	R	R	R^1	-	-	-	-	-	S	S
Commercial Developments (≥ 5,000 SF)	R	R	R	R	R	R^1	R^1	R^1	R^1	R^1	R^1	S	S
Automotive Repair Shops	R	R	R	R	R	R^1	R^1	-	R^1	R^1	R^1	S	S
Restaurants	R	R	R	R	R	R^1	R^1	R^1	-	R^1	-	S	S
Parking Lots (≥ 5,000 SF or 25 spaces)	R	R	R	R	R	R^1	R^1	-	-	-	-	S	S
Streets and Roads (≥ 1 ac. paved surface)	R	R	R	R	R	-	-	-	-	-	-	S	S
Retail Gasoline Outlets	R	R	R	R	R	R^1	-	-	-	-	-	S	S

R: required
R^1: required if outdoor activity is included in the project
S: select one or more applicable controls

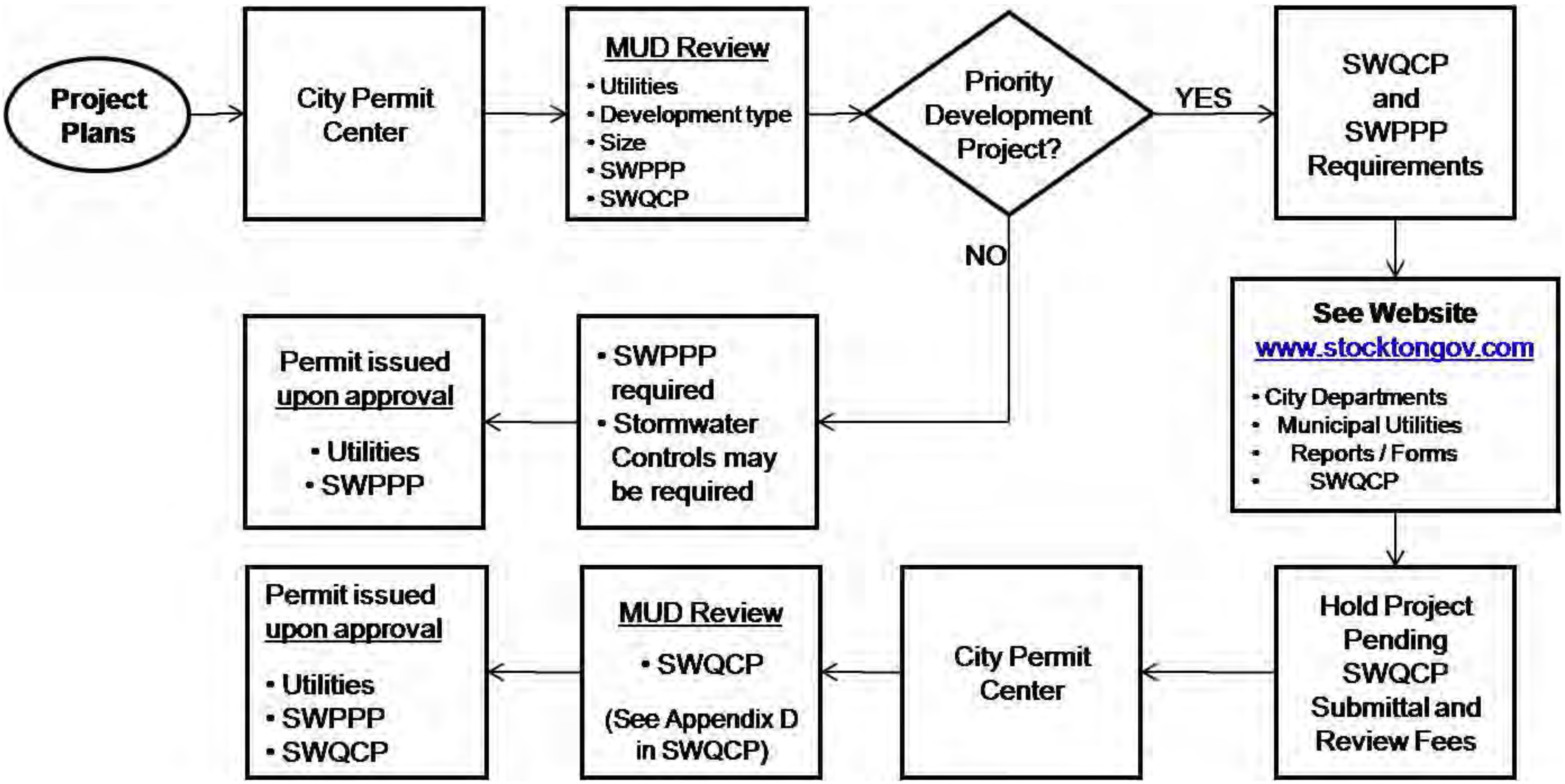


Figure 2-3. City of Stockton Stormwater Quality Control Plan (SWQCP) Review Process Flowchart

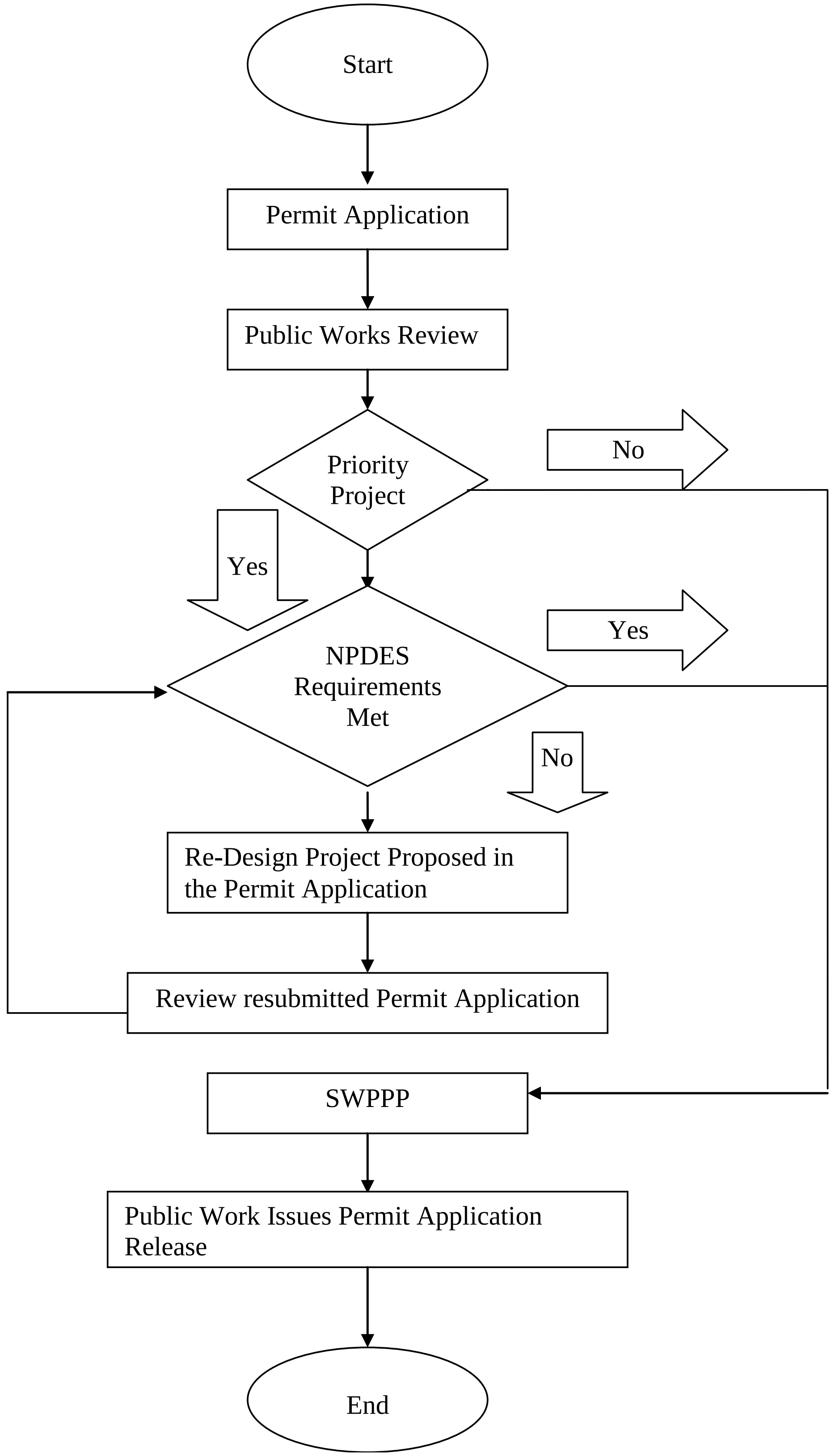


Figure 2-4. County of San Joaquin Stormwater Quality Control Plan (SWQCP) Review Process Flowchart

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SECTION 3
SITE DESIGN CONTROLS

3.1 INTRODUCTION

The principal objective of the Site Design Controls is to reduce stormwater runoff peak flows and volumes through appropriate site design. The benefits derived from this approach include:

- Reduced size of downstream treatment controls and conveyance systems;
- Reduced pollutant loading to treatment controls; and
- Reduced hydraulic impact on receiving streams.

Site Design Controls include the following design features and considerations designated as G-1 through G-4:

- G-1: Conserve Natural Areas
- G-2: Protect Slopes and Channels
- G-3: Minimize Soil Compaction
- G-4: Minimize Impervious Area

The Site Design Controls described in this Section are required for all Priority New Development and Significant Redevelopment projects unless the project proponent demonstrates to the satisfaction of the City or County that the particular measures are not applicable to the proposed project, or the project site conditions make it infeasible to implement the site design control measure in question. The applicability of specific controls outlined within this section should be confirmed with the local government.

3.2 DESCRIPTION

Detailed descriptions and design criteria for each of the Site Design Controls are presented in the following fact sheets.

Purpose

Each project site possesses unique topographic, hydrologic and vegetative features, some of which are more suitable for development than others. Locating development on the least sensitive portion of a site and conserving naturally vegetated areas can minimize environmental impacts in general and stormwater runoff impacts in particular.

Design Criteria

If applicable and feasible for the given site conditions, the following site design features or elements are required and should be included in the project site layout, consistent with applicable General Plan and Local Area Plan policies:

1. Preserve riparian areas and wetlands.
2. Concentrate or cluster development on least-sensitive portions of a site, while leaving the remaining land in a natural undisturbed state.
3. Identify and avoid areas susceptible to erosion and sediment loss.
4. Limit clearing and grading of native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection – this area may be defined as the development envelope.
5. Maintain existing topography and existing drainage divides to encourage dispersed flow.
6. Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought-tolerant plants.
7. Promote natural vegetation by using parking lot islands and other landscaped areas.

Purpose

Erosion of slopes and channels can be a major source of sediment and associated pollutants, such as nutrients, if not properly protected and stabilized.

Design Criteria

Slope Protection

Slope protection practices must conform to design requirements or standards set forth by local agency erosion and sediment control standards and design standards (City standards can be found in Municipal Code Sections 7-800 through 7-860.2 and 13-500 through 13-513 and County standards can be found in the County Improvement Standards. The design criteria described in this fact sheet are intended to enhance and be consistent with these local standards.

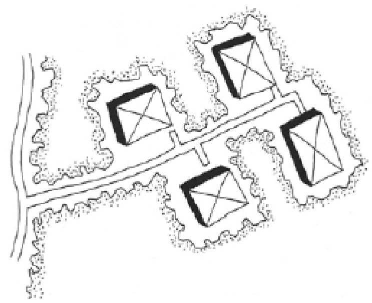
1. Slopes must be protected from erosion by safely conveying runoff from the tops of slopes.
2. Slopes must be vegetated (full-cover) with first consideration given to use of native or drought-tolerant species.

Channel Protection

The following measures should be implemented to provide erosion protection of unlined receiving streams. Activities and structures must conform to applicable standards and specifications of agencies with jurisdiction (e.g. U.S. Army Corps of Engineers, California Department of Fish and Game).

1. Utilize natural drainage systems where feasible, but minimize runoff discharge rate and volume to avoid erosive flows.
2. Stabilize permanent channel crossings.
3. In cases where beds and/or banks of receiving streams are fragile and particularly susceptible to erosion, special stabilization may be required.
    a. Small grade control structure (e.g. drop structure) may be used to reduce the slope of the channel.
    b. Severe bends or cut banks may need to be hardened by lining with grass or rock.
    c. Rock-lined, low-flow channels may be appropriate to protect fragile beds.
4. Install energy dissipaters, such as rock riprap, at the outlets of storm drains, culverts, conduits or channels that discharge into unlined channels to lessen erosion potential.

Purpose



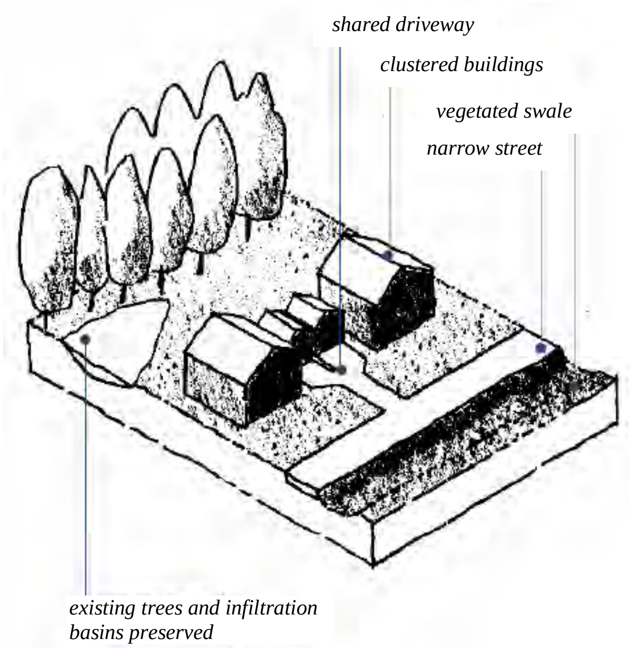
Source: Greenfield et al., 1991

This control works to protect water quality by preserving some of the natural hydrologic function of the site. Existing soils may contain organic material and soil biota that are ideal for storing and infiltrating stormwater. Clearing and grading and equipment can remove and compact existing soils and, therefore, limit their infiltrative capacity. The design criteria presented below are not intended to supersede compaction requirements associated with building codes.

Design Criteria

1. Delineate and flag the development envelope for the site (e.g., identify the minimum area needed to build lots, allow access and provide fire protection).
2. Restrict equipment access and storage of construction equipment to the development envelope.
3. Restrict storage of construction equipment within the development envelope.
4. Avoid the removal of existing trees and valuable vegetation, as feasible.
5. It may be difficult for infill and redevelopment developments to avoid soil disturbance. In these cases, the project should consider soil amendments to restore permeability and organic content.

Purpose



Source: County of San Diego LID Handbook

The potential for the discharge of pollutants in stormwater runoff from a project site increases as the percentage of impervious area within the project site increases because impervious areas increase the volume and rate of runoff flow. Pollutants deposited on impervious areas tend to be easily mobilized and transported by runoff flow. Minimizing impervious area through site design is an important means of minimizing stormwater pollutants of concern. In addition to the environmental and aesthetic benefits, a highly pervious site may allow reduction in the size of downstream conveyance and treatment systems, yielding savings in development costs.

Design Strategies

Some aspects of site design are directed by local agency building and fire codes and ordinances. The design strategies suggested in this fact sheet are intended to enhance and be consistent with these local codes and ordinances. Minimizing impervious surfaces at every possible opportunity requires integration of many small strategies. Suggested strategies for minimizing impervious surfaces through site design include the following:

1. Use minimum allowable roadway and sidewalk cross sections, driveway lengths and parking stall widths (refer to City of Stockton Standard Specifications and Plans or the County Improvement Standards for roadway and sidewalk specifications).
2. Minimizing or eliminating the use of curb and gutter so that roadway runoff drains to swales and other Volume Reduction Measures or LID Treatment Controls is strongly encouraged where slope and density permit.
3. Use two-track/ ribbon driveways or shared driveways.
4. Include landscape islands in cul-de-sacs (where approved).
5. Reduce the foot prints of building and parking lots.
6. Cluster buildings and paved areas to maximize pervious area.
7. Maximize tree preservation or tree planting.
8. Avoid compacting or paving over soils with high infiltration rates (see G-3).
9. Use pervious pavement materials where appropriate, such as modular paving blocks, turf blocks, porous concrete and asphalt, brick, and gravel or cobbles (Ref. BASMAA, 1999 for descriptions of pervious pavements options).
10. Use grass-lined channels or surface swales to convey runoff instead of paved gutters (see **Fact Sheet V-5**).

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SECTION 4
SOURCE CONTROLS

4.1 INTRODUCTION

Source controls are practices designed to prevent pollutants from contacting stormwater runoff or to prevent the discharge of contaminated runoff to the storm drainage system. This section addresses structural source controls consisting of specific design features or elements. Non-structural source controls, such as good housekeeping and employee training, are not included in this Plan. The California Stormwater Best Management Practices Handbooks may be consulted for information on non-structural source controls (CASQA, 2003). The City and County may require additional source controls not included in this Plan for specific pollutants, activities, or land uses.

This section describes control measures for activities that have been identified as potentially significant sources of pollutants in stormwater. Each of the measures specified in this Section should be implemented in conjunction with appropriate non-structural source controls to optimize pollution prevention.

The source controls addressed in this section apply to both stormwater and non-stormwater discharges. Non-stormwater discharges are the discharge of any substance, such as cooling water, irrigation water, process wastewater, etc., to the storm drainage system or water body that is not composed entirely of stormwater. Stormwater that is mixed or commingled with other non-stormwater flows is considered non-stormwater. Discharges of stormwater and non-stormwater to the storm drainage system or a water body may be subject to local, state, or federal permitting prior to commencement of any discharge. The appropriate agency should be contacted prior to any discharge. Discuss the matter with the City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division if you are uncertain as to which agency should be contacted.

Some of the source controls presented in this section require connection to the sanitary sewer system. Connection and discharge to the sanitary sewer system without prior approval or obtaining the required permits is prohibited. Contact the City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division to obtain information regarding obtaining sanitary sewer permits from the City or County. Discharges of certain types of flows to the sanitary sewer system may be cost prohibitive. The designer is urged to contact the City or County prior to completing site and equipment design of the facility.

4.2 DESCRIPTION

Source control measures and associated design features specified for various sites and activities are summarized in **Table 4-1**. Fact sheets are presented in this section for each source control measure. These sheets include design criteria established by the City and County to ensure effective implementation of the required source control measures.

Table 4-1. Summary of Source Control Design Features

Source Control[1]	Design Feature or Element						
	Signs, placards, stencils, stamps	Surfacing (compatible, impervious)	Covers, screens	Grading/berming to prevent run-on	Grading/berming to provide secondary containment	Sanitary sewer connection	Emergency Storm Drain Seal
Storm Drain Message and Signage (S-1)	X						
Outdoor Material Storage Area Design (S-2)		X	X	X	X		X
Outdoor Trash Storage and Waste Handling Area Design (S-3)	X	X	X	X		X	
Outdoor Loading/Unloading Dock Area Design (S-4)		X	X	X	X		
Outdoor Repair/Maintenance Bay Design (S-5)		X	X	X	X		X
Outdoor Vehicle/Equipment/ Accessory Washing Area Design (S-6)		X	X	X	X	X	X
Fueling Area Design (S-7)		X	X	X	X		X

[1]Refer to Fact Sheets in Section 4 for detailed information and design criteria

Purpose

Waste materials dumped into storm drain inlets can adversely impact surface and ground waters. Posting notices regarding discharge prohibitions at storm drain inlets can educate the public and prevent waste dumping. This fact sheet contains details on the installation of storm drain messages at storm drain inlets located in new or redeveloped commercial, industrial, and residential sites.

Design Criteria

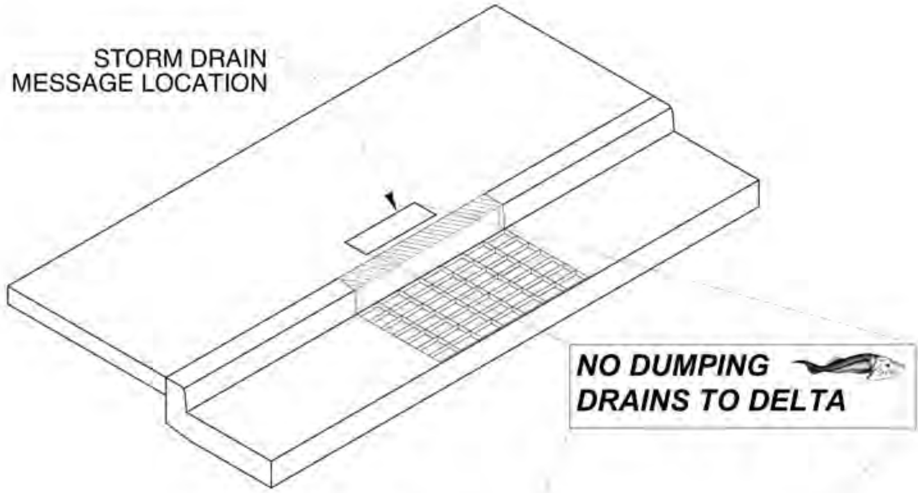
Storm drain messages have become a popular method of alerting the public about the effects of and the prohibitions against waste disposal into the storm drain system. The signs are typically stenciled or affixed near the storm drain inlet. The message simply informs the public that dumping of wastes into storm drain inlets is prohibited and/or the drain that discharges to a receiving water.

Storm drain message markers, placards or concrete stamps are required at all storm drain inlets within the boundary of the development project. The marker should be placed in clear sight adjacent to the inlet (see **Figure 4-1**). All storm drain inlet locations must be identified on the development site map.

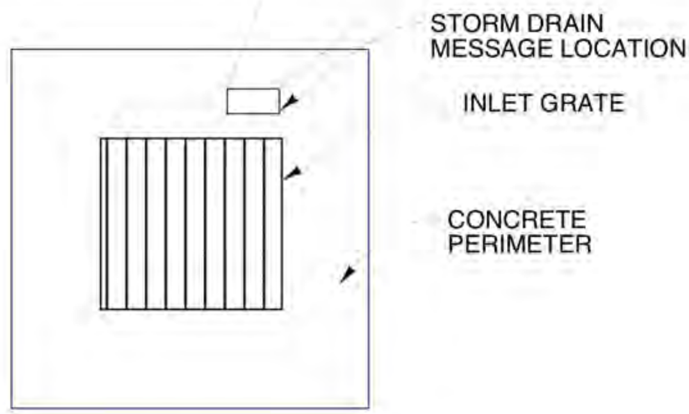
Signs with language and/or graphical icons, which prohibit illegal dumping, shall be posted at designated public access points along channels and streams within a project area. Consult the City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division to determine specific signage requirements.

Maintenance Requirements

Legibility of markers and signs shall be maintained.



CURB TYPE INLET



AREA TYPE INLET

NOTES:

1. DESIGN OF STORM DRAIN MESSAGE SHALL BE IN ACCORDANCE WITH DETAILS SHOWN ABOVE.
2. FOR NEW DEVELOPMENT, MESSAGE AND SYMBOL SHALL BE PERMANENTLY PLACED WITH THE USE OF BOMANITE, STAMPED INTO THE CONCRETE, OR OTHER METHODS APPROVED BY THE CITY ENGINEER.
3. FOR REDEVELOPMENT, MESSAGE AND SYMBOL SHALL BE PLACED WITH THE USE OF THERMOPLASTIC PAVEMENT MARKINGS.
4. PAINTING SHALL NOT BE ALLOWED FOR NEW DEVELOPMENT OR REDEVELOPMENT. PAINTING SHALL ONLY BE ALLOWED IN EXISTING AREAS FOR COMMUNITY AWARENESS ACTIVITIES. LETTERS SHALL BE 1-1/2 INCHES IN HIEGHT. OUTSIDE DIMENSION OF PUBLIC NOTICE BACKGROUND SHALL FIT BACK OF INLET OR BE PLACED IN SIDEWALK IMMEDIATELY BEHIND INLET AND SHALL BE 8 INCHES X 24 INCHES MINIMUM. LETTERING AND GRAPHIC SHALL BE BLACK WITH GRAY BACKGROUND UNLESS OTHERWISE APPROVED BY CITY ENGINEER.
5. DRIVEWAY INLETS SHALL HAVE NOTICE IN DRIVEWAY ADJACENT TO INLET.

Figure 4-1. Storm Drain Message Location

Purpose

Materials stored outdoors can become sources of pollutants in stormwater runoff if not handled or stored properly. Materials can be in the form of raw, finished, or waste products. The type of pollutants associated with the materials will vary depending on the type of commercial or industrial activity.

Some materials are more of a concern than others. Toxic and hazardous materials must be prevented from coming in contact with stormwater. Non-toxic or non-hazardous materials, such as debris and sediment, can have significant impacts on surface waters if discharged in significant quantities.

Applicability

Materials are placed into three categories based on the potential risk for pollutant release associated with stormwater contact – high risk, low risk, and non-risk. General types of materials under each category are listed below. City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division will make final determinations regarding category listings, if necessary.

High-Risk Materials	Low-Risk Materials	Non-Risk Materials
• Recycled materials with effluent potential • Corrosives • Food items • Chalk/gypsum products • Feedstock/grain • Fertilizer • Pesticides • Lime/lye/soda ash • Animal/human wastes	• Recycled materials without effluent potential • Scrap or salvage goods • Metal • Sawdust/bark chips • Sand/soil • Unwashed gravel/rock • Compost • Asphalt	• Washed gravel/rock • Finished lumber (non-pressure treated) • Rubber or plastic products • Clean, precast concrete products • Glass products (new) • Inert products • Gaseous products • Products in containers that prevent contact with stormwater (fertilizers and pesticides excluded)

Design Criteria

Design requirements for material storage areas are governed by Building and Fire Codes and by current City and County ordinances and zoning requirements. Source controls described in this fact sheet are intended to enhance and be consistent with these code and ordinance requirements. The following design features should be incorporated into the design of outdoor material storage areas when stored materials could potentially contribute significant pollutants to the storm drain. The level of controls required varies relative to the risk category of the material stored.

Design Feature	Design Criteria
Surfacing	• High-Risk Materials: o Construct or pave the storage area base with a material that is chemically resistant to the materials being stored and impervious to leaks and spills. • Low-Risk and Non-Risk Materials: o No requirement for surfacing
Covers	• High-Risk Materials: o Cover the storage area with a permanent canopy, roof, or awning to prevent precipitation from directly contacting the storage area. Direct runoff from the cover away from the storage area to a stormwater disposal point that meets all applicable code requirements and applicable requirements of this manual. o Covers 10 feet high or less shall have a minimum overhang of 3 feet measured from the perimeter of the hydraulically isolated storage area. o Cover higher than 10 feet shall have a minimum overhang of 5 feet measured from the perimeter of the hydraulically isolated storage area. • Low-Risk Materials: o At a minimum, completely cover erodible material with temporary plastic sheeting during rainfall events.
Hydraulic Isolation and Drainage	• High-Risk Materials: o Hydraulically isolate the storage area by means of grading, berms, or drains to prevent run-on of stormwater from surrounding areas or roof drains. o Direct runoff from surrounding areas away from the hydraulically isolated storage area to a stormwater disposal point that meets all applicable requirements of this manual and codes. o Drainage facilities are not required for the hydraulically isolated storage area. However, if drainage facilities are provided, drainage from the hydraulically isolated storage area must be directed to an approved City or County sanitary sewer or approved collection point. • Low-Risk Materials: o Drainage from storage area may be to an approved treatment control measure or possibly to an approved standard stormwater drain(s). o For erodible material, provide grading and a structural containment barrier on at least three sides of each stockpile to prevent run-on of stormwater from surrounding area and to prevent migration of material due to wind erosion.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit. Contact the City’s Environmental Control at 209.937.8740 or County of San Joaquin at 209.468.3000 regarding permits for discharge of contaminated accumulated water.

Purpose

Stormwater runoff from areas where trash is stored or disposed of can convey pollutants. In addition, loose trash and debris can be easily transported by water or wind into nearby storm drain inlets, channels, and/or creeks. Waste handling operations that may be sources of pollutants include dumpsters, litter control, and waste piles. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff associated with trash storage and handling.

Design Criteria

Design requirements for waste handling areas are governed by Building and Fire Codes, and by current local agency ordinances and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code and ordinance requirements. Hazardous waste should be handled in accordance with legal requirements established in Title 22, California Health and Safety Code.

Wastes from commercial and industrial sites are typically hauled away for disposal by either public or commercial carriers that may have design or access requirements for waste storage areas. The design criteria listed below are recommendations and are not intended to be in conflict with requirements established by the waste hauler. The waste hauler should be contacted prior to the design of your site trash collection area. Conflicts or issues should be discussed with City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division.

The following trash storage area design controls were developed to enhance the local agency codes and ordinances and should be implemented depending on the type of waste and the type of containment:

Source Control Design Feature	Design Criteria
Surfacing	• Construct the storage area base with a material impervious to leaks and spills.
Screens/Covers	• Install a screen or wall around trash storage area to prevent off-site transport of loose trash. • Use lined bins or dumpsters to reduce leaking of liquid wastes. • Use water-proof lids on bins/dumpsters or provide a roof to cover enclosure (City and County discretion) to prevent rainfall from entering containers.
Grading/Drainage	• Berm or grade the waste handling area to prevent run-on of stormwater. • Locate storm drains at least 35 feet from the waste handling area.
Signs	• Post signs inside enclosure and/or on all dumpsters prohibiting the disposal of liquids and hazardous materials therein.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g. screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the City or County and the owner/operator may be required. If required by the City or County, maintenance agreements or deed restrictions must be executed by the owner/operator before improvement plans are approved. Refer to **Appendix D** for a further guidance regarding maintenance agreements and plans.

Purpose

Materials spilled, leaked, or lost during loading or unloading may collect on impervious surfaces or in the soil and be carried away by runoff or when the area is cleaned. Also, rainfall may wash pollutants from machinery used to load or unload materials. Depressed loading docks (truck wells) are contained areas that can accumulate stormwater runoff. Discharges of spills or contaminated stormwater to the storm drain system is prohibited. This fact sheet contains details on specific measures recommended to prevent or reduce pollutants in stormwater runoff from outdoor loading or unloading areas.

Design Criteria

Design requirements for outdoor loading/unloading of materials are governed by Building and Fire Codes, and by current local agency ordinances and zoning requirements. Source controls described in the fact sheet are meant to enhance and be consistent with these code and ordinance requirements. Companies may have their own design or access requirements for loading docks. The design criteria listed below are not intended to be in conflict with requirements established by individual companies. Conflicts or issues should be discussed with the City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division.

The following design criteria should be followed when developing construction plans for material loading/unloading areas:

Design Feature	Design Criteria
Surfacing	Construct floor surfaces with paving material that is impervious and chemically resistant to materials being handled in the loading/unloading area.
Covers	• Cover outdoor loading/unloading areas to a distance of at least 10 feet beyond the loading dock or building face if there is no raised dock. • For interior transfer bays, provide a 10-ft minimum “no obstruction zone” to allow trucks or trailers to extend at least 5 feet inside the building. Identify “no obstruction zone” clearly on building plans and paint zone with high visibility floor paint. • If covers or interior transfer bays are not feasible, install a seal or door skirt and provide a rain cover to shield all material transfers between trailers and building.
Hydraulic Isolation and Drainage	• For outdoor loading/unloading areas, hydraulically isolate the first 6 feet of paved area measured from the building or dock face by means of grading, berms, or drains to prevent run-on of stormwater from surrounding areas or roof drains. Direct runoff and drainage from surrounding areas away from hydraulically isolated area to a stormwater discharge point that meets all applicable requirements of this manual. • For interior transfer bays or bay doors, prevent stormwater runoff from surrounding areas from entering the building by means of grading or drains. Do not install interior floor drains in the “no obstruction zone”. Hydraulically isolate the “no obstruction zone” from any interior floor drains. • Direct drainage from the hydraulically isolated loading/unloading area to an approved sediment/oil/water separator system connected to an approved City or County sanitary sewer or other approved collection point. Provide a manual emergency spill diversion valve upstream of the separator system to direct flow in the event of a spill to an approved spill containment vault sized to contain a volume equal to 125% of largest container handled at the facility.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces, such as depressed loading docks. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit. Contact the City's Environmental Control at 209.937.8740 or County of San Joaquin at 209.468.3000 regarding permits for discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g. screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the City or County and the owner/operator may be required. If required by the City or County, maintenance agreements or deed restrictions must be executed by the owner/operator before improvement plans are approved. Refer to **Appendix D** for a further guidance regarding maintenance agreements and plans.

Purpose

Activities that can contaminate stormwater include engine repair, service and parking (leaking engines or parts). Oil and grease, solvents, car battery acid, coolant and gasoline from the repair/maintenance bays can adversely impact stormwater if allowed to come into contact with stormwater runoff. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment maintenance and repair areas.

Design Criteria

Design requirements for vehicle maintenance and repair areas are governed by Building and Fire Codes, and by current local agency ordinances, and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment maintenance, and repair. All hazardous and toxic wastes must be prevented from entering the storm drainage system.

Source Control Design Feature	Design Criteria
Surfacing	• Construct the vehicle maintenance/repair floor area with Portland cement concrete.
Covers	• Cover areas where vehicle parts with fluids are stored. • Cover or enclose all vehicle maintenance/repair areas.
Grading/Contouring	• Berm or grade the maintenance/repair area to prevent run-on and runoff of stormwater or runoff of spills. • Direct runoff from downspouts/roofs away from maintenance/repair areas. • Grade the maintenance/repair area to drain to a dead-end sump for collection of all wash water, leaks and spills. Direct connection of maintenance/repair area to storm drain system is prohibited. • Do not locate storm drains in the immediate vicinity of the maintenance/repair area.
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit. Contact the City's Environmental Control at 209.937.8740 or County of San Joaquin at 209.468.3000 regarding permits for discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g. screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the City or County and the owner/operator may be required. If required by the City or County, maintenance agreements or deed restrictions must be executed by the owner/operator before improvement plans are approved. Refer to **Appendix D** for a further guidance regarding maintenance agreements and plans.

Purpose

Washing vehicles and equipment in areas where the wash water flows onto the ground can adversely impact receiving waters. Wash waters can contain high concentrations of oil and grease, solvents, phosphates and high suspended solids loads. Sources of contamination include outside vehicle/equipment cleaning or wash water discharge to the ground. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in runoff from vehicle and equipment washing areas.

Design Criteria

Design requirements for vehicle and equipment washing areas are governed by Building and Fire Codes, and by current local agency ordinances, and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code requirements. The following design criteria are required for vehicle and equipment washing areas. All hazardous and toxic wastes cannot enter the storm drain system.

Design Feature	Design Criteria
Surfacing	• Construct the vehicle/equipment wash area floors with Portland cement concrete.
Covers	• Provide a cover that extends at least 3 feet beyond the hydraulically isolated area for cover heights less than or equal 10 feet and at least 5 feet beyond the hydraulically isolated area for cover heights greater than 10 feet .
Grading/Drainage	• Hydraulically isolate the maintenance/repair area using berms or grading to prevent run-on and runoff of stormwater or runoff of spills. • Grade or berm the wash area to contain the wash water within the covered area and direct the wash water to treatment and recycle or pretreatment and proper connection to the sanitary sewer system. Obtain approval from the City or County before discharging to the sanitary sewer. • Direct runoff from downspouts/roofs away from wash areas. • Do not locate storm drains in the immediate vicinity of the wash area.
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit. Contact the City’s Environmental Control at 209.937.8740 or County of San Joaquin at 209.468.3000 regarding permits for discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g. screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the City or County and the owner/operator may be required. If required by the City or County, maintenance agreements or deed restrictions must be executed by the owner/operator before improvement plans are approved. Refer to **Appendix D** for a further guidance regarding maintenance agreements and plans.

Purpose

Spills at vehicle and equipment fueling areas can be a significant source of pollutants because fuels contain toxic materials and heavy metals that are not easily removed by stormwater treatment devices. When stormwater mixes with fuel spilled or leaked onto the ground, it becomes contaminated with petroleum-based materials that are harmful to humans, fish and wildlife. This contamination can occur at large industrial sites or at small commercial sites such as gas stations and convenience stores. This fact sheet contains details on specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment fueling areas, including retail gas outlets.

Design Criteria

Design requirements for fueling areas are governed by Building and Fire Codes and by current local agency ordinances and zoning requirements. The design requirements described in this fact sheet are meant to enhance and be consistent with these code and ordinance requirements.

Design Feature	Design Criteria
Surfacing	• Pave fuel dispensing and maintenance area with Portland cement concrete (PCC). The fuel dispensing area is defined as extending 6.5 feet from the corner of each fuel dispenser or the length at which the hose and nozzle assemble may be operated plus 1 foot, whichever is greater. The paving around the fuel dispensing area may exceed the minimum dimensions of the “fuel dispensing area” stated above. • Use asphalt sealant to protect asphalt paved areas surrounding the fuel dispensing or maintenance area.
Covers	• Cover the fuel dispensing or maintenance area with a permanent canopy, roof, or awning to prevent precipitation from directly contacting the fuel dispensing area. Direct runoff from the cover away from the fuel dispensing area to a stormwater disposal point that meets all applicable code requirements and applicable requirements of this manual. o Covers 10 feet high or less shall have a minimum overhang of 3 feet measured from the perimeter of the hydraulically isolated fuel dispensing area. o Cover higher than 10 feet shall have a minimum overhang of 5 feet measured from the perimeter of the hydraulically isolated fuel dispensing area. • For facilities designed to accommodate very large vehicles or equipment that would prohibit the use of covers, hydraulically isolate the uncovered fuel dispensing or maintenance area and direct drainage from the area through upstream controls to a sanitary sewer as described below.

<table>
<tr><th>Design Feature</th><th>Design Criteria</th></tr>
<tr><td>Hydraulic Isolation and Drainage</td><td>

Design the fuel dispensing or maintenance area pad with zero slope (flat) to keep minor spills and leaks on the pad and encourage use of proper cleanup methods. Proper cleanup methods shall consist of dry cleanup methods, such as sweeping for removal of litter and debris and use of absorbents for liquid spills and leaks.
Hydraulically isolate the paved fuel dispensing or maintenance area to prevent run-on of stormwater from surrounding areas or roof drains by one of the following methods. Design should conform to applicable ADA requirements for disabled access:

Berms: Design the berm height four (4) inches above the surface of the fuel dispensing or maintenance area pad such that the pd will serve as spill containment area.
Perimeter trench drains: Locate trench drains around the perimeter of the pad. Direct drainage from the perimeter drains to one of the following:

An approved City/County sanitary sewer. Provide an approved automatic shutoff valve installed upstream of the sanitary sewer connection and below grade in a manhole or similar concrete containment structure. The valve shall be designed to close automatically when the maximum oil/fuel storage capacity of the structure is reached.
An approved below grade containment vault with at least 60 ft^3 of storage capacity. The vault must be emptied, as required, and contents disposed of in accordance with applicable laws.

Direct runoff and drainage from surrounding areas away from hydraulically isolated area to a stormwater discharge point that meets all applicable requirements of this manual. Locate stormwater drains for surrounding areas at least 10 feet from the hydraulically isolated fuel dispensing or maintenance area.

</td></tr>
</table>

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit. Contact the City's Environmental Control at 209.937.8740 or County of San Joaquin at 209.468.3000 regarding permits for discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g. screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the City or County and the owner/operator may be required. If required by the City or County, maintenance agreements or deed restrictions must be executed by the owner/operator before improvement plans are approved. Refer to **Appendix D** for a further guidance regarding maintenance agreements and plans.

SECTION 5
VOLUME REDUCTION MEASURES

5.1 INTRODUCTION

Volume Reduction Measures are required to minimize potential water quality impacts from stormwater. Volume Reduction Measures are BMPs that can be used to direct, retain, reuse and/or infiltrate stormwater runoff (e.g., rain gardens and rain barrels). The type of Volume Reduction Measure to be implemented at a site depends on a number of factors including: type of potential pollutants in the stormwater runoff, quantity of stormwater runoff to be treated; project site conditions (e.g. soil type and permeability, groundwater levels); and receiving water conditions. Land area requirements and costs to design, construct and maintain Volume Reduction Measures vary.

5.2 VOLUME REDUCTION REQUIREMENT

The application of Volume Reduction Measures is driven, in part, by the **Volume Reduction Requirement**. The Volume Reduction Requirement is a new requirement developed in response to the recent municipal stormwater NPDES Permit requirements specifying the use of LID and a combination of non-structural and structural controls.

The Volume Reduction Requirement specifies that post-project runoff volumes be reduced to match pre-project levels for the 0.51-inch storm depth, which is the average 85th percentile/24-hour storm depth estimated for the Stockton area. New Development Priority Projects may apply a combination of Volume Reduction Measures and LID Treatment Controls (see Step 6) in order to meet the Volume Reduction Requirement. A summary of controls that reduce runoff volumes are provided in **Table 5-1**. As indicated in Table 5-1 some controls are better suited for reducing the volume associated with rooftop runoff (e.g. Rain Barrels) while others are more suited for reducing the volume associated with pavement runoff (e.g. Interception Trees). Suggested applications of Volume Reduction Measures are illustrated in **Figures 5-1a and b**.

Table 5-1. Summary of Volume Reduction and LID Treatment Controls

Control	Function		Disconnection Application	
	Volume Reduction	Treatment	Rooftop	Pavement
Volume Reduction Measures (Section 5)				
Rain Garden (V-1)	Primary	Secondary	X	X
Rain Barrel/Cistern (V-2)	Primary	Secondary	X	
Vegetated Roof (V-3)	Primary	Secondary	X	
Interception Trees (V-4)	Primary	Secondary		X
Grassy Channel (V-5)	Primary	Secondary	X	X
Vegetated Buffer Strip (V-6)*	Primary	Secondary	X	X
LID Treatment Controls (Section 6)				
Bioretention (L-1)	Secondary	Primary	X	X
Stormwater Planter (L-2)	Secondary	Primary	X	X

Control	Function		Disconnection Application	
	Volume Reduction	Treatment	Rooftop	Pavement
Tree-well Filter (L-3)	Secondary	Primary		X
Infiltration Basin (L-4)	Secondary	Primary	X	X
Infiltration Trench/Dry Well (L-5)	Secondary	Primary	X	X
Porous Pavement Filter (L-6)	Secondary	Primary		X
Vegetated (Dry) Swale (L-7)	Secondary	Primary	X	X
Grassy Swale (L-8)	Secondary	Primary	X	X
Grassy Filter Strip (L-9)	Secondary	Primary	X	X

*Disconnected rooftops (rooftops allowed to drain to lawn as opposed to impervious area) should utilize the Vegetated Buffer Strip (V-6) in order to receive credit towards the Volume Reduction Requirement.

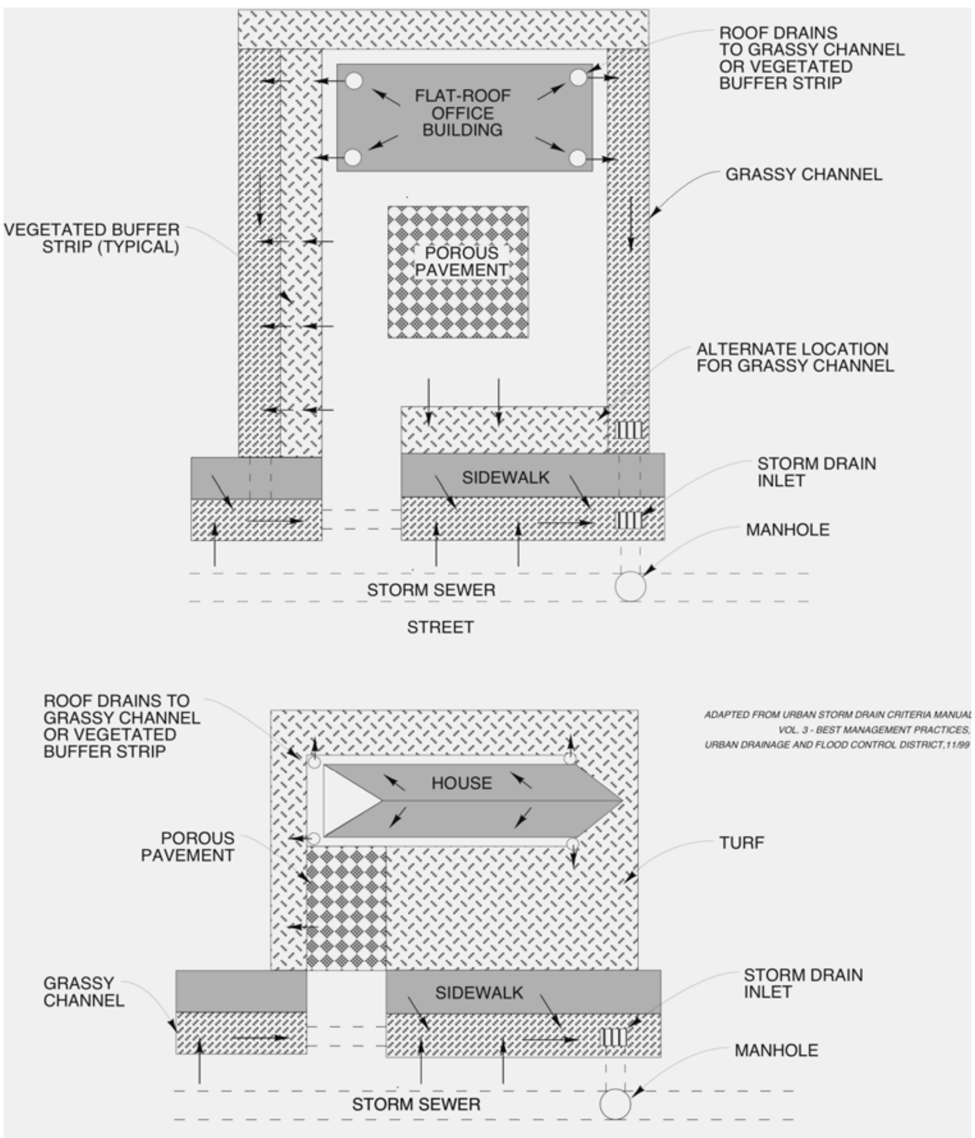


Figure 5-1a. Suggested Applications of Runoff Volume Reduction Measures

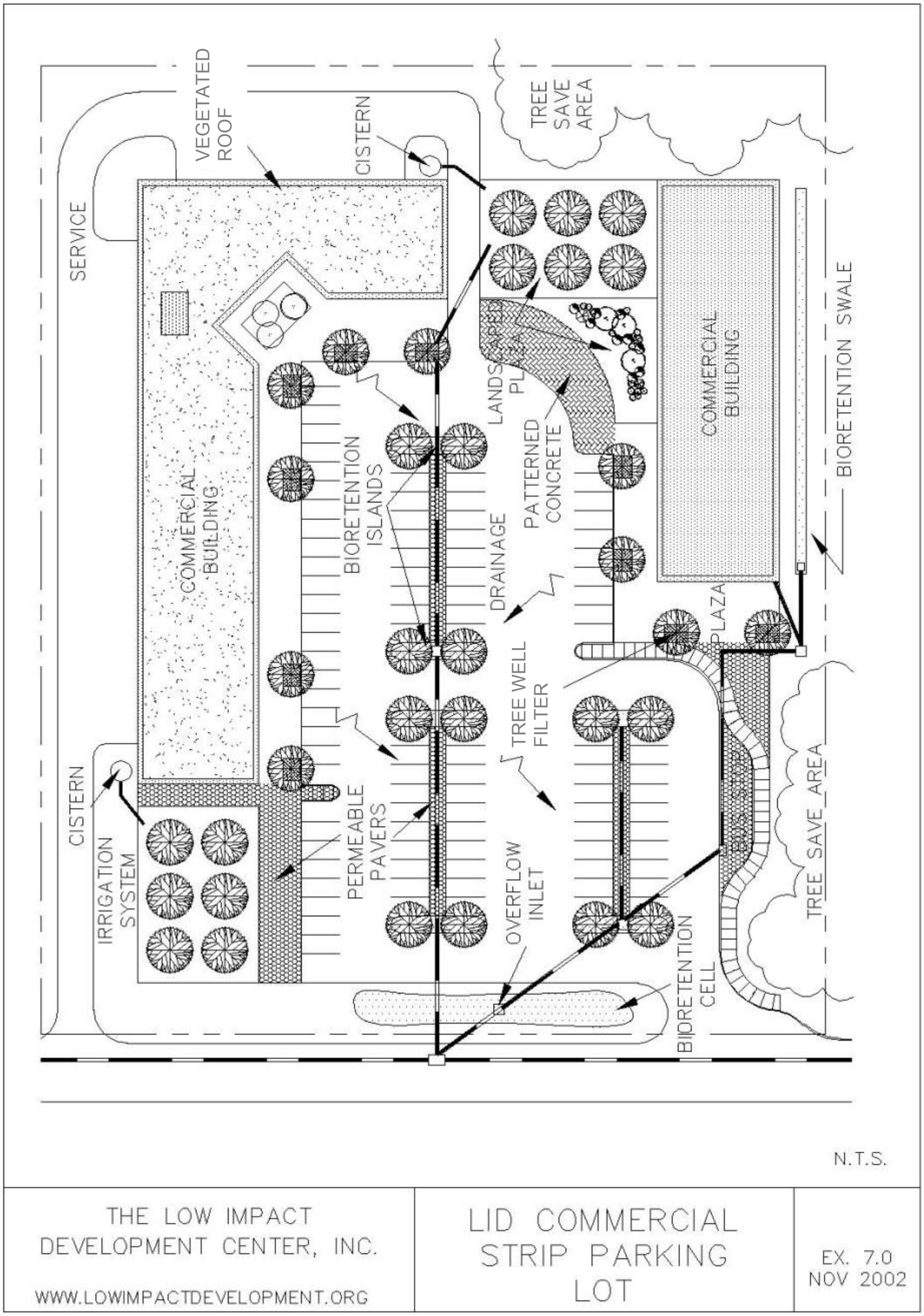


Figure 5-1b. Suggested Applications of Runoff Volume Reduction Measures (Source: LID Center)

To assist Priority Projects, **Appendix B** provides additional information on calculating and meeting the Volume Reduction Requirement. Projects may use the worksheet to help track compliance with the Volume Reduction Requirement. Compliance with the Volume Reduction Requirement can be demonstrated through the following steps:

1. Determine the volume of runoff from the site under pre-project conditions and the volume of runoff from the site under post-project conditions for the 0.51-inch storm depth. **Appendix B** provides additional information on calculating and meeting the Volume Reduction Requirement.

   > **Runoff Volume Calculation Procedure:**
   > Runoff Volume (ft^3) = 0.51"/12" x Site weighted runoff coefficient (C_{ra}) x Site area (ft^2)

   - Priority Significant Redevelopment Projects must also comply with the Volume Reduction Requirement; however an incentive in the form of credits may be applied based on the type of redevelopment. A credit of 0.05 inches from the 0.51 inch Volume Reduction Requirement may be applied to any of the following types of redevelopment. Credits are additive such that a maximum credit of 0.25 inches is possible for a project that meets all five criteria:
     - Significant Redevelopment (as defined in Section 2.1)
     - Brownfield redevelopment
     - High density (>7 units per acre)
     - Vertical Density, (Floor to Area Ratio (FAR) of 2 or >18 units per acre)
     - Mixed use and Transit Oriented Development (within ½ mile of public transit, such as a bus stop)

2. Calculate the Volume Reduction Requirement as the difference between the pre-project runoff volume and the post-project runoff volume (i.e., post – pre).

3. Select applicable Volume Reduction Measures (e.g. Interceptor Trees, Rain Barrels). Each Volume Reduction Measure has a certain volume reduction "credit" that can be applied towards the Volume Reduction Requirement. The Volume Reduction Measure fact sheets detail the calculation procedure for volume reduction.

> An example calculation is provided in **Appendix J** to illustrate the application of the Volume Reduction Requirement, Volume Reduction Measures, tributary impervious area credit and LID Treatment Controls.

4. Determine remaining Volume Reduction Requirement not met by the Volume Reduction Measures, if any. This remaining volume reduction requirement must be met by application of LID Treatment Controls as described in Step 6.

5. Determine tributary impervious area credits associated with the selected Volume Reduction Measures. These area credits can be applied to reduce the effective design area for treatment controls described in Step 6. Note that these credits must be applied to treatment controls that are in the same tributary drainage area as the Volume Reduction Measures for which the credits are determined and the credits cannot be greater than the tributary drainage areas of the treatment controls to which they are applied.

6. Apply LID Treatment Controls –
   - If the Volume Reduction Requirement is not entirely met through the use of Volume Reduction Measures, the project must apply LID Treatment Controls to further reduce the runoff volume to meet the Volume Reduction Requirement. LID Treatment Controls must be designed to treat the Stormwater Quality Design Volume (SQDV) or Stormwater Quality Design Flow (SQDF) as discussed in Section 6. The SQDV or SQDF is calculated using the effective tributary drainage area, which is determined by subtracting area credits (see Step 5) from the actual tributary drainage area for the treatment control under design.
   - If the Volume Reduction Requirement is met through the use of Volume Reduction Measures, the project may meet the Treatment Control requirement through the use of LID Treatment Controls and/or Conventional Treatment Controls.
7. If the Volume Reduction Requirement is not entirely met through the combination of Volume Reduction Measures and LID Treatment Controls, the project must submit a Volume Reduction Requirement Waiver Form as described below under Alternative Compliance Option. Priority New Development and Significant Redevelopment Projects that cannot fully meet the Volume Reduction Requirement and are located in a watershed with a 303d listed waterbody, must select Treatment Controls with a medium to high removal efficiency for the pollutant of concern (see Table 6-2).

Alternative Compliance Option

A waiver may be granted if the Volume Reduction Requirement cannot be fully met due to site constraints such as a high groundwater table. However, even if the project cannot meet the full Volume Reduction Requirement, the project must still reduce volume to the maximum extent practicable. Meeting the Volume Reduction Requirement is an iterative process. Designers should return to prior steps to explore alternative combinations of Volume Reduction Measures and LID Treatment Controls. The burden of proof is on the project applicant to show why the full Volume Reduction Requirement cannot be met. Economic hardship is not an acceptable reason for noncompliance. In general, the City and the County do not expect to grant waivers for the Volume Reduction Requirement. The final determination will be made by the City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division. Projects that are not able to fully meet the Volume Reduction Requirement must fill out and submit the Volume Reduction Requirement Wavier Form available in **Appendix C**.

The City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division have the authority to reject a Volume Reduction Waiver request if Volume Reduction Measures and/or LID Treatment Controls are considered feasible at the project site.

5.3 SELECTION OF VOLUME REDUCTION MEASURES

Various factors must be considered when selecting a Volume Reduction Measure. In addition to reducing volume, site considerations such as the size of the drainage area, depth between the water table and the control, soil type and permeability, slope and need for vegetation irrigation are important factors in selecting the proper Volume Reduction Measures. Vector breeding considerations must also be addressed because of nuisance and potential human health effects. The applicability of specific controls outlined within this Section should be confirmed with the City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division. The site constraints used to select Volume Reduction Measures are provided in **Table 5-2**.

Table 5-2. Site Constraints for Volume Reduction Measures

Volume Reduction Measure	Drainage Area (acres)	Depth to Water Table (ft)	Soil Type[1]		Slope (%)	Irrigation Required	Vector Control Frequency	Maintenance Frequency
			A/B	C/D				
Rain Garden (V-1)	<0.05	10 ft*	X	X	n/a	Y	L	M
Rain Barrel/Cistern (V-2)	<0.25	n/a	n/a	n/a	n/a	N	H[2]	L
Vegetated Roof (V-3)	n/a	n/a	n/a	n/a	n/a	Y	L	M[2]
Interception Trees (V-4)	n/a	n/a	X	X	n/a	Y	L	L
Grassy Channel (V-5)	<1	n/a	X	X	≤4%	Y	L	M[3]
Vegetated Buffer Strip (V-6)	<1	n/a	X	X	<5%	Y	L	M[3]

X: BMP is suitable for listed site condition
1: Type A soils are sands and gravels with typical infiltration rates of 1.0-8.3 inches/hour. Type B soils are sandy loams with moderately fine to moderately coarse textures and typical infiltration rates of 0.5-1.0 inches/hour. Type C soils are silty-loams or soils with moderately fine to fine texture and typical infiltration rates of 0.17-0.27 inches/hour. Type D soils are clays with infiltration rates of 0.02-0.10 inches/hour.
2: Concerns may be mitigated through design features; see corresponding fact sheet.
3: Once vegetation is established, maintenance is low.
n/a: Not applicable – this site condition does not effect the applicability of this Volume Reduction Measure
Y = Yes; N = No
H= High; M = Medium; L = Low
*=applies if rain garden is allowed to infiltrate

Source: Chicago Wilderness Magazine
Photo: Dave Jagodzinski.

Description

A rain garden is a planted depression that is designed to receive, retain, and infiltrate rainwater runoff from impervious areas, such as rooftops and pavement. Runoff is initially captured in a ponding zone above the vegetated surface. Captured runoff infiltrates the surface layer of the garden and filters through a planting soil layer before entering the groundwater or being collected by an under drain system. The garden may include a gravel retention zone below the planting soil layer to facilitated infiltration. Treatment of the runoff occurs through a variety of natural mechanisms as the runoff filters through the root zone of the vegetation. A portion of the water held in the root zone of the garden is returned to the atmosphere through transpiration by the plants. Rain gardens are typically planted with native, drought tolerant vegetation that do not require fertilization and can withstand wet soils for at least 24 hours, such as wildflowers, sedges, rushes, ferns, shrubs and small trees. Root systems of the plants enhance infiltration, moisture redistribution, and diverse microbial populations involved in biofiltration.

> A rain garden is similar in most respects to a bioretention area, but differs in the level of engineering design criteria specified for subsurface soil matrix and construction and, thus, the level of treatment provided.

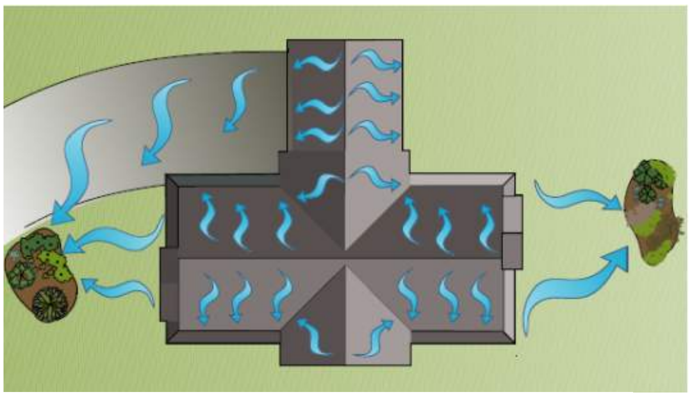
Other Names: Micro-bioretention, biofiltration

Advantages

- Low installation cost.
- Enhances site aesthetics.
- Reduces stormwater volume and pollutant discharge.
- Potential water conservation.
- Easy to maintain.

Limitations

- Volume reduction may may be limited by space available.
- Requires underdrains for low permeability soils.
- Requires individual owners/tenants to perform maintenance.
- Not suitable for industrial sites or sites where spills may occur unless infiltration is prevented by impermeable liner.



Source: Washington State University, 2007

Planning and Siting Considerations

- Locate rain gardens at least 10 feet from building foundations.
- Maintain a slope of at least one (1) percent from impervious surface to rain garden inlet.

- Provide for overflow discharge that drains away from building foundations to the storm drain system or, if possible, to vegetated surfaces (e.g. grassy buffers, grassy swales/channels) or more suitable infiltration areas.

Design Criteria

Design criteria for rain gardens are listed in **Table 5-3**. A schematic showing the basic elements of a typical rain garden is presented in **Figure 5-2**.

Table 5-3. Rain Garden Design Criteria

Design Parameter	Criteria	Notes
Surface area of ponding zone	20 to 30%	Typical percentage of impervious area draining to rain garden. Smaller percentages are acceptable with overflow drainage provided
Maximum depth of ponding zone (D_{RG})	6 inches	Depth above top of mulch layer
Depth of top mulch layer	2 - 3 inches	Shredded hardwood or softwood or compost
Depth of planting media	12 - 18 inches	Mix: 60-65% loamy sand + 35-40% compost or 30% loamy sand + 30% course sand + 40 % compost
Depth of retention zone (optional)	9 - 12 inches	Washed drain rock (0.5 – 1.5 inch diameter). Use with under drain
Under drain pipe (optional)	4-inch	Perforated PVC or HDPE. Use with C and D soils
Excavation side slope of (H:V)	3:1	Maximum steepness

Volume Reduction and Tributary Impervious Area Credit

Rain Gardens provide volume reduction through retention of water in the pore spaces of the planting soil layer (detention/filtration zone) and infiltration into the underlying soil. Rain gardens may be used to help meet the Volume Reduction Requirement and can also be used to reduce the size of required treatment controls (see Section 6). The calculation procedure for volume reduction and tributary impervious area credits for rain gardens is presented in **Table 5-4. Appendix B** provides additional information on calculating and meeting the Volume Reduction Requirement.

Rain Gardens can also be used to reduce the size of required treatment control through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls (see Section 6). The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of Rain Gardens reduces effective impervious area and thereby the volume of water to be treated. The credit is based on the ratio of volume reduction to the SQDV for the Rain Garden drainage area. Note that these credits must be applied to treatment controls that are in the same tributary drainage area as the Rain Garden for which the credits are determined and the credits cannot be greater than the tributary drainage areas of the Rain Garden. **Table 5-4** details how the tributary impervious area credit is calculated for Rain Gardens.

Table 5-4. Rain Garden Volume and Tributary Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
Rain Garden without Subsurface Drain		
1. Volume Reduction for rain garden ($Vol_{reduction}$)		
a. Depth of ponding zone (D_{PZ})	D_{PZ} = ________ ft	Infiltration allowance for water in ponding zone water = 1.0
b. Area of ponding zone (A_{PZ})	A_{PZ} = ________ ft^2	
c. Depth of detention zone (D_{DZ})	D_{DZ} = ________ ft	Available Water Holding Capacity of soil in detention zone = 0.1 x volume
d. Area of detention zone (A_{DZ})	A_{DZ} = ________ ft^2	
e. $Vol_{reduction}$= (D_{PZ} x A_{PZ}) + (D_{DZ} x A_{DZ} x 0.1)	$Vol_{reduction}$ =________ ft^3	
Rain Garden with Subsurface Drain		
1. Volume Reduction for rain garden ($Vol_{reduction}$)		
a. Depth of ponding zone (D_{PZ})	D_{PZ} = ________ ft	Infiltration allowance for water in ponding zone water = 0.25
b. Area of ponding zone (A_{PZ})	A_{PZ} = ________ ft^2	
c. Depth of detention zone (D_{DZ})	D_{DZ} = ________ ft	Available Water Holding Capacity of soil in detention zone = 0.10 x volume
d. Area of detention zone (A_{DZ})	A_{DZ} = ________ ft^2	
e. Depth of retention zone (D_{RZ})	D_{RZ} = ________ ft	Retention zone is optional. Porosity of retention zone = 0.30
f. Area of retention zone (A_{RZ})	A_{RZ} = ________ ft^2	
g. $Vol_{reduction}$= (D_{PZ} x A_{PZ} x 0.25) + (D_{DZ} x A_{DZ} x 0.10) + (D_{RZ} x A_{RZ} x 0.30)	$Vol_{reduction}$ =________ ft^3	
2. Impervious area tributary to rain garden (A_{imp})	A_{imp} = ________ ft^2	
3. SQDV for A_{imp} based on 12-h drawdown SQDV = 0.32 in x A_{imp} / 12 in/ft	SQDV =________ ft^3	Unit basin storage volume for 12-h drawdown at 100% imperviousness (0.95 Runoff Coefficient) = 0.32 in. (see Figure 6-1). Adjust value for A_{imp} < 100% impervious
4. Tributary Impervious Area Credit for rain garden ($Area_{credit}$) $Area_{credit}$ = A_{imp} x $Vol_{reduction}$ / SQDV	$Area_{credit}$ =________ ft^2	Maximum allowable $Area_{credit}$ = A_{imp}

Construction Considerations

See Fact Sheet L-1: Bioretention.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes Volume Reduction Measures such as Rain Gardens. Such agreements will typically include requirements such as those outlined in **Table 6-10** in Fact Sheet L-1: Bioretention. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City or County with complete access to the Volume Reduction Measure and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**.

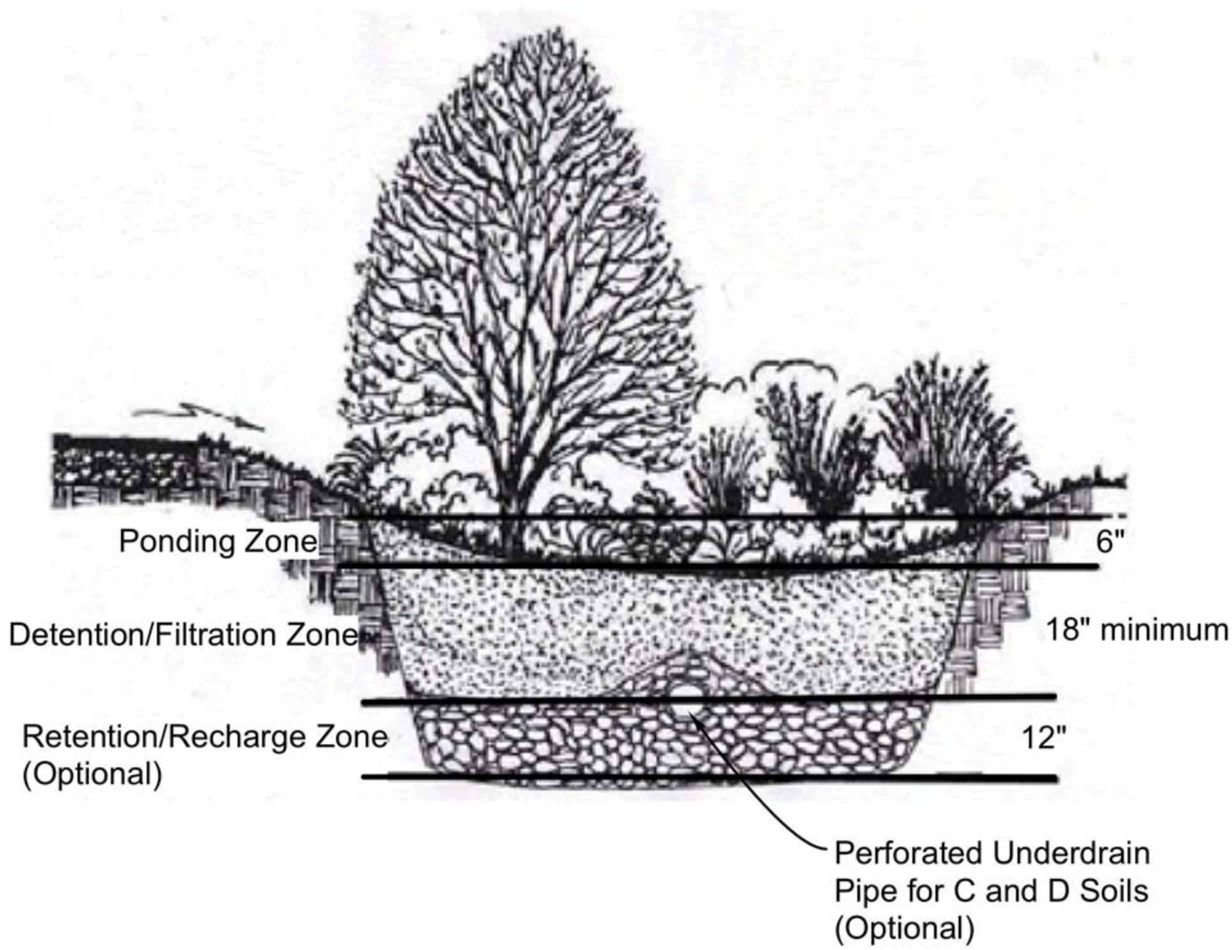


Figure 5-2. Rain Garden

Source: University of Connecticut

Source: City of Santa Monica

Description

Rain barrels and cisterns are containers that collect and store rainwater from rooftop drainage systems that would otherwise be lost to runoff and diverted to storm drains. Rain barrels are placed above ground beneath a shortened downspout next to a home or building and typically range in size from 50 to 180 gallons. Cisterns are larger storage tanks that may be sited above or below ground. Rain barrels are equipped with a removable cover to allow access for maintenance, a screened inlet opening to trap debris and exclude mosquitoes, an outlet spigot typically fitted for garden hose attachment, and an overflow outlet with discharge pipe or hose (**Figure 5-3**). Stored rainwater is typically used for landscape irrigation, but can be used for washing. Water stored in rain barrels and cisterns should not be discharged to the storm drain system.

Advantages

- Low installation cost.
- Small footprint.
- Reduces stormwater volume and pollutant discharge.
- Potential water conservation.
- Easy to maintain.

A wide variety of manufactured rain barrels are available for purchase or units can be made at home.

Limitations

- Storage volume may be limted.
- Stored water is not suitable for human or pet consumption.
- Contact of stored water with fruits vegetables should be avoided due to unknown risks.
- May not be compatible with site aethetics.
- Potential for mosquitoe breeding if not properly covered and maintained.
- Requires individual owners/tenants to perform maintenance and empty rain barrels between storms.

Planning and Siting Considerations

- Locate rain barrels and cisterns to allow easy access for maintenance.
- Elevate rain barrel above ground surface with sturdy platform to provide spigot clearance.
- Provide screens or deflectors on rain gutters to minimize discharge of debis to rain barrels.
- Direct cistern overflow discharge to drain away from building foundations and to vegetated areas.

Source: Chesapeake Bay Foundation

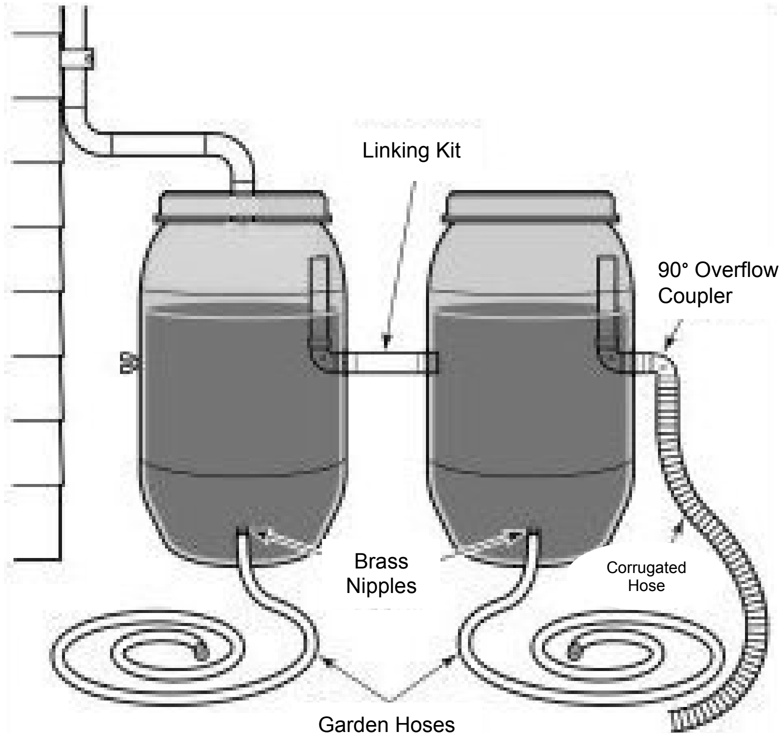


Figure 5-3. Rain Barrel Schematic (Source: LID Center)
Linked rain barrels as shown in figure are optional

Volume Reduction and Tributary Impervious Area Credit

Rain Barrels and Cisterns provide volume reduction through storage of water in the container. Rain Barrels and Cisterns may be used to help meet the Volume Reduction Requirement and can also be used to reduce the size of required treatment controls (see Section 6). The calculation procedure for volume reduction and area reduction for rain barrels and cisterns is presented in **Table 5-5. Appendix B** provides additional information on calculating and meeting the Volume Reduction Requirement.

Rain Barrels can also be used to reduce the size of required treatment control through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls (see Section 6). The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of Rain Barrels reduces effective impervious area and thereby the volume of water to be treated. The credit is based on the ratio of volume reduction to the SQDV for the Rain Barrel drainage area. Note that these credits must be applied to treatment controls that are in the same tributary drainage area as the Rain Barrel for which the credits are determined and the credits cannot be greater than the tributary drainage areas of the Rain Barrel. **Table 5-5** details how the tributary impervious area credit is calculated for Rain Barrels.

Table 5-5. Rain Barrel/Cistern Volume and Tributary Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Volume reduction for rain barrel ($Vol_{reduction}$)		
a. Total storage volume of rain barrels (V_s)	V_s = ____________ ft^3	
b. Effectiveness factor (Eff) = 75%	Eff = 0.75	Effectiveness factor considers that storage container may not be emptied between each storm
c. $Vol_{reduction} = V_s \times Eff$	$Vol_{reduction}$ = ____________ ft^3	
2. Total roof area (A_{roof})	A_{roof} = ____________ ft^2	
3. SQDV for roof area based on 12-h drawdown SQDV = 0.32 in x A_{roof} / 12 in/ft	SQDV = ____________ ft^3	Unit basin storage volume for 12-h drawdown at 100 % imperviousness (C_r= 0.95) = 0.32 in (see Figure 6-1)
4. Tributary Impervious Area Credit for rain barrel ($Area_{credit}$) $Area_{credit} = A_{roof} \times Vol_{reduction}$ / SQDV	$Area_{credit}$ = ____________ ft^2	Maximum allowable $Area_{credit} = A_{roof}$

Construction Considerations

Stormwater should not be diverted to the rain barrel or cistern until the overflow discharge area has been stabilized.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes Volume Reduction Measures such as rain barrels and cisterns. Such agreements will typically include requirements such as those outlined in **Table 5-6**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City or County with complete access to the Volume Reduction Measure and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**.

Table 5-6. Inspection and Maintenance Requirements for Rain Barrels and Cisterns

Activity	Schedule
Inspect: roof connection; gutter; downspout, rain barrel/ cistern, mosquito screen, and overflow pipes for leaks and obstructions	Twice per year. Repair as required
Inspect insect and debris screens. Clean as required	Following significant rainfall events

Source: Chong and Partners Architecture

Description

A vegetated roof is a multi-layered rooftop system designed for filtering, absorbing, and retaining stormwater. Vegetated roofs comprise lightweight growth media and a specialized mix of vegetation underlain by a root barrier, a drainage layer, and a waterproofing membrane that protects the building structure. A vegetated roof retains rainfall within the pore space of the growing medium and releases that volume slowly via evaporation from soil and transpiration by plants. Vegetated roofs reduce the runoff volume and peak discharge flow rate of runoff from roofs during storm events by retaining and slowly releasing the water that would otherwise flow quickly into the storm drain system. Vegetated roofs improve the quality of runoff through the biological, physical, and chemical processes that occur within the plants and growth media to prevent airborne pollutants from entering the storm drain system. There are two types of vegetated roofs: intensive and extensive. An extensive vegetation roof consists of a thin layer of soil and a cover of grass, sedums or moss. Intensive green roofs are characterized by thick soil depths, heavy weights and elaborate plantings that include shrubs and trees.

Other Names: Ecoroof, green roof, green rooftop, nature roofs, vegetated roof covers, living roof

Advantages

- Allows for reduction in drainage capacity requirements at both the roof and ground levels.
- Provides thermal insulation, which reduces energy costs.
- Extends roof life by protecting the underlying roof material from climatic extremes, ultraviolet light, and damage.
- Reduces the amount of airborne pollutants entering the storm drain system.
- Reduces volume and peak flows of stormwater.
- Absorbs air pollution, collects airborne particulate matter, and negates acid rain effect.
- Provides “island” or “stepping stone” habitat for wildlife, particularly avian species.
- Reduces urban heat island effect.
- Provides sound insulation to reduce outdoor noise transfer (e.g., air traffic).

> A vegetated roof differs from a rooftop garden, which is characterized by freestanding containers of plants on a terrace or deck.

Limitations

- Vegetated roofs are best incorporated into plans for new buildings that provide adequate structural support; however, they can be retrofitted for existing buildings.
- Special structural design requirements increase building costs.
- Vegetation maintenance – appropriate plant selection is necessary to ensure plant survival. Irrigation during the first year may be necessary in order to establish vegetation. Plants should be selected that are drought tolerant and require little maintenance.

Planning and Siting Considerations

- Climate, especially temperature and rainfall patterns.
- Size, slope, height, and directional orientation of the roof. Green rooftops are typically installed on flat roofs but may be installed on roofs with slopes up to 10%.
- Roof must be capable of handling vegetated roof load.
- Accessibility and intended use. Safe access must be available for workers and materials during both construction and maintenance.
- Visibility, architectural fit and aesthetic preferences.
- Compatibility with other systems (e.g., solar panels).
- Appropriate vegetation selection (drought tolerant and requires little maintenance) is extremely important to the success of this Volume Reduction Measure.

Design Criteria

Design criteria for Vegetated Roofs are listed in **Table 5-7**. A typical Vegetated Roof configuration is provided in **Figure 5-4**.

Table 5-7. Vegetated Roof Design Criteria

Characteristic	Extensive Vegetated Roof	Intensive Vegetated Roof
Growth Media	Typical depth range: 1 – 5 inches Mix should have a high mineral content	Typical depth range: 6 – 24 inches Mix should have a high mineral content
Vegetation	Variety of vegetative ground cover and grasses. Select vegetation that is drought tolerant and requires little maintenance.	Large trees, shrubs, and complex gardens. Select vegetation that is drought tolerant and requires little maintenance.
Waterproofing Membrane	Resistant to biological and root attack	Resistant to biological and root attack
Load	12-50 pounds per square foot	80-150 pounds per square foot
Public Access	Usually not designed for public access	Accommodated and encouraged
Maintenance	Annual maintenance walks should be performed until plants are established	Significant maintenance required
Drainage	Simple irrigation and drainage systems	Complex irrigation and drainage systems

Figure 5-4. Typical Vegetated Roof Configuration (Source: American Wick Drain Corporation)

Volume Reduction and Tributary Impervious Area Credit

Vegetated Roofs provide volume reduction through storage of water in the pore space of the planting/growing medium. Vegetated Roofs may be used to help meet the Volume Reduction Requirement and can also be used to reduce the size of required treatment controls (Section 6). The calculation procedure for volume reduction and tributary impervious area credit for Vegetated Roofs is presented in **Table 5-8. Appendix B** provides additional information on calculating and meeting the Volume Reduction Requirement.

Vegetated Roofs can also be used to reduce the size of required treatment control through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls (see Section 6). The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of Vegetated Roofs reduces effective impervious area and thereby the volume of water to be treated. The credit is based on the ratio of volume reduction to the SQDV for the Vegetated Roof drainage area. Note that these credits must be applied to treatment controls that are in the same tributary drainage area as the Vegetated Roof for which the credits are determined and the credits cannot be greater than the tributary drainage areas of the Vegetated Roof. **Table 5-8** details how the tributary impervious area credit is calculated for Vegetated Roofs.

Table 5-8. Vegetated Roof Volume and Tributary Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Volume credit for vegetated roof ($Vol_{reduction}$)		
a. Volume of growth medium (V_{GM})	V_{GM} = ____________ ft^3	
b. AWHC of growth medium (W_{GM})	W_{GM} = ____________	AWHC= Available water holding capacity of growth medium. Use 0.1 for default value.
c. $Vol_{reduction} = V_{GM} \times W_{GM}$	$Vol_{reduction}$ = ____________ ft^3	
2. Total roof area (A_{roof})	A_{roof} = ____________ ft^2	
3. SQDV for roof area based on 12-h drawdown SQDV = 0.32 in x A_{roof} / 12	SQDV = ____________ ft^3	Unit basin storage volume for 12-h drawdown at 100 % imperviousness (C_r = 0.95) = 0.32 in (see Figure 6-1)
4. Impervious Area credit for vegetated roof ($Area_{credit}$) $Area_{credit} = A_{roof} \times Vol_{reduction} / SQDV$	$Area_{credit}$ = ____________ ft^2	Maximum allowable $Area_{credit} = A_{iroof}$

Construction Considerations

- Vegetation selection and planting is critical to the success of this control. Plants should be selected, installed, and maintained by experienced horticulturists or landscape contractors who understand Stockton's local environment and climate.
- Vegetated Roof components, particularly the vegetation, must be protected until established.
- Load bearing capacity of roof must be adequate to support soils, plants, and rain.
- Appropriate safety measures for working on industrial/commercial rooftops should be followed.
- The Vegetated Roof should be constructed in sections for easier inspection and maintenance access to the membrane and roof drains.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes Volume Reduction Measures such as vegetated roofs. Such agreements will typically include requirements such as those outlined in **Table 5-9**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City or County with complete access to the Volume Reduction Measure and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is provided in **Appendix D**.

Once a properly-installed Vegetated Roof is established, its maintenance requirements are usually minimal. However, of the two basic types of Vegetated Roof systems, extensive and intensive, the latter tends to have higher maintenance requirements due to its increased weight and more concentrated plantings.

Table 5-9. Inspection and Maintenance Requirements for Vegetated Roofs

Activity	Schedule
Irrigation: Extensive Vegetated roof	Establishment of vegetation and during periods of drought
Irrigation: Intensive Vegetated roof	Year-round, except during rain events
Weeding	Establishment of vegetation; thereafter, as needed
Repair/replace vegetation to maintain desired cover	As needed (2-3 times per year)
Inspection and maintenance of waterproof membrane	2-3 times per year
Inspection and maintenance of the drainage layer flow paths	As needed
Fertilization: To achieve water quality benefits, vegetated roofs should generally not be fertilized.	None

Source: City of El Cerrito

Description

Interception trees are used in residential and commercial settings to reduce stormwater runoff volume. Tree canopies can intercept a significant fraction of rainfall (10 - 40%) depending on the type of tree and climate. Tree canopies that project over impervious areas provide the greatest volume reduction benefit. **Figure 5-5** illustrates the rainfall interception and evaporation benefits received through a tree's hydrologic cycle.

> Broadleaf evergreens and conifers intercept more rainfall than deciduous species where winter rainfall patterns prevail.

Advantages

- Reduces stormwater volume and pollutant discharge.
- Enhances site aesthetics.
- Increases property values.
- Provides shading and cooling.
- Improves air quality.
- Can be used to also meet local parking lot landscaping requirements.

Limitations

- Fire safety may be a consideration for sites with increased fire risk.

Planning and Siting Considerations

- Trees should be selected that maximize tree canopy, are low maintenance, drought tolerant, and appropriate for local soil conditions. Recommended trees can be found in Appendix D of the Sacramento Stormwater Quality Design Manual (2007).
- Locate trees appropriate distances from buildings and infrastructure to avoid damage by roots and interference by branches.
- Locate trees such that canopies project over impervious areas to the maximum extent possible.

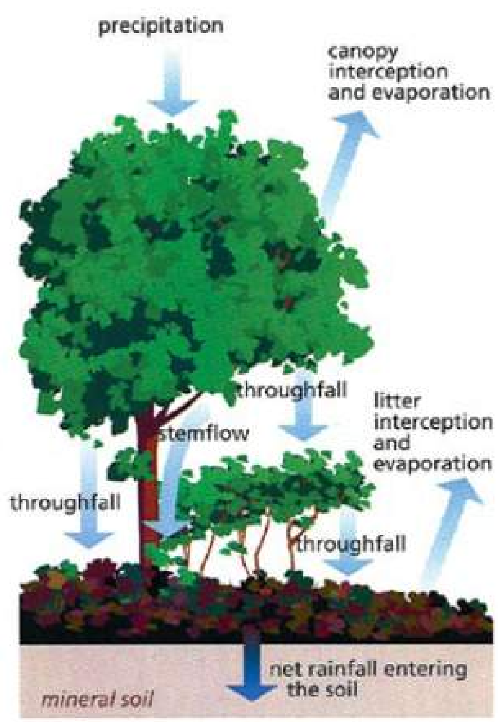


Figure 5-5. Schematic of a Tree's Hydrologic Cycle
(Source: FISRWG, 1998)

Volume Reduction and Tributary Impervious Area Credit

Interception Trees provide volume reduction through storage of water in the leave branches and stem of the tree. Interception Trees may be used to help meet the Volume Reduction Requirement and can also be used to reduce the size of required treatment controls (see Section 6). The calculation procedure for volume reduction and tributary impervious area credit for Interception Trees is presented in **Table 5-10. Appendix B** provides additional information on calculating and meeting the Volume Reduction Requirement.

Interception Trees can also be used to reduce the size of required treatment control through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls (see Section 6). The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of Interception Trees reduces effective impervious area and thereby the volume of water to be treated. The credit based on the area of canopy projection over impervious areas and the percentage of rainfall interception allowed for the type of tree selected. **Table 5-10** details how the tributary impervious area credit is calculated for Interception Trees.

Table 5-10. Interception Tree Volume and Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Percent rainfall interception by tree (Int) a. Evergreen tree Int = 40% b. Deciduous tree Int = 20 %	Int = ______ %	
2. No. of trees	No. of trees = ______	Provide separate total for each type of tree
3. Canopy projected over impervious area/tree	$Area_p$ = ______ ft^2	
4. Design storm depth (d)	d = ______ in	d = 0.51 inch
4. Volume reduction for interception ($Vol_{reduction}$) $Vol_{reduction} = d \times Area_p \times Int \times \text{No. of trees} / 12 \text{ in/ft}$	$Vol_{reduction}$ = ______ ft^3	Provide separate calculation for each type of tree with different canopy and Int value
5. Tributary Impervious Area Credit for tree interception $Area_{credit} = Area_p \times Int$	$Area_{credit}$ = ______ ft^2	Provide separate calculation for each type of tree with different canopy and Int value.

Construction Considerations

Urban tree mortality can be high. The following construction considerations can help to increase the life expectancy of urban trees:

- Utilize planting arrangements that allow shared rooting spaces
- Provide at least 400 cubic (optimally 1,000) feet of soil for large trees (Urban, 1999)

- Limit use of heavy equipment in planting areas to prevent soil compaction
- Use tree cages to protect trees from lawnmowers, heavy foot traffic and vehicles
- Select drought tolerant tree species

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes Volume Reduction Measures such as Interception Trees. Such agreements will typically include requirements such as those outlined in **Table 5-11**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City or County with complete access to the Volume Reduction Measure and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**.

Table 5-11. Inspection and Maintenance Requirements for Interception Trees

Activity	Schedule
Remove and replace any diseased or dying trees	Annually
Maintain trees (watering, pruning)	As needed

Description

Grassy Channels are densely vegetated drainage ways with gentle side slopes and gradual longitudinal slopes in the direction of flow that receive runoff from impervious areas and slowly convey the runoff to downstream points of treatment or discharge. Grassy Channels provide an opportunity for infiltration, reduce peak flows from impervious areas, and provide a degree of pollutant removal. Where development density, topography and soils permit, Grassy Channels are a preferable alternative to curb and gutter and storm drains as a stormwater conveyance system. The features and function of Grassy Channels are similar to the full treatment Grassy Swale described in Fact Sheet L-8 in Section 6.

Grassy Channels are appropriate for use in residential, commercial, industrial, and institutional settings, as illustrated in **Figure 5-1**. They can be used in conjunction with Grassy Filter Strips and are located adjacent to impervious areas to be mitigated. Drainage areas are typically less than 5 acres. Several Grassy Channels may be used on a single site, each designed to receive flow from different impervious areas. Grassy channels can also provide pretreatment for other stormwater treatment controls, such as bioretention areas. Irrigation and regular mowing are required to maintain the turf grass cover.

> A grassy channel is similar in most respects to a grassy swale, but differs in the level of engineering design criteria specified contact time, depth of flow, and flow velocity.

Other Names: Grassy Swale, Bioswale

Advantages

- Low installation cost.
- Compatible with site landscaping.
- Reduces stormwater volume and pollutant discharge.
- Easy to maintain.
- Prefered alternative to curb and gutter, where feasible.

Limitations

- Not suitable for industrial sites or sites where spills may occur unless infiltration is prevented by impermeable liner.
- Requires individual owners/tenants to perform maintenance.

Design Criteria

Design elements, construction considerations and maintenance requirements of Grassy Channels are similar in most respects to those of full treatment Grassy Swales presented in **Fact Sheet L-8** in **Section 6**. Grassy Channels typically differ in terms of the values used for the three principal design parameters that govern treatment performance:

- Contact time, which is a function of swale length
- Depth of flow
- Flow velocity

Key design criteria and reference values for Grassy Channels are listed in **Table 5-12** along with reference values for use in calculation of credits for reducing effective impervious area. The ratios of design values and reference values are used in the calculation of credits for reducing effective impervious area.

Table 5-12. Grassy Channel Design Criteria and Reference Values

Design Parameter	Criteria	Notes
Longitudinal slope (flow direction)	4% 0.5%	Maximum Minimum
Maximum bottom width	6 ft	
Maximum side slopes (H:V)	4:1	Side slopes to allow for ease of mowing.
Roughness coefficient (n) for treatment design	0.2	Reflects the roughness of swale when depth of flow is below the height of the grass.
Roughness coefficient (n) for conveyance design	0.1	Reflects the roughness of swale when depth of flow is above the height of the grass. Used to determine capacity of swale to convey peak hydraulic flows.
Vegetation	–	Turf grass (irrigated)
Vegetation height (typical)	4 to 6 in.	Vegetation should be maintained at a height greater than the depth of flow at design flow rate but sufficiently low to prevent lodging or shading of the vegetation.
Reference Values for Credit Calculation	**Criteria**	**Notes**
Reference Design Flow ($SQDF_{ref}$)	SQDF	SQDF = 0.20 in/hr × C × A (see **Section 6**)
Reference contact time (t_{ref})	7 min	
Reference flow depth (D_{ref})	3 in	In flow direction
Reference flow velocity (v_{ref})	1 ft/sec	In flow direction

Volume Reduction and Tributary Impervious Area Credit

Grassy Channels provide volume reduction through infiltration of water during conveyance and retention of water in the vegetative layer. Grassy Channels may be used to help meet the Volume Reduction Requirement and can also be used to reduce the size of required treatment controls (see Section 6). Volume reduction achieved with C and D soils is less than that achieved with A and B soils because less infiltration will occur with C and D soils. The calculation procedure for volume reduction and tributary impervious area credit for Grassy Channels is presented in **Table 5-13. Appendix B** provides additional information on calculating and meeting the Volume Reduction Requirement, and an example is provided below.

Grassy Channels can also be used to reduce the size of required treatment control through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls (see Section 6). The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of Grassy Channels reduces effective impervious area and thereby the volume of water to be treated. The credit is based on the ratio of volume reduction to the SQDF for the Grassy Channel drainage area. Note that these credits must be applied to treatment controls that are in the same tributary drainage area as the Grassy Channel for which the credits are determined and the credits cannot be greater than the tributary drainage areas of the Grassy Channel. **Table 5-13** details how the tributary impervious area credit is calculated for Grassy Channels.

Table 5-13. Grassy Channel Volume and Tributary Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Determine reference SQDF		
a. Impervious tributary area	A_{imp} = ______ ft^2	
b. Impervious are runoff coefficient (C_{imp})	C_{imp} = ______	C_{imp}= 0.95
c. $SQDF_{ref}$ = 0.2 x A_{imp} x C_{imp} / 43,560	$SQDF_{ref}$ = ______ cfs	
2. Design bottom width of Grassy Channel (W_{GC})	W_{GC} = ______ ft	
3. Design longitudinal slope (s_{GC})	s_{GC} = ______ ft/ft	
4. Design length of Vegetated Buffer Strip (L_{GC})	L_{VBS} = ______ ft	
5. Flow geometry @ SQDF from Manning equation		
a. Design flow depth (D_{GC})	D_{GC} = ______ ft	
b. Design flow area (A_{GC})	A_{GC} = ______ ft^2	
c. Design flow velocity (v_{GC})	v_{GC} = ______ ft/sec	
6. Contact time @ SQDF (t_{GC})		
t_{GC} = L_{GC} / v_{GC} / 60 sec	t_{GC} = ______ min	
7. Impervious Area credit for Grassy Channel (A_{credit}) A_{credit} = $(D_{aref}/D_{GC})^2$ x $(V_{ref}/V_{GC})^2$ x (t_{GC}/t_{ref}) x A_{imp}	A_{credit} = ______ ft^2	If calculated values of (q_{aref}/q_a), (V_{ref}/V_{GC}), or (t_{GC}/t_{ref}) are > 1.0, the value is set to 1.0
8. Volume Reduction for Grassy Swales ($Vol_{reduction}$)		
a. V_{soils} for A and B soils = 0.50	V_{soils} = ______ ft^3	V_{soils} is volume reduction factor allowed for infiltration, which varies with soil permeability
b. V_{soils} for C and D soils = 0.25		
c. $Vol_{reduction}$ = (A_{credit}) x V_{soils} x (0.51/12)	$Vol_{reduction}$ = ______ ft^3	

Credit Calculation Examples

Examples for volume reduction and tributary impervious area credit calculations are presented below.

Step 1 – Calculate Stormwater Quality Design Flow (SQDF) for impervious area tributary to Grassy Channel

Using procedures described in Section 6, determine SQDF for area tributary to Grassy Channel.

$SQDF_{ref}$ = i × C × A

where

SQDF = Stormwater Quality Design Flow, cfs

i = Design storm intensity = 0.20 in/hr

C_{imp} = Runoff coefficient for impervious area tributary to Grassy Channel

A_{imp} = impervious area tributary to Grassy Channel, acres

Example:

C_{imp} = 0.95

A_{imp} = 4,000 ft^2

$SQDF_{ref}$ = 0.20 x 0.95 x 4,000/43,560 = 0.0174 cfs

Step 2 – Determine design bottom width of Grassy Channel (W_{GC})

Note: Design width of Grassy Channel is not restricted to any value but ease of mowing and maintenance should be considered.

Example:

W_{GC} = 0.5 ft

Step 3 – Determine design longitudinal slope of Grassy Channel (s_{GC}) and side slope (H:V)

s_{GC} = 4% maximum; 0.5% minimum

H:V = 4:1

Example:

s_{GC} = 1% = 0.01ft/ft

Step 4 – Determine design length of Grassy Channel (L_{GC})

Note: Design length of Grassy Channel is not restricted to any minimum value

Example:

L_{GC} = 20 ft

Step 5 – Calculate design depth of flow and flow velocity at SQDF using Manning's Equation

$$Q = \frac{1.49}{n}\frac{A^{5/3}}{P^{2/3}} \times s^{1/2}$$

where

Q = $SQDF_{ref}$

A = Cross sectional area of flow

P = Wetted perimeter of flow

s = Bottom slope in flow direction

n = Manning's n (roughness coefficient) = 0.2 for depth < 6 in

Solve Manning's equation by trial and error to determine the depth of flow, flow area, and flow velocity at the SQDF and the design channel geometry

Example:

D_{GC} = 1.5 in

A_{GC} = 0.0625 ft^2

v_{GC} = Q_{SQDF} / A_{GC} = 0.0174 cfs / 0.0625 ft^2

v_{GC} =0.28 ft/sec

Step 6 – Calculate contact time for Grassy Channel (t_{GC})

t_{GC} = L_{GC} / v_{GC}

t_{GC} = 20 ft / 0.28 ft/sec / 60 sec

t_{GC} = 1.19 min

Step 7 – Calculate impervious area credit for Grassy Channel (A_{credit})

$A_{credit} = (D_{ref}/D_{GC})^2 \times (v_{ref}/v_{GC})^2 \times (t_{GC}/t_{ref}) \times A_{imp}$

Note: The ratios, (D_{ref}/D_{GC}) and (v_{ref}/v_{GC}) are squared to account for reduced efficiency of full treatment systems at higher hydraulic loading rates.

If calculated values of (D_{ref}/D_{GC}), (v_{ref}/v_{GC}), or (t_{GC}/t_{ref}) are > 1.0, the value is set to 1.0

The maximum allowable value of A_{credit} = A_{imp}

Example:

A_{credit} = $(3/1.5)^2$ x $(1/0.28)^2$ x (1.19/7) × 4,000

A_{credit} = $(1)^2$ x $(1)^2$ x 0.17 x 4,000 ft^2

A_{credit} = 680.3 ft^2

Step 8 – Calculate volume reduction credit for 0.51-inch storm depth

$Vol_{reduction} = (A_{credit}) \times V_{soils} \times (0.51/12)$

Example:

V_{soils} = 0.25 for C and D soils

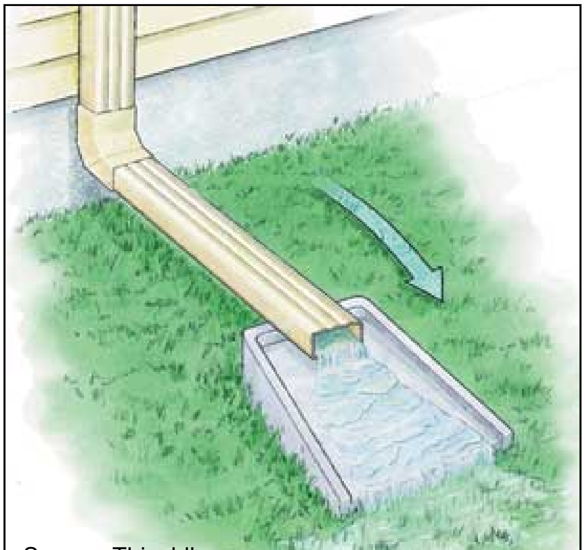
$Vol_{reduction}$= 680.3 × 0.25 × (0.51/12) = 7.2 ft^3

Construction Considerations

See Fact Sheet L-8: Grassy Swale in Section 6.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes Volume Reduction Measures such as Grassy Channels. Such agreements will typically include requirements such as those outlined in **Table 6-26** in Fact Sheet L-8: Grassy Swale in Section 6. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City or County with complete access to the Volume Reduction Measure and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**.



Source: Thisoldhouse.com

Description

A Vegetated Buffer Strip for rooftop and pavement disconnection is a gently sloped soil surface planted with dense turf grass or groundcover designed to receive and convey flow from rooftop drainage systems and adjacent paved areas. Runoff volume reduction is achieved through retention of a portion of the flow in the surface soil and thatch layer of the strip as well as infiltration. Some pollutant removal is also achieved as the runoff flows through the vegetation and over the soil surface at a shallow depth by a variety of physical, chemical, and biological mechanisms.

For rooftop drainage disconnection, splash runoff away from the building foundation and disperse flow to the strip. Buried extensions with pop-up outlets, as shown in the figure below, can be used for the same purpose. To increase the effectiveness of a strip, the concentrated flow from the roof drain should be dispersed across the top of the strip to the extent possible to maximize the width of flow down the length of the strip. A pea gravel level spreader can be used for this purpose if slope of the strip exceeds 4 percent (See **Figure 6-14** in Fact Sheet L-9: Grassy Filter Strip).

> A Vegetated Buffer Strip is similar in most respects to a Grassy Filter Strip (L-9), but differs in the level of engineering design criteria specified for minimum flow length and maximum application rates

Other Names: Vegetated Filter Strips, Grassy Buffer Strips, Grassy Filter Strips

Advantages

- Relatively inexpensive when used to replace part of a conventional storm drainage system and integrated into site landscaping.
- Reduces peak flows and runoff volume.
- Easy to maintain.

Limitations

- Not suitable for industrial sites or sites where spills may occur unless infiltration is prevented by impermeable liner.

Source: Gutterleaf.com

Planning and Siting Considerations

- Select location where site topography allows for the design of buffer strips with proper slopes in flow direction.
- Integrate Vegetated Buffer Strips into open space buffers, undisturbed natural areas, and other landscape areas when possible.
- Irrigation is typically required to maintain viability of the buffer strip vegetation. Coordinate design of general landscape irrigation system with that of the Vegetated Buffer Strip, as applicable.

Design Criteria

Design elements, construction considerations and maintenance requirements of Vegetated Buffer Strips are similar in most respects to those of full treatment Vegetated Buffer Strips presented in Fact Sheet L-9 in Section 6. Grassy Channels typically differ in terms of the values used for the two principal design parameters that govern treatment performance:

- Length of strip in direction of flow
- Application rate across top of strip

Key design criteria and reference values for Grassy Channels are listed in **Table 5-14** along with reference values for use in calculation of credits for reducing effective impervious area. The ratios of design values and reference values are used in the calculation of credits for volume reduction and for effective impervious area reduction.

Table 5-14. Vegetated Buffer Strips Design Criteria and Reference Values

Design Parameter	**Criteria**	**Notes**
Minimum design length (L_{VBS})	3 ft	In flow direction
Slope (flow direction)	4%	Maximum
	0.5%	Minimum
Vegetation	–	Turf grass or dense ground cover (irrigated)
Vegetation height (typical)	1 – 3 in.	
Reference Values for Credit Calculation	**Criteria**	**Notes**
Reference Design Flow ($SQDF_{ref}$)	SQDF	SQDF = 0.20 in/hr × C × A (see **Section 6**)
Reference linear application rate (q_{aref})	0.005 cfs/ft width	
Width for normal to flow (default value)	3 ft	Greater flow widths will increase credit values and can be achieved with flow spreader devices.
Reference length (in flow direction) (L_{ref})	20 ft	Maximum length for credit. Longer lengths receive no additional credit
Runoff coefficient for VBS	0.18	A and B soils
	0.25	C and D soils

Volume Reduction and Tributary Impervious Area Credit

Vegetated Buffer Strips provide volume reduction through infiltration of water during conveyance and retention of water in the vegetative layer. Vegetated Buffer Strips may be used to help meet the Volume Reduction Requirement and can also be used to reduce the size of required treatment controls (see Section 6). The calculation procedure for volume reduction and tributary impervious area credit for Vegetated Buffer Strips is presented in **Table 5-15. Appendix B** provides additional information on calculating and meeting the Volume Reduction Requirement, and an example is provided below.

Vegetated Buffer Strips can also be used to reduce the size of required treatment control through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls (see Section 6). The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of Vegetated Buffer Strips reduces effective impervious area and thereby the volume of water to be treated. The credit is based on the ratio of volume reduction for the Vegetated Buffer Strip in question to the volume reduction estimated for reference Vegetated Buffer Strip that would provide full treatment for the drainage area (see L-9: Grassy Filter Strip). Note that these credits must be applied to treatment controls that are in the same tributary drainage area as the Vegetated Buffer Strip for which the credits are determined and the credits cannot be greater than the tributary drainage areas of the Grassy Vegetated Buffer Strip. **Table 5-15** details how the tributary impervious area credit is calculated for Vegetated Buffer Strips.

Table 5-15. Vegetated Buffer Strip Volume and Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Determine reference SQDF		
a. Impervious tributary area	A_{imp} = ________ ft^2	
b. Impervious area runoff coefficient (C_{imp})	C_{imp} = ________	C_{imp}= 0.95
c. $SQDF_{ref} = 0.2 \times A_{imp} \times C_{imp} / 43{,}560$	$SQDF_{ref}$ = ________ cfs	
2. Design width of Vegetated Buffer Strip (W_{vbs})	W_{VBS} = ________ ft	Minimum default width = 3.0 ft
3. Design linear application rate (q_a) $q_a = SQDF_{ref} / W_{VBS}$	q_a = ________ cfs/ft	Reference q_a = 0.005 cfs/ft
4. Design length of Vegetated Buffer Strip (L_{VBS})	L_{VBS} = ________ ft	Reference L_{VBS} = 20 ft, which is max length allowed for credit
5. Tributary Impervious Area credit for Vegetated Buffer Strip (A_{credit}) $A_{credit} = (q_{aref}/q_a)^2 \times (L_{VBS}/L_{ref}) \times A_{imp}$	A_{credit} = ________ ft^2	If calculated values of (q_{aref}/q_a) or (L_{VBS}/L_{ref}) are > 1.0, the value is set to 1.0. Maximum allowable credit = A_{imp}
6. Volume Reduction for Vegetated Buffer Strip ($Vol_{reduction}$) $Vol_{reduction} = (A_{credit}) \times C_{imp} - C_{VBS}) \times (0.51/12)$	$Vol_{reduction}$ = ________ ft^3	C_{VBS} = 0.18 for A and B soils C_{VBS} = 0.25 for C and D soils

Credit Calculation Examples

Examples for volume and area credit calculation are presented below.

Step 1 – Calculate Stormwater Quality Design Flow (SQDF) for impervious area tributary to Vegetated Buffer Strip

Using **Fact Sheet T-0** in **Section 6**, determine SQDF for impervious area tributary to Vegetated Buffer Strip.

$SQDF_{ref} = i \times C \times A_{imp}$

where

$SQDF_{ref}$ = Stormwater Quality Design Flow, cfs

i = Design storm intensity = 0.20 in/hr

C = Runoff coefficient for impervious area tributary to Vegetated Buffer Strip

A_{imp} = impervious area tributary to Vegetated Buffer Strip, acres

Example:

$C = 0.95$

$A_{imp} = 3{,}600\ ft^2$

$SQDF_{ref} = 0.20 \times 0.95 \times 3{,}600/43{,}560 = 0.0157$ cfs

Step 2 – Determine design width of Vegetated Buffer Strip (W_{VBS})

Note: Design width of Vegetated Buffer Strip is not restricted to any value but runoff flow must be distributed uniformly across the width of the strip. The minimum default width is 3 feet. Wider values can be used if flow is dispersed with a spreader device

Example:

$W_{VBS} = 3.0$ ft

Step 3 – Calculate design linear application rate (q_a)

$q_a = SQDF_{ref} / W_{VBS}$

Example:

$q_a = 0.0157$ cfs/3.0 ft = 0.005 cfs/ft

Step 4 – Determine design length of Vegetated Buffer Strip (L_{VBS})

Note: Design length of Vegetated Buffer Strip is not restricted to any maximum, but 20 feet is the maximum length for credit calculation.

Example:

$L_{VBS} = 12.0$ ft

Step 5 – Calculate impervious area credit for Vegetated Buffer Strip (A_{credit})

$A_{credit} = (q_{aref}/q_a)^2 \times (L_{VBS}/L_{ref}) \times A_{imp}$

Note: The ratio, (q_{aref}/q_a) is squared to account for reduced efficiency of full treatment systems at higher hydraulic loading rates.

If calculated values of (q_{aref}/q_a) or (L_{VBS}/L_{ref}) are > 1.0, the value is set to 1.0

The maximum allowable value of $A_{credit} = A_{imp}$

Example:

A_{credit} = $(0.005/0.005)^2 \times (12/20) \times 3{,}600$ ft^2

A_{credit} = $(1.0)^2 \times (12/20) \times 3{,}600$ ft^2

A_{credit} = $0.6 \times 3{,}600$ ft^2 = 2,160 ft^2

Step 6 – Calculate Volume reduction for 0.51-inch storm depth

$Vol_{reduction} = (A_{credit}) \times. C_{imp} - C_{VBS}) \times (0.51/12)$

Example:

C_{VBS} = 0.25 for C and D soils

$Vol_{reduction} = 2{,}160 \times (0.95 - 0.25) \times (0.51/12) = 64.3$ ft^3

Construction Considerations

See Fact Sheet L-9: Grassy Filter Strip in Section 6.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes Volume Reduction Measures such as Vegetated Buffer Strips. Such agreements will typically include requirements such as those outlined in **Table 6-29** in Fact Sheet L-9: Grassy Filter Strip in Section 6. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City or County with complete access to the Volume Reduction Measure and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**.

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SECTION 6
TREATMENT CONTROLS

6.1 INTRODUCTION

Treatment controls, or Best Management Practices (BMPs) are required in addition to Site Design Controls, Source Controls and Volume Reduction Measures to reduce pollutants in stormwater discharges to the maximum extent practicable. Treatment controls are engineered technologies designed to remove pollutants from stormwater runoff. The type of treatment control(s) to be implemented at a site depends on a number of factors including: type of pollutants in the stormwater runoff, quantity of stormwater runoff to be treated, project site conditions (e.g. soil type and permeability, slope, etc.), receiving water conditions, and state industrial permit requirements, when applicable. Land requirements, and costs to design, construct and maintain treatment controls vary by treatment control.

Unlike flood control measures that are designed to handle peak flows, stormwater treatment controls are designed to treat the more frequent, lower-flow storm events, or the first flush portions of runoff from larger storm events (typically referred to as the first-flush events). Small, frequent storm events represent most of the total average annual rainfall for the area. The flow and volume from such small events, referred to as the Stormwater Quality Design Flow (SQDF) and Stormwater Quality Design Volume (SQDV), are targets for treatment. There is marginal water quality benefit gained by sizing treatment facilities to treat flows or volumes larger than the SQDF or SQDV.

The treatment controls presented in the 2009 SWQCCP are designed based on flow rates or volume of runoff. Those designed based on flow are to be designed for the SQDF, and those designed based on volume are to be designed for the SQDV. Definitions and calculation procedures to determine SQDF and SQDV are presented in this Section. The treatment controls specified in this SQWCCP are to be sized for the SQDF or SQDV. Flows in excess of SQDF or SQDV are to be diverted around or through the treatment control.

Treatment Controls are categorized as either Low Impact Development (LID) Treatment Controls or Conventional Treatment Controls (**Table 6-1**). LID Treatment Controls have the ability to reduce stormwater runoff volumes and may be used in combination with the Volume Reduction Measures described in Section 5 to meet the Volume Reduction Requirement. Conventional Treatment Controls typically do not reduce stormwater runoff volumes.

Table 6-1. LID Treatment Controls and Conventional Treatment Controls

LID Treatment Controls	Conventional Treatment Controls
Bioretention (L-1)	Constructed Wetland (C-1)
Stormwater Planter (L-2)	Extended Detention Basin (C-2)
Tree-well Filter (L-3)	Wet Pond (C-3)
Infiltration Basin (L-4)	Proprietary Control Device (C-4)
Infiltration Trench/Dry Well (L-5)	
Porous Pavement Filter (L-6)	
Vegetated (Dry) Swale (L-7)	
Grassy Swale (L-8)	
Grassy Filter Strip (L-9)	

The stormwater treatment controls specified in this section are the more common non-proprietary measures being implemented nationwide. Studies have shown these measures to be reasonably effective if properly installed and maintained. Consequently, application of these controls is considered to achieve compliance with the objective of controlling pollutants to the maximum extent practicable (MEP) and working towards attaining and/or maintain water quality standards in receiving water. The relative effectiveness of treatment controls specified in this section for reducing pollutants of concern is shown in **Table 6-2**. Pollutants of concern listed are those that have been identified as causing or contributing to impairment of beneficial uses of water bodies in California. These waterbodies are listed as impaired under Clean Water Act Section 303(d). The most current and up to date 303(d) list can be found at: www.swrcb.ca.gov/centralvalley/water_issues/tmdl/impaired_waters_list/.

Selection of Treatment Controls should be based on their ability to reduce runoff volumes and remove pollutants of concern. Priority New Development and Significant Redevelopment Projects that cannot fully meet the Volume Reduction Requirement and are located in a watershed with a 303d listed waterbody, must select Treatment Controls with a Medium to High removal efficiency for the pollutant of concern (see Table 6-2).

Table 6-2. Efficiency of Treatment Controls for Reduction of the Concentration of Pollutants of Concern

Treatment Controls	Pollutant of Concern[1]			
	Bacteria	Pesticides	Oxygen Demanding Substances	Sediments
LID Treatment Controls				
Bioretention (L-1)	M	M	M	M
Stormwater Planter (L-2)	M	M	M	M
Tree-well Filter (L-3)	M	M	M	M
Infiltration Basin (L-4)	H	M	M	H
Infiltration Trench (L-5)	H	M	M	H
Porous Pavement Filter (L-6)	M	M	M	H
Vegetated (Dry) Swale (L-7)	L[2]	L[2]	M	M
Grassy Swale (L-8)	L[2]	L[2]	M	M
Vegetated Buffer Strip (L-9)	M	M	M	H
Conventional Treatment Controls				
Constructed Wetland (C-1)	M	M	M	M
Extended Detention Basin (C-2)	M	M	M	M
Wet Pond (C-3)	M	M	M	H
Proprietary Devices(C-4)[3]	–	–	–	–

[1] H = >75% expected pollutant removal efficiency for typical urban stormwater runoff; M = 75% to 25% expected removal efficiency for typical urban stormwater runoff; L = <25% expected removal efficiency for typical urban stormwater runoff.

[2] If the project is located in a watershed with a 303d listed waterbody for bacteria or pesticides, swales should only be used in combination (e.g., used in a treatment train) with Treatment Controls with a Medium to High removal efficiency for bacteria or pesticide removal efficiency.

[3] Effectiveness of proprietary devices varies depending on the manufacturer and type of device. Limited performance data are available.

6.2 SELECTION OF TREATMENT CONTROLS

Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The applicability of specific controls outlined within this Section should be confirmed with the local government. The site constraints that are considered in selection of treatment controls are presented in **Table 6-3**.

Volume Reduction Requirement

All New Development Priority Projects must meet the Volume Reduction Requirement (see Sections 2 and 5) through a combination of Volume Reduction Measures and LID Treatment Controls. <u>If project applicants do not fully meet the Volume Reduction Requirement through the use of Volume Reduction Measures (Section 5), the project must use LID Treatment Controls to further reduce stormwater runoff volumes and treat the SQDF or SQDV</u>. If the Volume Reduction Requirement has been met through the use of Volume Reduction Measures, then a treatment control may be chosen from the LID Treatment Control or Conventional Treatment Control list. Calculation procedures for determining the volume reduction for LID Treatment Controls are provided within each fact sheet. Design Summary Worksheets are provided in **Appendix B** to aid the applicant in summarizing calculation results.

> An example calculation is provided in **Appendix J** to illustrate the application of the Volume Reduction Requirement, Volume Reduction Measures, tributary impervious area reduction credits and LID Treatment Controls.

If the Volume Reduction Requirement cannot be fully met due to site constraints, see "Alternative Compliance Option" in Section 5. Projects that do not fully meet the Volume Reduction Requirement and are located in a watershed draining to a 303d listed waterbody must select Treatment Controls with a <u>M</u>edium to <u>H</u>igh removal efficiency for the pollutant of concern (see Table 6-2).

6.3 MAINTENANCE AND MONITORING REQUIREMENTS FOR TREATMENT CONTROLS

Failure to properly operate and maintain the measures could result in reduced treatment of stormwater runoff or a concentrated loading of pollutants to the storm drain system. Unless otherwise agreed to by the City or the County, the landowner, developer, site operator, or successors-in-interest (e.g. homeowner's association) is responsible for the operation and maintenance of the treatment controls. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time.

Certification of Responsibility

Project developers/property owners are responsible for the maintenance of structural stormwater control measures implemented pursuant to the requirements of the 2009 SWQCCP until the property ownership is legally transferred or the stormwater or other agency assumes responsibility through annexation. A sample owner/developers certification of responsibility is included in **Appendix D** of the Plan.

Maintenance Plan

To protect against failure of a treatment control, a Maintenance Plan must be developed and implemented for all treatment controls (see Section 7). Maintenance Plans must include guidelines for how and when inspection and maintenance should occur for each control. Guidelines for maintenance plans are provided in **Appendix E**. The Plan must be made submitted to the City or County as part of the Project Stormwater Quality Control Plan submittal.

Maintenance Entities and Agreements

Owners, developers, and/or successors-in-interest (ODS) must establish a maintenance entity acceptable to the City or County that will be responsible for funding and performing the long-term operation, maintenance, replacement, and administration of the proposed treatment controls. Maintenance entities may be either private or public depending on the ownership of facilities.

Private Maintenance Entity

The ODS of treatment controls that are constructed and located in private facilities must execute a Maintenance Agreement with the City or County prior to final acceptance of a development project. The ODS will remain the responsible party for funding and performing the long-term operation, maintenance, replacement, and administration of the treatment controls. A sample Maintenance Agreement is included in **Appendix D**.

Public Maintenance Entity

The ODS of any subdivision project that includes treatment controls pursuant to the 2009 SWQCCP and that will be annexed to the City is required to form a Zone within the Stockton Consolidated Storm Drainage Maintenance Assessment District No. 2005-1(approved and adopted by City Council on July 26, 2005) to provide funding for the long-term operation, maintenance, replacement, and administration of the treatment controls constructed for the project. The Zone must be formed prior to recordation of a Final Map. Formation of the Zone requires submittal to and approval by the City of an Engineer's Report that shall contain a boundary map and an allocation of the costs referenced above. A sample Engineer's Report is included in **Appendix D**.

Monitoring

Monitoring may be conducted by the site operator, the City/County, or both. Monitoring may be required for a period of time to help the City or County evaluate the effectiveness of treatment controls in reducing pollutants in stormwater runoff.

6.4 DESCRIPTION OF TREATMENT CONTROLS

This Section provides fact sheets for design and implementation of recommended treatment controls. The fact sheets include siting considerations, design criteria, and maintenance requirements to ensure optimal performance of the measures. The 2009 SWQCCP also contains calculation fact sheets and worksheets to aid in the design of water quality treatment controls.

Table 6-3. Site Constraints for Treatment Controls

Treatment Control	Drainage Area		Depth to Groundwater		Soil Type[1]		Maximum Slope		Hydraulic Head	Vegetation Irrigation	Vector Control Frequency	Maintenance Frequency
	<10 acres	>10 acres	<10 feet	>10 feet	A or B only	A, B, C or D	~0%	<15%				
LID Treatment Controls												
Bioretention (L-1)	X		X	X		X		X	M	Y	M	M
Stormwater Planter (L-2)	X		X	X		X		X	M	Y	M	M
Tree-well Filter (L-3)	X		X	X		X		X	M	Y	M	M
Infiltration Basin (L-4)	X			X	X			X	H	Y*	L	M
Infiltration Trench (L-5)	X			X	X			X	H	N	L	L
Porous Pavement Filter (L-6)	X		X	X		X		X	M	N	L	L
Vegetated (Dry) Swale (L-7)	X		X	X		X		X	L	Y	L	L
Grassy Swale (L-8)	X		X	X		X		X	L	Y	M	L
Grassy Filter Strip (L-9)	X		X	X		X		X	L	Y	L	L
Conventional Treatment Controls												
Constructed Wetland (C-1)		X	X	X		X	X		L	Y	H	H
Extended Detention Basin (C-2)		X	X	X		X	X		L	Y*	M	M
Wet Pond (C-3)		X	X	X		X	X		L	Y*	H	M
Proprietary Devices[2] (C-4)												

X: indicates Treatment Control is suitable for listed site condition.

H= high; M = medium; L = low;

Y= yes; Y* = yes if vegetated; N= no

1. Type A soils are sands and gravels with typical infiltration rates of 1.0-8.3 inches/hour. Type B soils are sandy loams with moderately fine to moderately coarse textures and typical infiltration rates of 0.5-1.0 inches/hour. Type C soils are silty-loams or soils with moderately fine to fine texture and typical infiltration rates of 0.17-0.27 inches/hour. Type D soils are clays with infiltration rates of 0.02-0.10 inches/hour.
2. Suitability of proprietary devices varies depending on the manufacturer and type of device.

INTRODUCTION

The primary control strategy for all of the treatment control measures specified in this Section is to treat the SQDF or SQDV of the stormwater runoff. The following paragraphs present calculation procedures and design criteria necessary to determine the SQDF and SQDV, which are distinct and separate parameters from the Volume Reduction Requirement discussed in Section 5. The SQDF and SQDV are required design parameters used to size treatment controls. The Volume Reduction Requirement (Section 5.2) is a separate and independent requirement that must be met by application of a combination of Volume Reduction Measures and LID Treatment Controls.

The treatment controls specified in this Section are listed in **Table 6-4** along with the basis of design, SQDF or SQDV, to be used for the listed control measure. Also is listed in Table 6-4 are the design drawdown periods for those treatment control measures that use the SQDV as the basis for design (**Figure 6-1**). LID-type treatment controls are identified as L-1, L-2, etc. Conventional treatment controls are identified as C-1, C-2, etc.

Table 6-4. Sizing Criteria for Treatment Controls

Treatment Control	Design Basis	Design Drawdown*
Bioretention (L-1)	SQDV	12 hours
Stormwater Planter (L-2)	SQDV	12 hours
Tree-well Filter (L-3)	SQDV	12 hours
Infiltration Basin (L-4)	SQDV	48 hours
Infiltration Trench (L-5)	SQDV	48 hours
Porous Pavement Filter (L-6)	SQDV	12 hours
Vegetative (Dry) Swale (L-7)	SQDV	12 hours
Grassy Swale (L-8)	SQDF	N/A
Grassy Filter Strip (L-9)	SQDF	N/A
Constructed Wetland (C-1)	SQDV	24 hours
Extended Detention Basin (C-2)	SQDV	48 hours
Wet Pond (C-3)	SQDV	12 hours
Proprietary Control Measures (C-4)	SQDV or SQDF	48 hours

*Design drawdown period used to determine Unit Basin Storage Volume (see Figure 6-1)

DETERMINING DESIGN IMPERVIOUSNESS, RUNOFF COEFFICIENT AND EFFECTIVE AREA

Calculation of the SQDV and SQDF requires determination of the following parameters associated with the drainage area tributary to the treatment control under design:

- Weighted runoff coefficient (C_r) (without application of impervious area credits)
- Effective tributary area following application of area credits (A_{eff})

Weighted Imperviousness and Runoff Coefficient Calculations

Projects typically comprise a variety of site elements that have variable values of imperviousness and associated runoff coefficients. The runoff coefficient is a function of imperviousness and the permeability of the soil, if the runoff contacts the soil. Values of imperviousness and runoff coefficients that are to be used for purposes of calculating SQDV and SQDF under the 2009 SWQCCP are listed in **Table 6-5** for typical site elements. The weighted runoff coefficient value for a particular drainage area is determined as follows:

1. Determine area associated with each site element ($A_{element}$)
2. Determine sum of site element areas (A_{site})
3. Determine fraction of total area associated with each site element ($A_{element}/A_{site}$)
4. Determine the runoff coefficient (C_r) associated with each site element from Table 6-5.
5. Calculate weighted imperviousness (I_a) or runoff coefficient (C_{ra}):

$$I_a = \Sigma\ I_i \times\ A_{element(i)} / A_{site}$$

$$C_{ra} = \Sigma\ C_r \times\ A_{element(i)} / A_{site}$$

Table 6-5. Values of Runoff Coefficients for Typical Site Elements[1,2]

Site Element	Runoff Coefficient (C_r)	
	A and B Soils	C and D Soils
Asphalt/concrete pavement	0.95	0.95
Roofs	0.95	0.95
Gravel pavement	0.35	0.35
Permeable pavement	Variable[3]	Variable[3]
Managed turf	0.18	0.25
Disturbed soils	0.18	0.25
Vegetated areas w/ amended Type A soil	0.03	n/a
Forest/undisturbed open space	0.03	0.05

1. Adapted from Center for Watershed Protection, Ellicott City, MD.
2. Not for design of storm drain system piping. Use City of Stockton Standard Drawing No. 76 for storm drain system design.
3. Variable with product type. Consult manufacturer for appropriate design values.

Example calculations for weighted runoff coefficient for a site with Type D soils are shown in **Table 6-6.**

Table 6-6. Example Calculation Table for Weighted Runoff Coefficient

Site Element	Element Area[(a)], ft^2 ($A_{element}$)	Fraction of Total Area ($A_{element}/A_{site}$)	Element Runoff Coefficient (C_r)	Weighted Runoff Coefficient (C_{ra})
Asphalt/concrete pavement	40,000	0.40	0.95	0.38
Roofs	30,000	0.30	0.95	0.29
Permeable pavement	5,000	0.05	0.35	0.17
Managed turf	20,000	0.20	0.25	0.05
Area amended w/ Type A soil	5,000	0.05	0.03	0.01
Total Site (A_{site})	**100,000**			**0.90**

a. Actual area without adjustment for tributary impervious area credits from volume reduction measures

Effective Tributary Area Calculations

The effective tributary area is defined as the effective area to be used in calculations for SQDV and SQDF for a specific treatment control measure and is determined by subtracting the tributary impervious area credits earned for Volume Reduction Measures from the actual tributary drainage area served by the treatment control ($A_{eff} = A_{tributary} - A_{credit}$). Note that a tributary impervious area credit for a Volume Reduction Measure must be applied to a treatment control that serves the same tributary drainage area as the Volume Reduction Measure for which the credit is earned and the credits cannot be greater than the tributary drainage areas of the treatment controls to which they are applied. Example calculations for effective area are shown in **Table 6-7**.

Table 6-7. Example Calculation Table for Effective Tributary Area

Site Element	Element Area, ft^2	Area Credit[a] (A_{credit}), ft^2	Effective Area (A_{eff}), ft^2
Asphalt/concrete pavement	40,000	10,000	30,000
Roofs	30,000	15,000	15,000
Permeable pavement[b]	5,000	0	5,000
Managed Turf	20,000	0	20,000
Amended Soil Area Type A	5,000	0	5,000

a. Area Credit from Volume Reduction Measures (e.g. rain gardens, rain barrels, vegetated roof, interception trees, grassy channel, or vegetated buffer strip)

b. Credit for permeable pavement has already been provided in the form of a reduced runoff coefficient (see Tables 6-5 and 6-6).

STORMWATER QUALITY DESIGN FLOW (SQDF) CALCULATION

Hydrologic calculations for design of flow-based stormwater treatment controls in the Stockton area shall be in accordance with the latest version of the City of Stockton Standard Specifications (Red Book) and the County of San Joaquin Improvement Standards and Hydrology Manual, together with the procedure set forth herein.

The SQDF is defined to be equal to the maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two. The 85th percentile hourly rainfall intensity for the Stockton area is estimated to be approximately 0.10 inches/hour, based on cumulative frequency curve for Sacramento presented in the *California Storm Water Best Management Practices Handbook – New Development and Redevelopment,* (2003) for representative rainfall gauges throughout California (not to be confused with the 85th percentile, 24 hour storm <u>depth</u> associated with the Volume Reduction Requirement). The curve for Sacramento is considered representative of rainfall intensities in the Stockton area.

Calculation Procedure

1. Determine the 85th percentile hourly rainfall intensity for the Stockton area. <u>Use 0.10 in/hr.</u>
2. Multiply the 85th percentile hourly rainfall intensity by a factor of two to obtain design rainfall intensity. <u>Use i = 0.10 × 2 = 0.20 in/hr.</u>
3. Determine the weighted runoff coefficient for project area using the procedure illustrated in **Table 6-6**.

4. Determine the effective area (A_{eff}) of the drainage area using the procedure illustrated in **Table 6-7**.
5. Calculate the SQDF using the following equation.

$$SQDF = i \times C_{ra} \times A_{eff} = 0.20 \times C_{ra} \times A_{eff}$$

where

SQDF	=	Stormwater Quality Design flow, cfs
i	=	Design storm intensity = 0.20 in/hr
C_{ra}	=	Weighted runoff coefficient for project area
A_{eff}	=	Effective project drainage area, acres (Note: Area converted to acres for ease of calculation. Resulting conversion factor is approximately equal to 1.0)

Example Calculation

Project site conditions from previous example: A_{eff} = 75,000 ft^2; C_{ra} = 0.90

$$SQDF = 0.20 \times 0.90 \times 75{,}000/43{,}560 = 0.31 \text{ cfs}$$

STORMWATER QUALITY DESIGN VOLUME (SQDV) CALCULATION

Hydrologic calculations for design of volume-based stormwater treatment controls in the Stockton urbanized area shall be in accordance with the procedures set forth herein.

The SQDV is defined as the volume necessary to capture and treat 80 percent or more of the average annual runoff volume from the site at the design drawdown period specified in the Fact Sheet for the proposed treatment control. The SQDV volume should not be confused with the Volume Reduction Requirement, which is a separate requirement as defined in Section 5.

Calculation Procedure

1. Review the area draining to the proposed treatment control. Determine the weighted runoff coefficient (C_{ra}) of the drainage area using the procedure illustrated in **Table 6-6**.
2. **Figure 6-1** provides a direct reading of Unit Basin Storage Volumes required for 80% annual capture of runoff for values of "C_{ra}" determined in Step 1. Enter the horizontal axis of Figure 6-1 with the "C_{ra}" value from Step 1. Move vertically up Figure 6-1 until the appropriate drawdown period line is intercepted. (The design drawdown period specified in the respective Fact Sheet for the proposed treatment control). Move horizontally across Figure 6-1 from this point until the vertical axis is intercepted. Read the Unit Basin Storage Volume along the vertical axis. Figure 6-1 is based on rain gauge data from the Stockton urbanized area.
3. Determine the effective area of the drainage area using the procedure illustrated in Table 6-7.
4. The SQDV for the proposed treatment control is then calculated by multiplying the Unit Basin Storage Volume by the contributing drainage area. Due to the mixed units that result (e.g., acre-inches, acre-feet), it is recommended that the resulting volume be converted to cubic feet for use during design.

$$SQDV = V_u \times A_{eff}$$

Example Calculation

Project site conditions from previous example: A_{eff} = 75,000 ft^2; C_{ra} = 0.90

1. Determine design drawdown period for proposed control measure.

   Example: L-1: Bioretention → Drawdown period = 12 hrs

2. Determine the Unit Basin Storage Volume for 80% Annual Capture, V_u using Figure 6-1.

   Example: for C_{ra} = 0.90 and drawdown = 12 hrs → V_u = 0.31 in

3. Calculate the SQDV for the basin.

$$SQDV = V_u \times A_{eff} = (0.31\text{ in}) \times (75{,}000\text{ ft}^2) \times (1\text{ ft}/12\text{ in}) = 1{,}938\text{ ft}^3$$

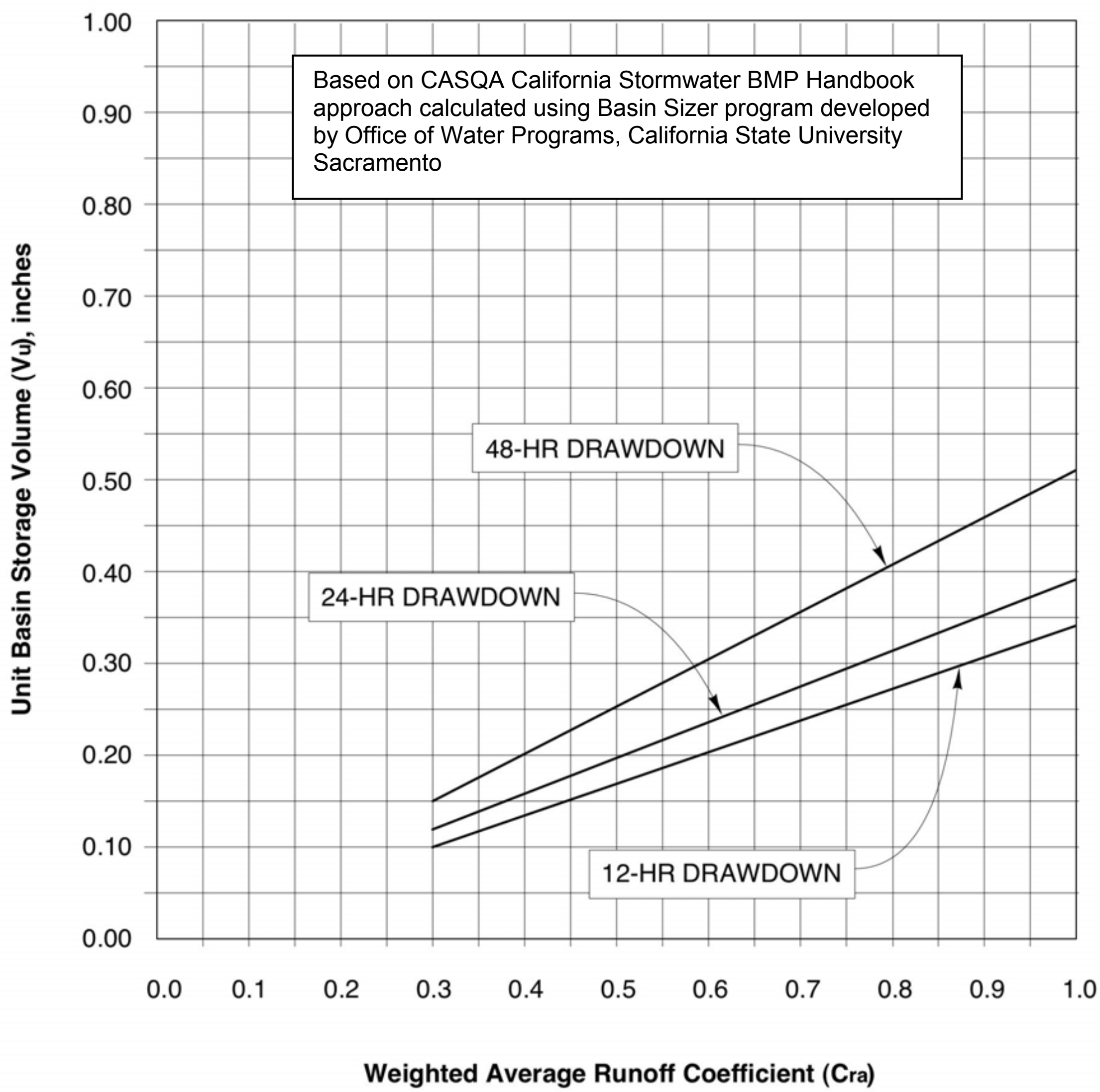


Figure 6-1. Unit Basin Storage Volume vs. Weighted Runoff Coefficient

Source: University of Connecticut

Description

A bioretention area is a vegetated shallow depression that is designed to receive, retain, and infiltrate rainwater runoff from downspouts, piped inlets, or sheet flow from adjoining paved areas. A shallow surcharge or ponding zone is provided above the vegetated surface for temporary storage of the captured runoff. During stormwater events, runoff accumulates in the surcharge zone and gradually infiltrates the surface and filters through the engineered soil matrix, filling the void spaces of the matrix before infiltrating the underlying soil or being collected by an underdrain system.

Treatment of the runoff occurs through a variety of natural mechanisms as the runoff filters through the root zone of the vegetation and during detention of the runoff in the pore space of the engineered soil matrix. A portion of the water held in the root zone of the soil media is returned to the atmosphere through transpiration by the plants. Bioretention areas are typically planted with native, drought tolerant plant species that do not require fertilization and can withstand wet soils for at least 24 hours, such as wildflowers, sedges, rushes, ferns, shrubs and small trees. Root systems of the plants enhance infiltration, moisture redistribution, and diverse microbial populations involved in biofiltration. If underlying soils are rapidly permeable with permeability greater than the engineered soil layers (typically types A or B soils), the bioretention area can be constructed without an underdrain pipe, in which case the all of the captured runoff will infiltrate into the underlying soil profile. If less permeable underlying soils (types C or D) are present or slopes are steep, an underdrain is required to prevent excessive ponding. However, a portion of the captured runoff will infiltrate into the underlying soil, the amount of which will depend on the permeability of the underlying soils.

> Bioretention is similar in most respects to a rain garden, but differs in the typical size and level of engineering design criteria specified for construction.

Advantages

- Low installation cost.
- Enhances site aesthetics.
- Reduces stormwater volume and pollutant discharge.
- Potential water conservation.
- Easy maintenance.

Limitations

- Not suitable for industrial sites or sites where spills may occur unless infiltration is prevented by impermeable liner.

- Requires underdrains for low permeability soils or steep slopes.
- May require individual owners/tenants to perform maintenance.
- Not appropriate for areas with steep slopes or high groundwater unless infiltration is prevented by impermeable liner.

Planning and Siting Considerations

- Locate bioretention areas sufficiently far from structure foundations to avoid damage to structures (as determined by a structural or geotechnical engineer).
- Maintain a slope of at least 1 percent from impervious surface to bioretention areas inlet.
- Provide for overflow discharge that drains away from building foundations to storm drain system or more suitabel infiltration area.
- Provide underdrain pipe in areas with C and D soils.
- Provide underdrain pipe and impermeable liners in areas subject to spills or pollutant hot spots.

Design Criteria

Design criteria for bioretention are listed in **Table 6-8**. A typical cross section illustrating design features is shown in **Figure 6-2**.

Table 6-8. Bioretention Design Criteria

Design Parameter	Criteria	Notes
Maximum depth of ponding zone (D_{PZ})	12 inches	Depth above top much layer
Depth of top mulch layer	2 - 3 inches	Shredded hardwood or softwood or compost
Depth of planting media	18 - 24 inches	Mix: 60-65% loamy sand + 35-40% compost or 30% loamy sand + 30% course sand + 40 % compost
Aggregate filter blanket	9 - 12 inches	For use with subsurface drain pipe
Subsurface drain pipe	4 - 8 inch	Slotted PVC per ASTM D1785 SCH 40. (Use with C and D soils)
Excavation side slope of (H:V)	2:1	Maximum steepness

Design Procedure

Step 1 – Calculate Water Quality Volume (SQDV)

Using the procedures presented in Fact Sheet T-0, determine the stormwater quality design volume, SQDV, based on a 12-hour drawdown period and the effective contributing area, after allowance for impervious area credits.

Step 2 – Design average ponding depth (D_{PZ})

Select the average SQDV depth between six (6) and twelve (12) inches. Average depth is defined as water volume divided by the water surface area of the planter.

Step 3 – Calculate planter surface area (A_S)

The design surface area of the planter is determined from the design SQDV and D_{PZ} as follows:

$A_S = SQDV/ D_{PZ}$

Step 4 – Design base courses

Planting media layer – Provide a mix of 60-65% loamy sand + 35-40% compost or 30% loamy sand + 30% course sand + 40 % compost. The long-term hydraulic conductivity of the mix should be ≥ 1.0 in/hr at 80 percent compaction This layer should be a minimum of 18 inches deep, but a deeper layer is recommended to promote healthy vegetation and improve nutrient removal.

Gravel envelope (for subsurface drain pipe) – Place drain pipe on a 3- ft wide, 6-inch deep bed of gravel (Class 2 Permeable Material per Caltrans Spec 68-1.025). Cover top and sides of pipe with gravel to a minimum depth of 12 inches. Do not wrap pipe or gravel envelop with filter fabric to prevent clogging.

Step 5 – Select subbase liner

If expansive soils or rocks are a concern, chemical or petroleum products are handled or stored within the tributary catchment, or infiltration is not desired for any reason, use an impermeable liner at the bottom of the bioretention facility.

Step 6 – Design subsurface drainpipe (if required)

If C or D soils are present or infiltration is not desired, provide subsurface drainpipe with diameter sized for required hydraulic capacity (4-in minimum). Use heavy-walled, slotted PVC pipe (ASTM D1785 SCD 40) to allow pressure water cleaning and root cutting, if necessary. Connect subsurface drainpipe to downstream open conveyance (e.g. swale), another bioretention cell, a dispersion area, or to the storm drain system.

Step 7 – Select vegetation

Select vegetation that:

- Is suited to well-drained soil;
- Will be dense and strong enough to stay upright, even in flowing water;
- Has minimum need for fertilizers;
- Is not prone to pests and is consistent with IPM practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

Avoid the use of bark or similar buoyant material that will tend to float when the vegetated area is inundated.

Step 8 – Design overflow device

Provide an overflow device with an inlet to open conveyance or to storm drainage system. Set the overflow inlet elevation above the SQDV surcharge water level. A drop inlet or an overflow standpipe with an inverted opening are appropriate overflow devices).

Volume Reduction Calculation

Bioretention may be used to achieve the Volume Reduction Requirements in addition to treatment control requirements. The volume reduction for a bioretention area is less if subsurface drain pipe is provided, because less infiltration will occur. The calculation procedure for volume reduction for bioretention is presented in **Table 6-9.**

Table 6-9. Bioretention Volume Reduction Calculation

Design Parameter	Criteria	Notes
Bioretention with Subsurface Drain Pipe		Required for C and D soils
1. Ponding Zone		Infiltration allowance for water in ponding zone water = 0.25
a. Depth of ponding zone (D_{PZ})	D_{PZ} = ____________ ft	
b. Area of ponding zone (A_{PZ})	A_{PZ} = ____________ ft^2	
2. Planting Media Layer		Available Water Holding Capacity of planting media layer = 0.1 x volume
a. Depth of planting media layer (D_{PM})	D_{PM} = ____________ ft	
b. Area of planting media layer (A_{PM})	A_{PM} = ____________ ft^2	
3. Gravel Zone		Porosity of gravel zone = 0.30
a. Depth of gravel below pipe (D_{GZ})	D_{GZ} = ____________ ft	Minimum depth below pipe = 6 in
b. Area of gravel below pipe (A_{GZ})	A_{GZ} = ____________ ft^2	Minimum width of gravel = 3 ft
4. Volume Reduction for bioretention ($Vol_{reduction}$)		
$Vol_{reduction} = (D_{PZ} \times A_{PZ} \times 0.25) + (D_{PM} \times A_{PM} \times 0.1) + (D_{GZ} \times A_{GX} \times 0.3)$	$V_{reduction}$ = ____________ ft^3	
Bioretention without Subsurface Drain Pipe		Recommended for A and B soils
1. Ponding Zone		
c. Depth of ponding zone (D_{PZ})	D_{PZ} = ____________ ft	
d. Area of ponding zone (A_{PZ})	A_{PZ} = ____________ ft^2	
2. Planting Media Layer		
c. Depth of planting media layer (D_{PM})	D_{PM} = ____________ ft	Minimum depth = 18 inches
d. Area of planting media layer (A_{PM})	A_{PM} = ____________ ft^2	
3. Volume Reduction for bioretention ($Vol_{reduction}$)		
$Vol_{reduction} = (D_{PZ} \times A_{PZ}) + (D_{PM} \times A_{PM} \times 0.10)$	$Vol_{reduction}$= ____________ ft^3	Available Water Holding Capacity of planting media layer = 0.1 x volume

Construction Considerations

- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the bioretention area to prevent high sediment loads from entering the area during ongoing construction activities.
- Avoid compaction of native soils below planting media layer or gravel zone.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City or County may require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Bioretention. Such agreements will typically include requirements such as those outlined in **Table 6-10**. The property owner or his/her designee is responsible for compliance with the agreement. Maintenance agreements and plans with shared controls or controls located on more than one property must address shared maintenance responsibilities. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-10. Inspection and Maintenance Requirements for Bioretention Areas

Activity	Schedule
Remulch void areas	As needed
Treat diseased trees and shrubs	As needed
Water plants daily for two weeks	At project completion
Inspect soil and repair eroded areas	Monthly
Remove litter and debris	Monthly
Remove and replace dead and diseased vegetation	Twice per year
Add additional mulch	Once per year
Replace tree stakes and wire	Once per year

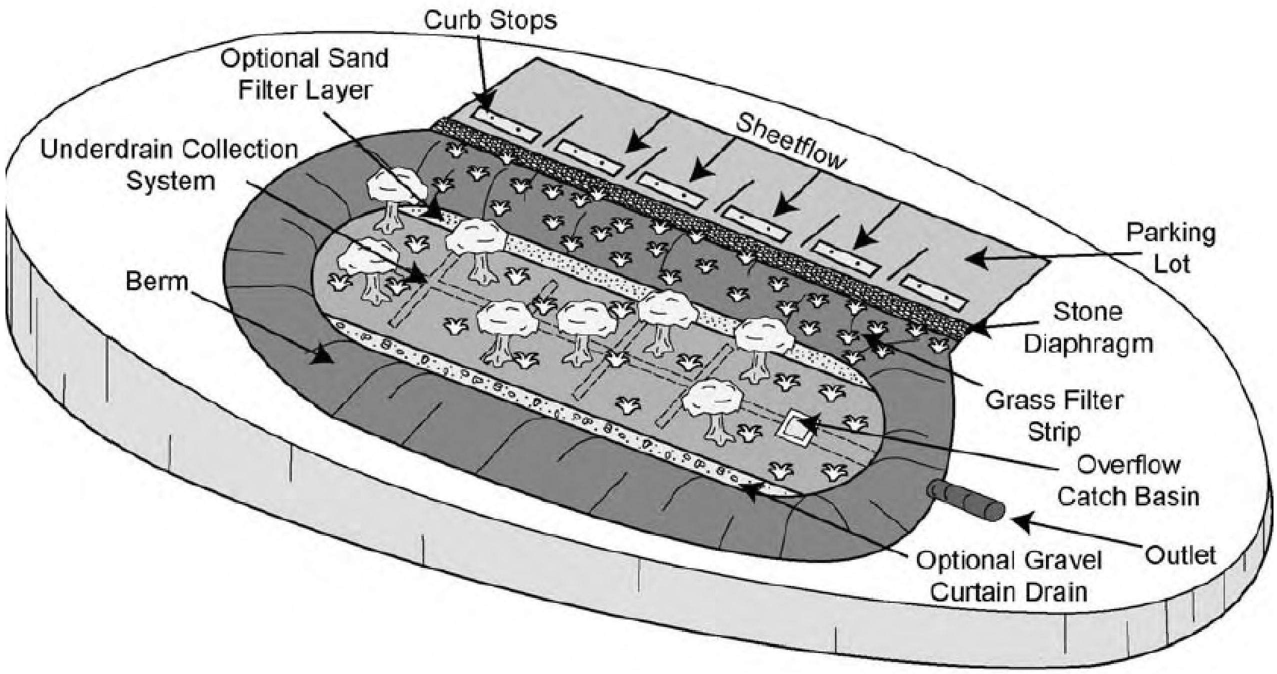


Figure 6-2a. Bioretention Schematic (Source: CWP, 2007)

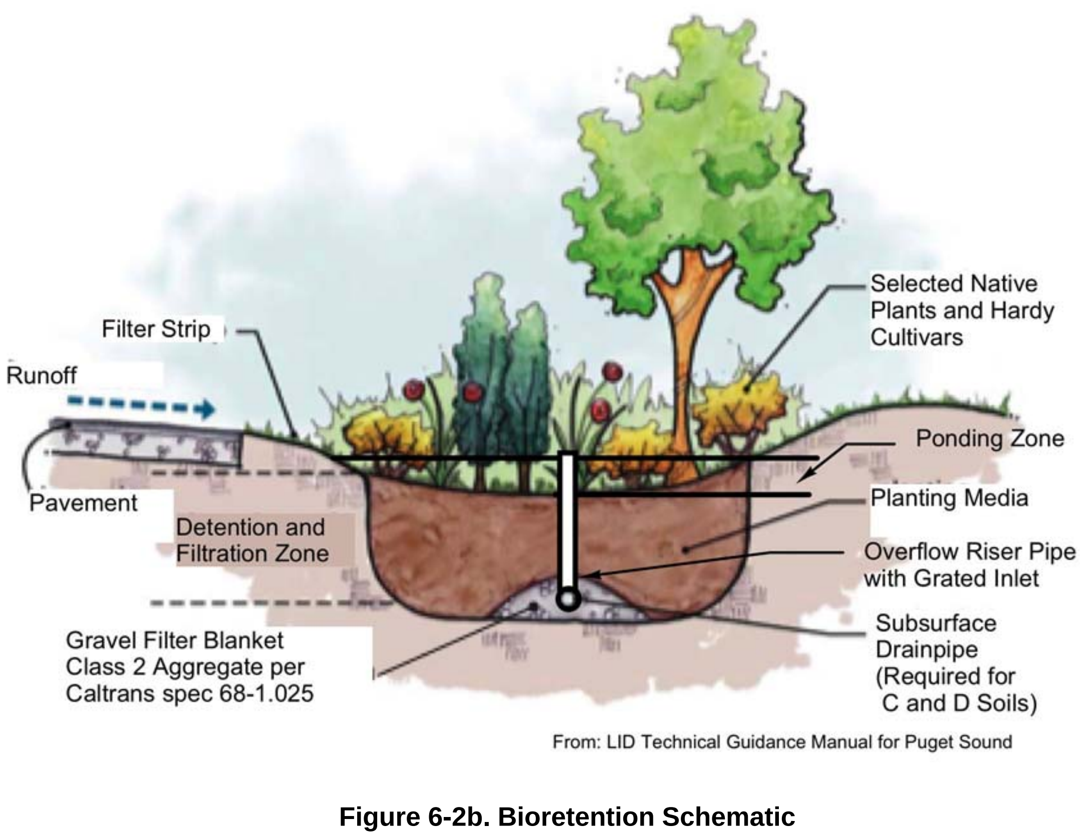


Figure 6-2b. Bioretention Schematic

Source: City of Emeryville, CA

Description

A Stormwater Planter is a vegetated in-ground or above ground planter box containing an engineered soil matrix consisting of layers of topsoil, a sand/peat mixture, and gravel that is designed to receive and capture runoff from downspouts or piped inlets or sheet flow from adjoining paved areas. A shallow surcharge zone is provided above the vegetated surface for temporary storage of the captured runoff. During rainfall events, runoff accumulates in the surcharge zone, gradually infiltrates the surface, and filters through the engineered soil matrix, filling the void spaces of the matrix before infiltrating the underlying soil or being collected by an underdrain system. Treatment of the runoff occurs through a variety of natural mechanisms as the runoff infiltrates through the root zone of the vegetation and during detention of the runoff in the underlying sand/peat bed. Stormwater Planters are typically planted with native, drought tolerant vegetation that does not require fertilization and can withstand wet soils for at least 24 hours, such as wildflowers, sedges, rushes, ferns, shrubs and small trees.

If Infiltration Stormwater Planters are used, the volume of runoff can be reduced through infiltration into underlying soils. For planters underlain with expansive soils or located next to buildings where infiltration of runoff is undesirable, the Flow-through Stormwater Planter with an impermeable bottom liner should be employed. This type of planter features an impermeable bottom liner to prevent infiltration and a perforated underdrain pipe to collect treated runoff. The underdrain gradually dewaters the sand/peat bed over the drawdown period and discharges the runoff to downstream conveyance. If infiltration of runoff is acceptable or desired, the Infiltration Stormwater Planter should be used. If underlying soils are rapidly permeable with permeability greater than the sand/peat layer (typically types A or B soils), the planter can be installed without an underdrain pipe, in which case the SQDV will infiltrate into the underlying soil profile. If less permeable underlying soils (types C or D) are present, an underdrain is required, but a portion of the infiltrated runoff will infiltrate into the underlying soil. See **Figures 6-3** and **6-4** for typical Stormwater Planter configurations.

> Stormwater planters are similar in most respects to bioretention areas (see L-1), but differ in the design feature of structural side walls (typically concrete).

Other Names: Bioretention, Infiltration Planter, Flow-through Planter, Biofilter, Porous Landscape Detention, Rain Garden

Advantages

- Relatively inexpensive when integrated into site landscaping.

- Suitable for parking lots and sites with limited open area available for stormwater detention.
- Reduces peak flows during small storm events.
- Enhances site aesthetics.
- Easy maintenance.

Limitations

- Irrigation typically required to maintain vegetation. May conflict with water conservation ordinances or landscape requirements.
- Not appropriate for industrial sites or locations where spills may occur unless infiltration is prevented.
- Not suitable for steeply sloping areas.
- Potential increased cost associated with water proofing of exterior building walls, if needed

Planning and Siting Considerations

- Select location where site topography is relatively flat and allows runoff drainage to the Stormwater Planter.
- Integrate Stormwater Planters into other landscape areas when possible.
- Stormwater Planters may have a non-rectangular footprint to fit the site landscape design.
- In expansive soils, locate Stormwater Planters far enough from structure foundations so as to avoid damage to structures (as determined by a structural or geotechnical engineer), or use a Flow-through Stormwater Planter.

Design Criteria

Design criteria for Stormwater Planters are listed in **Table 6-11**.

Table 6-11. Stormwater Planter Design Criteria

Design Parameter	Criteria	Notes
Drainage area	≤ 1 acre	Ideally suited for small areas such as parking lot islands, perimeter building planters, street medians, roadside swale features, and site entrance or buffer features. Can be implemented on a larger scale,.
Design volume	SQDV	See Fact Sheet T-0
Design drawdown time	12 hrs	Period of time over which SQDV drains from planter.
Design average surcharge depth (d_s)	6-12 in.	
Depth to groundwater	> 10 ft	From planter soil surface (without underdrain)
Topsoil layer	6 in. (minimum)	Sandy loam topsoil. Deeper layer recommended for better vegetation establishment. Note: planting media specified for Bioretention (L-1) may be used as an alternate for the topsoil and sand and peat layers.
Sand-peat layer	18 in. (minimum)	75% ASTM C-33 Sand + 25% peat
Gravel layer	9 in.	Class 2 Aggregate per Caltrans Spec 68-1.025

Design Procedure

Step 1 – Calculate Water Quality Volume (SQDV)

Using **Fact Sheet T-0**, determine the contributing area and stormwater quality design volume, SQDV, based on a 12-hour drawdown period.

Step 2 – Design average ponding zone depth (D_{PZ})

Select the average SQDV depth between six (6) and twelve (12) inches. Average depth is defined as water volume divided by the water surface area of the planter.

Step 3 – Calculate planter surface area (A_S)

The design surface area of the planter is determined from the design SQDV and d_s as follows:

$A_S = SQDV/D_{PZ}$

Step 4 – Design base courses

Topsoil layer – Provide a sandy loam topsoil layer above the sand-peat mix layer. This layer should be a minimum of six (6) inches deep, but a deeper layer is recommended to promote healthy vegetation.

Sand/Peat layer – Provide an 18-inch (minimum) sand and peat layer over a 9-inch gravel layer as shown in **Figures 6-3** and **6-4**. Thoroughly mix 75% sand (ASTM C-33) with 25% peat for filtration and adsorption of contaminants. Note: The planting media mix specified for bioretention (Fact Sheet L-1) may be used as an alternate to the top soil and sand/peat mix.

Gravel envelope (for subsurface drain pipe) – Place drainpipe on a 3- ft wide, 3-inch deep bed of gravel (Class 2 Permeable Material per Caltrans Spec 68-1.025). Cover top and sides of pipe with gravel to a minimum depth of 6 inches. Place a strip of non-woven filter fabric on top of gravel layer that extends 18 inches on either side of the drainpipe. Do not wrap drainpipe or gravel envelop with filter fabric to prevent potential clogging.

Step 5 – Select sub base liner

If expansive soils or rocks are a concern, chemical or petroleum products are handled or stored within the tributary catchment, or infiltration is not desired for any reason, use a Flow-through Stormwater Planter with an impermeable liner (see **Figure 6-4**).

Step 6 – Design subsurface drainpipe (if required)

If C or D soils are present or impermeable liner is used, provide subsurface drainpipe with diameter sized for required hydraulic capacity (4-in minimum). Use heavy-walled, slotted PVC pipe (ASTM D1785 SCD 40) to allow pressure water cleaning and root cutting, if necessary. Connect subsurface drainpipe to downstream open conveyance (e.g. swale) or to the storm drain system.

Step 7 – Select vegetation

Select vegetation that:

- Is suited to well-drained soil;
- Will be dense and strong enough to stay upright, even in flowing water;
- Has minimum need for fertilizers;
- Is not prone to pests and is consistent with IPM practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

Avoid the use of bark or similar buoyant material that will tend to float when the vegetated area is inundated.

Step 8 – Design overflow device

Provide an overflow device with an inlet to storm drainage system. Set the overflow inlet elevation above the SQDV surcharge water level. A drop inlet or an overflow standpipe with an inverted or grated opening are appropriate overflow devices (see Figures 6-3 and 6-4).

Volume Reduction Calculation

Stormwater Planters may be used to achieve the Volume Reduction Requirements in addition to treatment control requirements. The volume reduction for a stormwater planter is less if subsurface drainpipe is provided, because less infiltration will occur. The calculation procedure for volume reduction for stormwater planter is presented in **Table 6-12**.

Table 6-12. Stormwater Planter Volume Reduction Calculation

Stormwater Planter with Subsurface Drain Pipe		Required for C and D soils and impermeable liners
1. Ponding Zone		Infiltration allowance for water in ponding zone water = 0.25
a. Depth of ponding zone (D_{PZ})	D_{PZ} = ________ ft	
b. Area of ponding zone (A_{PZ})	A_{PZ} = ________ ft^2	
2. Planting Media Layer		Available Water Holding Capacity of planting media layer = 0.1 x volume
a. Depth of planting media layer (D_{PM})	D_{PM} = ________ ft	
b. Area of planting media layer (A_{PM})	A_{PM} = ________ ft^2	
3. Gravel Zone		Porosity of gravel zone = 0.30
a. Depth of gravel below pipe (D_{GZ})	D_{GZ} = ________ ft	Minimum depth below pipe = 6 in
b. Area of gravel below pipe (A_{GZ})	A_{GZ} = ________ ft^2	Minimum width of gravel = 3 ft
4. Volume Reduction for planters ($Vol_{reduction}$)		For planters with impermeable liners, volume reduction credit is only given for retention in the planting media layer:
$Vol_{reduction} = (D_{PZ} \times A_{PZ} \times 0.25) + (D_{PM} \times A_{PM} \times 0.1) + (D_{GZ} \times A_{GX} \times 0.3)$	$Vol_{reduction}$ = ________ ft^3	$Vol_{reduction} = (D_{PM} \times A_{PM} \times 0.1)$
Stormwater Planter without Subsurface Drain Pipe		Recommended for A and B soils
1. Ponding Zone		Infiltration allowance for water in ponding zone water = 1.0
a. Depth of ponding zone (D_{PZ})	D_{PZ} = ________ ft	
b. Area of ponding zone (A_{PZ})	A_{PZ} = ________ ft^2	
2. Planting Media Layer		
a. Depth of planting media layer (D_{PM})	D_{PM} = ________ ft	Minimum depth = 18 inches
b. Area of planting media layer (A_{PM})	A_{PM} = ________ ft^2	
3. Volume Reduction for planters ($Vol_{reduction}$)		Available Water Holding Capacity of planting media layer = 0.1 x volume
$Vol_{reduction} = (D_{PZ} \times A_{PZ}) + (D_{PM} \times A_{PM} \times 0.10)$	$Vol_{reduction}$= ________ ft^3	

Construction Considerations

- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the planter to prevent high sediment loads from entering the planter during ongoing construction activities.
- Avoid compaction of native soils below planting media layer or gravel zone for infiltration planter.
- Repair, seed, or re-plant damaged areas immediately.
- For planters next to buildings, provide water proofing of exterior building walls as directed by architect or structural engineer.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Stormwater Planters. Such agreements will typically include requirements such as those outlined in **Table 6-13**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-13. Inspection and Maintenance Requirements for Stormwater Planters

Activity	Schedule
Trim vegetation (as applicable) and remove weeds to limit unwanted vegetation	As required
Remove litter and debris from landscape area	As required
Use integrated pest management (IPM) techniques	As required
Inspect the planter to determine if runoff is infiltrating properly	At least twice per year during storm events. Additional inspections after periods of heavy runoff are desirable.
If infiltration is significantly reduced, remove and replace topsoil and sand/peat layer	May be required every 5 to 10 years or more frequently, depending on sediment loads

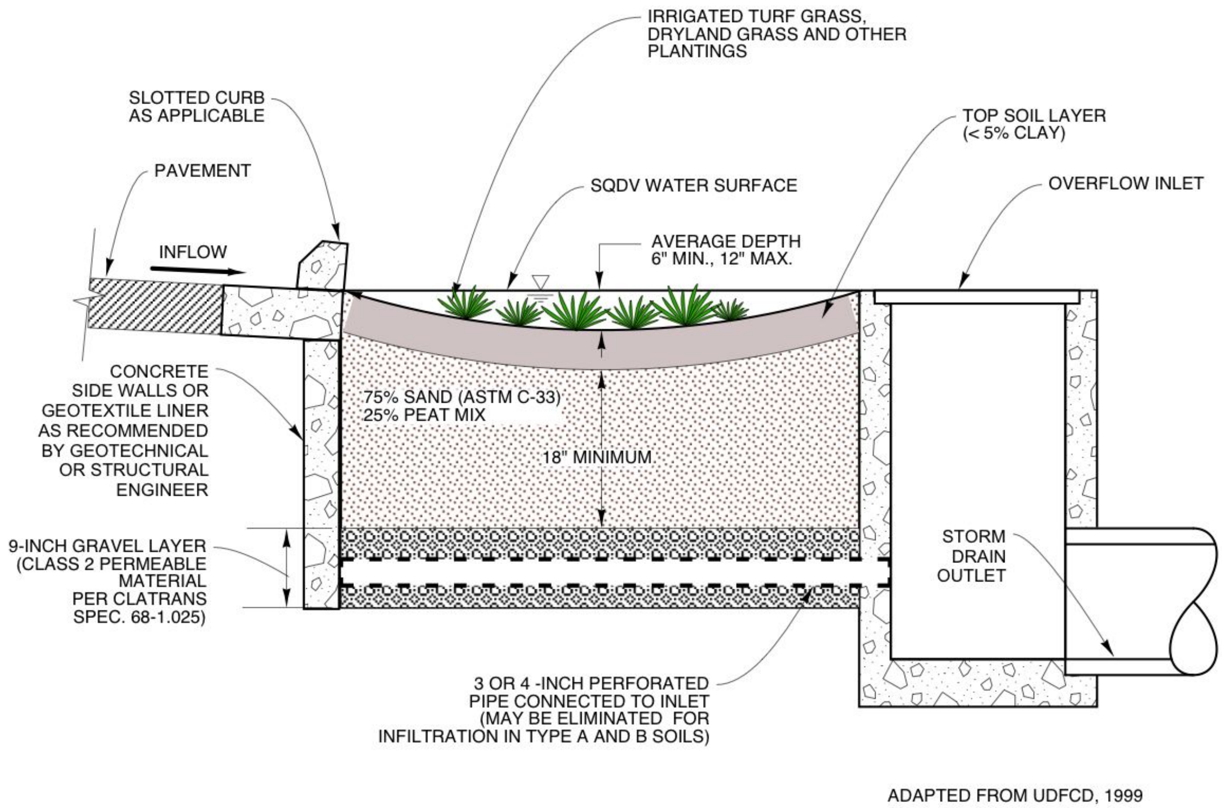


Figure 6-3. Infiltration Stormwater Planter Configuration

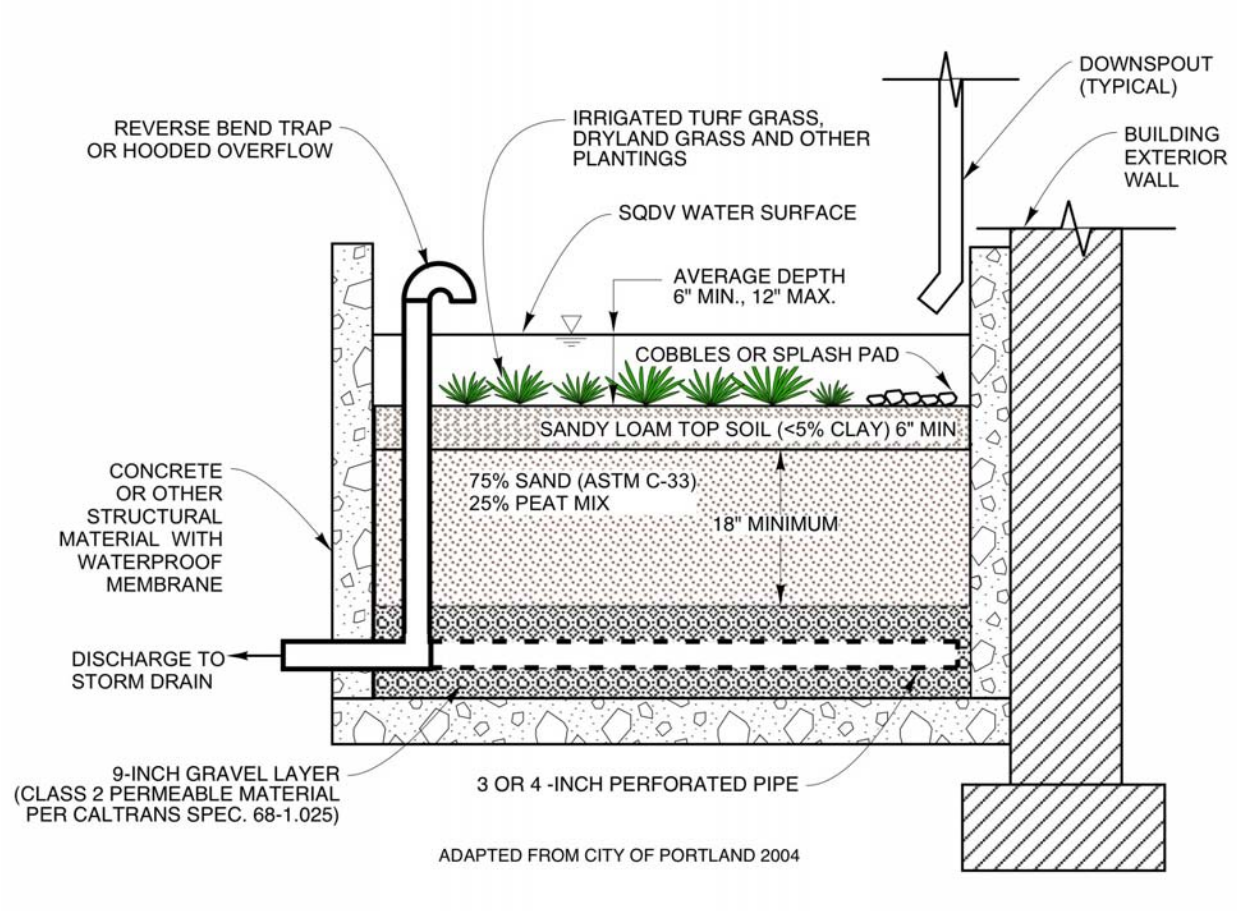


Figure 6-4. Flow-through Stormwater Planter Configuration

Source: Low Impact Development Center (top) and University of New Hampshire Stormwater Center (bottom)

Description

A Tree-well Filter is similar to the Bioretention (L-1) and Stormwater Planters (L-2) and consists of one or multiple chambered pre-cast concrete boxes with a small tree or shrub planted in a bed filled with engineered soil media. A Tree-well Filter is installed along the edge of a parking lot or roadway, where street tree might normally be installed, and is designed to receive, retain, and infiltrate rainwater runoff from adjoining paved areas. During stormwater events, runoff flows into the chamber and gradually infiltrates the surface and filters through the engineered soil matrix, filling the void spaces of the matrix before infiltrating the underlying soil or being collected by an underdrain system. Treatment of the runoff occurs through a variety of natural mechanisms as the runoff filters through the root zone of the vegetation and during detention of the runoff in the pore space of the engineered soil matrix. A portion of the water held in the root zone of the soil media is returned to the atmosphere through transpiration by the vegetation.

A Tree-well Filter may be installed in open or closed bottom chambers. If underlying soils are rapidly permeable with permeability greater than the engineered soil layers (typically types A or B soils), the Tree-well Filter can be constructed with an open bottom with an underdrain pipe. If less permeable underlying soils (types C or D) are present an underdrain pipe is required. If infiltration must be avoided due to site constraints, an impermeable liner or concrete bottom should be provided as well as an underdrain pipe.

Other Names: Stormwater Tree Pit, Tree Box Filter

Advantages

- Enhances site aesthetics.
- Integrates well with street landscapes.
- Takes up very little space, may be ideal for highly developed sites.
- Adaptable, may be used in a variety of site conditions.
- Reduces stormwater volume and pollutant discharge.

Disadvantages

- May require individual owners/tenants to perform maintenance.
- Irrigation typically required to maintain vegetation. May conflict with water conservation ordinances for landscape requirements.
- Not appropriate for industrial sites or locations where spills may occur unless infiltration is prevented.

Planning and Siting Considerations

- Select location where site topography is relatively flat and allows runoff drainage to the Tree-well Filter.
- Integrate Tree-well Filters into other landscape areas when possible.
- Tree-well Filters may have a non-rectangular footprint to fit the site landscape design.
- Connect underdrain into storm drain system.

Design Criteria

Design criteria for Tree-well Filters are listed in **Table 6-14**. A Design Data Summary Sheet is provided at the end of this fact sheet.

Table 6-14. Tree-well Filter Design Criteria

Design Parameter	Criteria	Notes
Drainage area	≤ 1 acre	Ideally suited for small areas such as parking lot islands, perimeter building planters, street medians, roadside swale features, and site entrance or buffer features.
Design volume	SQDV	See Fact Sheet T-0
Design drawdown time	12 hrs	Period of time over which SQDV drains from tree well.
Design average ponding depth (d_s)	6-12 in.	
Depth to groundwater	> 10 ft	From tree-well soil surface (without underdrain)
Topsoil layer	6 in. (minimum)	Sandy loam topsoil. Deeper layer recommended for better vegetation establishment
Sand-peat layer	18 in. (minimum)	75% ASTM C-33 Sand + 25% peat. Note: planting media specified for Bioretention (L-1) may be used as an alternate for the topsoil and sand and peat layers.
Gravel layer	9 in.	Class 2 Aggregate per Caltrans Spec 68-1.025

Design Procedure

Step 1 – Calculate Water Quality Volume (SQDV)

Using **Fact Sheet T-0**, determine the contributing area and stormwater quality design volume, SQDV, based on a 12-hour drawdown period.

Step 2 – Design average surcharge depth (d_s)

Select the average SQDV depth between six (6) and twelve (12) inches. Average depth is defined as water volume divided by the water surface area of the planter.

Step 3 – Calculate tree-well filter surface area (A_S)

The design surface area of the planter is determined from the design SQDV and d_s as follows:

$$A_S = SQDV/d_s$$

Step 4 – Design base courses

Sand/Peat layer – Provide an 24-inch (minimum) sand and peat layer over a 9-inch gravel layer as shown in **Figures 6-5**. Thoroughly mix 75% sand (ASTM C-33) with 25% peat for filtration and adsorption of contaminants. Note: The planting media mix specified for bioretention (Fact Sheet L-1) may be used as an alternate to the top soil and sand/peat mix.

Gravel envelope (for subsurface drain pipe) – Place drainpipe on a 3- ft wide, 3-inch deep bed of gravel (Class 2 Permeable Material per Caltrans Spec 68-1.025). Cover top and sides of pipe with gravel to a minimum depth of 6 inches. Place a strip of non-woven filter fabric on top of gravel layer that extends 18 inches on either side of the drainpipe. Do not wrap drainpipe or gravel envelop with filter fabric to prevent potential clogging.

Step 5 – Select subbase liner

If expansive soils or rocks are a concern, chemical or petroleum products are handled or stored within the tributary catchment, or infiltration is not desired for any reason, use a Tree-well Filter with an impermeable liner.

Step 6 – Design subsurface drainpipe (if required)

If C or D soils are present or an impermeable liner is used, provide subsurface drainpipe with diameter sized for required hydraulic capacity (4-in minimum). Use heavy-walled, slotted PVC pipe (ASTM D1785 SCD 40) to allow pressure water cleaning and root cutting, if necessary. Connect subsurface drainpipe to downstream open conveyance (e.g. swale) or to the storm drain system.

Step 7 – Select tree

Select tree that:

- Is suited to well-drained soil;
- Will be dense and strong enough to stay upright, even in flowing water;
- Has minimum need for fertilizers;
- Is not prone to pests and is consistent with IPM practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

Avoid the use of bark or similar buoyant material that will tend to float when the vegetated area is inundated.

Step 8 – Design overflow device

Provide an overflow device with an inlet to storm drainage system. Set the overflow inlet elevation above the SQDV surcharge water level. A drop inlet or an overflow standpipe with an inverted or grated opening are appropriate overflow devices (see **Figure 6-5**).

Volume Reduction Calculation

Tree-well Filters may be used to achieve the Volume Reduction Requirements in addition to treatment control requirements. The volume reduction for a tree-well filter is less if an impermeable bottom is used, because less infiltration will occur. The calculation procedure for volume reduction for Tree-well Filter is presented in **Table 6-15.**

Table 6-15. Tree-well Filter Volume Reduction Calculation

Design Parameter	Criteria	Notes
Tree-well Filter with Subsurface Drain Pipe		Required for C and D soils and impermeable bottoms
1. Ponding Zone		Infiltration allowance for water in ponding zone water = 0.25
a. Depth of ponding zone (D_{PZ})	D_{PZ} = ____________ ft	
b. Area of ponding zone (A_{PZ})	A_{PZ} = ____________ ft^2	
2. Planting Media Layer		Available Water Holding Capacity of planting media layer = 0.1 x volume
a. Depth of planting media layer (D_{PM})	D_{PM} = ____________ ft	
b. Area of planting media layer (A_{PM})	A_{PM} = ____________ ft^2	
3. Gravel Zone		Porosity of gravel zone = 0.30
a. Depth of gravel below pipe (D_{GZ})	D_{GZ} = ____________ ft	Minimum depth below pipe = 6 in
b. Area of gravel below pipe (A_{GZ})	A_{GZ} = ____________ ft^2	Minimum width of gravel = 3 ft
4. Volume Reduction for tree wells ($Vol_{reduction}$) $Vol_{reduction} = (D_{PZ} \times A_{PZ} \times 0.25) + (D_{PM} \times A_{PM} \times 0.1) + (D_{GZ} \times A_{GX} \times 0.3)$	$Vol_{reduction}$ = ____________ ft^3	For tree wells with impermeable liners, volume reduction credit is only given for retention in the planting media layer: $Vol_{reduction} = (D_{PM} \times A_{PM} \times 0.1)$
Tree Well Filters without Subsurface Drain Pipe		Recommended for A and B soils
1. Ponding Zone		Infiltration allowance for water in ponding zone water = 1.0
a. Depth of ponding zone (D_{PZ})	D_{PZ} = ____________ ft	
b. Area of ponding zone (A_{PZ})	A_{PZ} = ____________ ft^2	
2. Planting Media Layer		
a. Depth of planting media layer (D_{PM})	D_{PM} = ____________ ft	Minimum depth = 18 inches
b. Area of planting media layer (A_{PM})	A_{PM} = ____________ ft^2	
3. Volume Reduction for tree wells ($Vol_{reduction}$) $Vol_{reduction} = (D_{PZ} \times A_{PZ}) + (D_{PM} \times A_{PM} \times 0.10)$	$Vol_{reduction}$= ____________ ft^3	Available Water Holding Capacity of planting media layer = 0.1 x volume

Construction Considerations

- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the tree-well to prevent high sediment loads from entering the planter during ongoing construction activities.
- Avoid compaction of native soils below planting media layer or gravel zone.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Tree-well Filters. Such agreements will typically include requirements such as those outlined in **Table 6-16**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-16. Inspection and Maintenance Requirements for Tree-well Filters

Activity	Schedule
Trim vegetation (as applicable) and remove weeds to limit unwanted vegetation	As required
Remove litter and debris from landscape area	As required
Use integrated pest management (IPM) techniques	As required
Inspect the planter to determine if runoff is infiltrating properly	At least twice per year during storm events. Additional inspections after periods of heavy runoff are desirable.
If infiltration is significantly reduced, remove and replace topsoil and sand/peat layer	May be required every 5 to 10 years or more frequently, depending on sediment loads

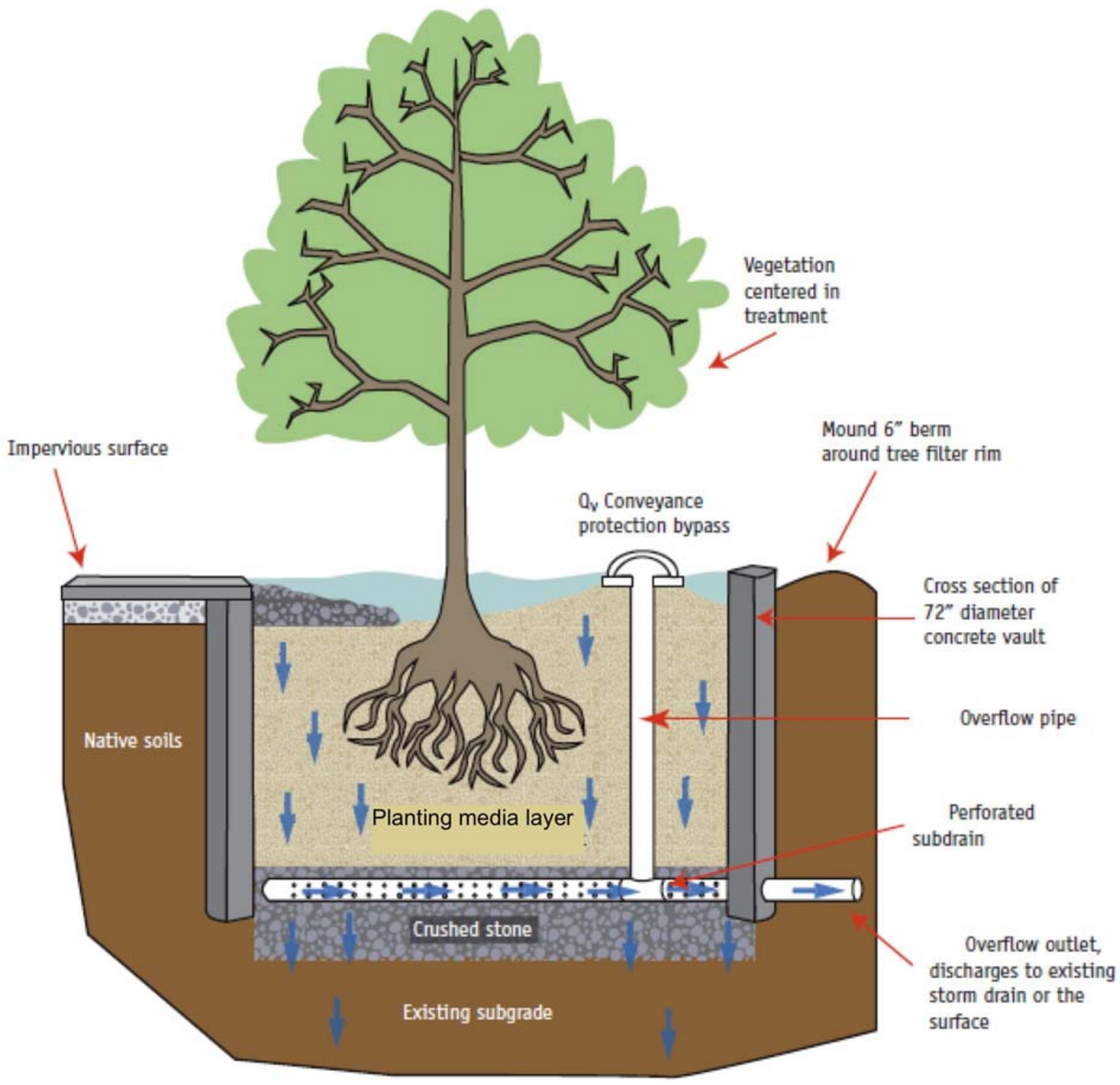


Figure 6-5. Tree-well Filter Schematic (Source: University of New Hampshire, Stormwater Center)

Source: Washington County, MD

Description

An Infiltration Basin is a shallow earthen basin constructed in naturally pervious soils (type A or B) designed for infiltrating stormwater. An Infiltration Basin functions by retaining the SQDV and allowing the retained runoff to percolate into the underlying native soils and into the groundwater table over a specified period of time. The bottoms of the basins are typically vegetated with dry-land grasses or irrigated turf grass. Treatment of the runoff occurs through a variety of natural mechanisms as the water flows through the soil profile. To ensure adequate treatment, the depth of unsaturated soil between the Infiltration Basin bottom and the seasonal maximum groundwater surface level should be a minimum of 10 feet. A typical layout of an Infiltration Basin is shown in **Figure 6-6.**

Other Names: Percolation Basin

Advantages

- Reduces or eliminates stormwater discharge to surface waters during most storm events.
- Reduces peak flows during small storm events.
- Can be incorporated into site landscape features or multi-use facilities, such as parks or athletic fields.

Limitations

- Not appropriate for areas with slowly permeable soils or high groundwater.
- Not appropriate for industrial sites or locations where spills may occur.
- Must be protected from high sediment loads. Once clogged with sediment, restoration of basin infiltration capacity may be difficult.
- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the basin is properly designed, constructed, and operated to maintain its infiltration capacity.
- Not appropriate on fill or steep slopes.

Planning and Siting Considerations

- Soil permeability, depth to groundwater, and design safety factors should be determined by a qualified geotechnical engineer or geologist to ensure that conditions conform to the criteria listed in **Table 6-17.**
- Integrate Infiltration Basins into open space buffers, undisturbed natural areas, and other landscape areas when possible.
- Irrigation may be required to maintain viability of vegetation on the slopes and bottom of the basin if vegetation is included in the design. Coordinate design of the general landscape irrigation system with that of the basin, as applicable.
- Plan for setback requirements (see **Table 6-17**).

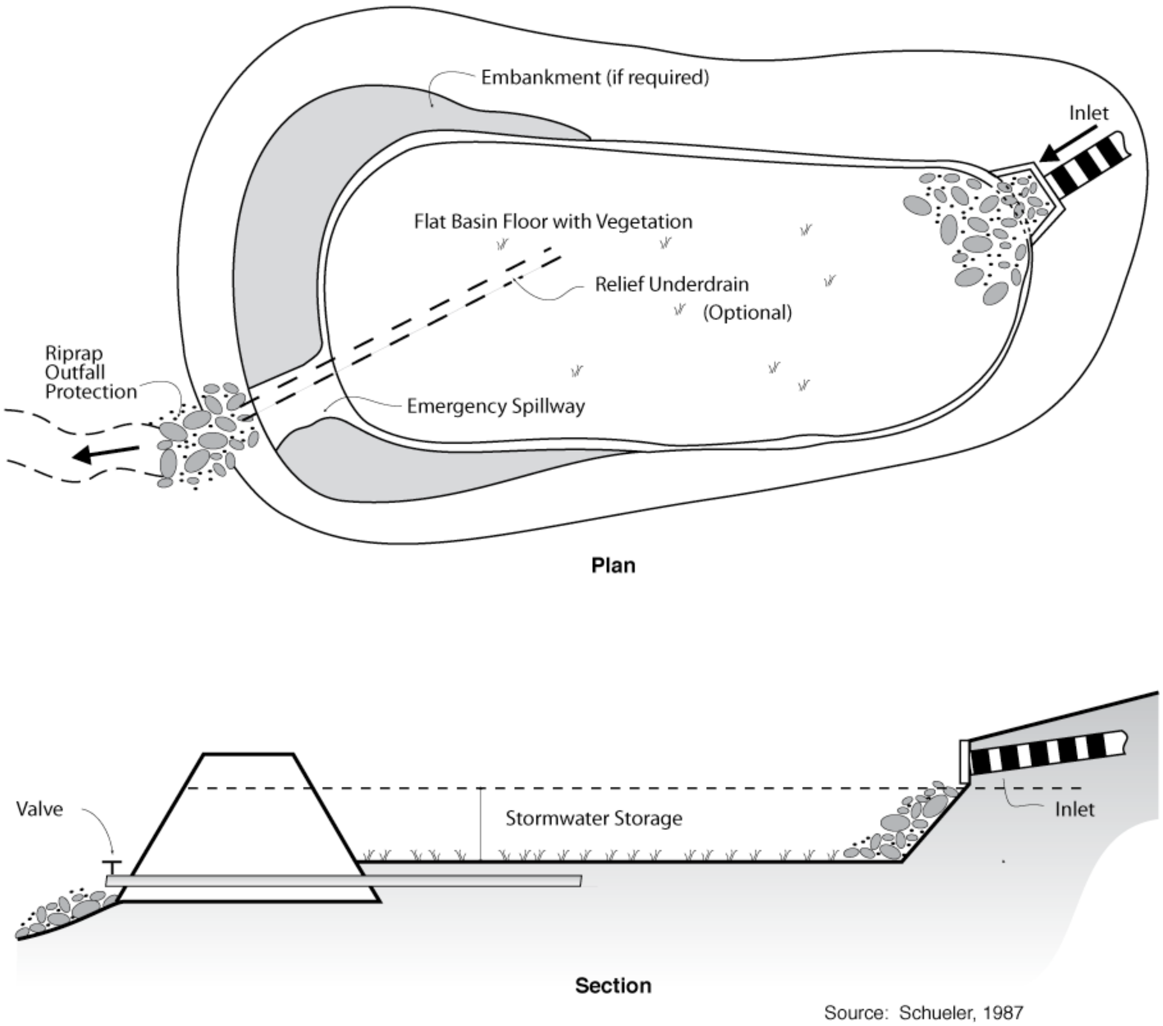


Figure 6-6. Infiltration Basin

Design Criteria and Procedure

Principal design criteria for infiltration basins are listed in **Table 6-17**.

Table 6-17. Infiltration Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	48
SQDV	ac-ft	80% annual capture. Use Figure 6-1 @ 48-hr drawdown
Soil permeability range	in./hr	0.6 - 2 (Saturated vertical permeability)
Bottom Basin Elevation	ft	10 ft above seasonally high groundwater table minimum.
Freeboard (minimum)	ft	1.0
Setbacks	ft	100 ft from wells, tanks, fields, springs
	ft	20 ft down slope or 100 ft up slope from foundations
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Embankment side slope (H:V)	–	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete
Vegetation	–	Side slopes and bottom (may require irrigation during summer)

Design Procedure

Step 1- Calculate Water Quality Volume (SQDV)

Using the *Fact Sheet T-0*, determine the tributary drainage area and stormwater quality design volume (SQDV) for 48-hour drawdown.

Step 2– Calculate design maximum depth of water surcharge in Infiltration Basin (D_{max})

$$D_{max} = \frac{t_{max} \times I}{12 \times s}$$

where

t_{max} = Maximum drawdown time = 48 hrs

I = Site infiltration rate (soil permeability) (in/hr)

s = Safety factor

In the formula for maximum allowable depth, the safety factor accounts for the possibility of inaccuracy in the infiltration rate measurement. The less certain the infiltration rate the larger the safety factor should be. Safety factors typically range between two (2) and ten (10) and should be determined by a qualified geotechnical engineer or geologist based on field measurements of saturated vertical permeability at the proposed site. Note that soils with permeability greater than two (2) inches per hour may be used if full pretreatment is provided using one of the approved treatment controls from the 2009 SWQCCP.

Step 3- Calculate minimum surface area of Infiltration Basin bottom (A_{min})

A_{min} = SQDV/D_{max}

where

A_{min} = minimum area required (ft^2)

D_{max} = maximum allowable depth (ft)

Step 4 – Design forebay settling basin

The forebay provides a zone for removal of course sediment by sedimentation. The volume of the forebay should be five (5) to ten (10) percent of the SQDV. The forebay should be separated from the basin by a berm or similar feature. An outlet pipe connecting the bottom of the forebay and the basin should be provided and sized to allow the forebay volume to drain within 45 minutes.

Step 5 – Design embankments

Interior slopes (H:V) should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.

Step 6 – Design Maintenance Access

Provide for all-weather access for maintenance vehicles to the bottom and outlet works. Maximum grades of access ramps should be ten (10) percent and minimum width should be ten (10) feet. Ramps should be paved with concrete colored to blend with surroundings.

Step 7 – Design Security Fencing

Provide aesthetic security fencing around the Infiltration Basin to protect habitat except when specifically waived by the City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division. Fencing design shall be approved by the City or County.

Step 8 – Design Bypass

Provide for bypass or overflow of runoff volumes in excess of the SQDV. Provide spillway or overflow structures, as applicable (see **Figure 6-6**).

Step 9 – Design Relief Drain

Provide 4-inch diameter perforated plastic relief underdrain with a valved outlet to allow removal of standing water in the event of loss of soil infiltration capacity.

Step 10 – Select Vegetation

Plant basin bottoms, berms, and side slopes with native grasses or with irrigated turf. Vegetation provides erosion protection and sediment entrapment.

Step 11 – Design irrigation system

Provide an irrigation system to maintain viability of vegetation, if applicable.

Volume Reduction Calculation

Infiltration Basins may be used to achieve Volume Reduction Requirements in addition to treatment control requirements. The volume reduction allowed for L-4 Infiltration Basins is equal to the SQDV for the infiltration basin calculated in Step 1 of the design procedure.

Construction Considerations

- If possible, stabilize the entire tributary area to the Infiltration Basin before construction begins. If this is not possible, divert flow around the basin to protect it from sediment loads during construction or remove the top two inches of soil from the basin floor after the entire site has been stabilized.
- Once construction is complete, stabilize entire tributary area to the basin before allowing runoff to enter infiltration facility.
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment.
- Construct basin using equipment with extra wide, low-pressure tires. Prevent construction traffic from entering basin to avoid compaction of surface.
- Final grading shall produce a level basin bottom without low spots or depressions.
- After final grading, deep till the basin bottom.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City or County requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Infiltration Basins. Such agreements will typically include requirements such as those outlined in **Table 6-18**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-18. Inspection and Maintenance Requirements for Infiltration Basins

Activity	Schedule
If erosion occurs within the basin, re-vegetate immediately and stabilize with erosion control mulch or mat until vegetation cover is established.	As required
Monitor infiltration rate in basin after storms by recording the drop in water depth versus time using a calibrated rod or staff gauge	Several times during first year following installation. During subsequent seasons, at the beginning and end of wet season. Additional monitoring after periods of heavy runoff is desirable.
If drawdown time is observed to have increased significantly over the design drawdown time, clean, re-grade, and till basin bottom to restore infiltrative capacity. This maintenance activity is expensive and the need for it can be minimized through prevention of upstream erosion.	As required
Trim vegetation to prevent the establishment of woody vegetation and for aesthetic and vector control reasons	At the beginning and end of the wet season
Monitor health of vegetation and replace	As required
Remove litter and debris from Infiltration Basin area	As required
Inspect basin to identify potential problems such as erosion of the basin side slopes and invert, standing water, trash and debris, and sediment accumulation	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
Remove accumulated sediment and re-grade when the accumulated sediment volume exceeds ten (10) percent of the basin volume. Note: scarification or other activities creating disturbance should only be performed when there are actual signs of clogging, rather than on a routine basis.	As required for both forebay and basin


Source: Washington County Maryland

Description

An Infiltration Trench or Vault is a narrow trench constructed in naturally pervious soils (Type A or B soils) and filled with gravel and sand, although use of manufactured percolation tank modules may be considered in place of gravel fill. Runoff is stored in the trench until it infiltrates into the soil profile over a specified drawdown period. Overflow drains are often provided to allow drainage if the Infiltration Trench becomes clogged. Infiltration Vaults and Infiltration Leach Fields are subsurface variations of the Infiltration Trench concept in which runoff is distributed to the upper zone of the subsurface gravel bed by means of perforated pipes.

An Infiltration Trench is designed to retain the stormwater quality volume in the trench and allow that volume to infiltrate into the native soil profile over the design drawdown period. Infiltrated water typically reaches the underlying groundwater. Treatment of the runoff occurs through a variety of natural mechanisms as the water flows through the trench media and the soil profile. To ensure adequate treatment and protect groundwater, the depth of unsaturated soil between the trench bottom and the maximum groundwater surface level should be a minimum of 10 feet.

A typical Infiltration Trench configuration is shown in **Figure 6-7**. Configurations for the Infiltration Vault and Infiltration Leach Field variations of the Infiltration Trench are shown in **Figures 6-8** and **6-9**, respectively. Note that Infiltration Trenches are not allowed in areas under the jurisdiction of the County of San Joaquin without specific written approval from the Environmental Health Department.

Other Names: Percolation trench, dispersal trench

Advantages

- Provides effective water quality enhancement through settling and filtering while requiring relatively small space.
- Can be placed below ground.
- Suitable for use when water is not available for irrigation or base flow.
- Suited for most soil conditions. The presence of permeable soils is not a requirement.
- Reduces peak flows during small storm events.

Limitations

- Potential for clogging of media. Upstream treatment controls to remove large sediment may be required to prevent or minimize media clogging. The cost of restorative maintenance can be high if the soil infiltration rates are significantly reduced due to sediment deposition.
- Not appropriate for areas with slowly permeable soils (C and D type) or high groundwater.

- Not appropriate for industrial sites or locations where spills may occur.

Planning and Siting Considerations

- Integrate Infiltration Trenches into open space buffers, undisturbed natural areas, and other landscape areas when possible
- Plan for setback requirements as listed in **Table 6-19**.
- Do not locate trenches under tree drip lines
- Pretreatment using grassy buffer strips is required to protect the trench from high sediment loads (see **Figure 6-7**).

Design Criteria

Design criteria for Infiltration Trenches are listed in **Table 6-19.**

Table 6-19. Infiltration Trench Design Criteria

Design Parameter	Criteria	Notes
Tributary Drainage Area	≤ 5 acres	
Design volume	SQDV	See *Fact Sheet T-0*
Maximum drawdown time for SQDV	48 hrs	Based on SQDV
Soil permeability range	0.6-2 in./hr	Saturated vertical permeability
Minimum groundwater separation	10 ft	Between trench bottom and seasonally high groundwater table
Maximum trench surcharge depth (D_{max})	10 ft	
Setbacks	100 ft	From wells, tanks, fields, springs
	20 ft	Downslope from foundations
	100 ft	Upslope from foundations
	–	Do not locate under tree drip-lines
Trench media material size/type	1-3 in.	Washed gravel
Trench lining material	–	Geotextile fabric (see **Table 6-20**) prevents clogging
Observation well size	4-6 in.	Perforated PVC pipe with removable cap
Pretreatment grassy buffer strip length/slope	10 ft/5%	Minimum length/maximum slope in flow direction

Table 6-20. Geotextile Fabric Specifications

Property	Test Method	Unit	Specification
Material			Nonwoven geotextile fabric
Unit Weight		oz/yd^3	8 (min.)
Filtration Rate		in/sec	0.08 (min.)
Puncture Strength	ASTM D-751 (Modified)	lbs	125 (min.)
Mullen Burst Strength	ASTM D-751	psi	400 (min.)
Tensile Strength	ASTM-D-1682	lbs	300 (min.)
Equiv. Opening Size	US Standard Sieve	No.	80 (min.)

Design Procedure

Step 1 – Calculate Water Quality Volume (SQDV)

Using the *Fact Sheet T-0* determine the tributary drainage area and stormwater quality design volume (SQDV) for 48-hour drawdown.

Step 2 – Calculate minimum surface area of Infiltration Trench bottom (A_{min})

$$Area_{min} = \frac{SQDV \times s \times 12}{t_{max} \times I}$$

where

t_{max} = Maximum drawdown time = 48 hrs

I = Site infiltration rate (soil permeability) (in/hr)

s = Safety factor

In the formula for minimum surface area, the safety factor accounts for the variability in soil permeability at the site and the relative uncertainty in the infiltration rate measurements. The more variable the soil conditions and the less certain the infiltration rate, the higher the safety factor should be. Safety factors typically range between two (2) and ten (10) and should be determined by a qualified geotechnical engineer or geologist based on field measurements of saturated vertical permeability at the proposed site. Note that soils with permeability greater than two (2) inches per hour may be used if full pretreatment is provided using one of the approved treatment controls from the 2009 SWQCCP.

Step 3 – Calculate design depth of water surcharge in Infiltration Trench (D_{max})

$$D_{max} = \frac{SQDV}{P \times Area_{min}}$$

where

P = Porosity of Infiltration Trench gravel material (use 0.30) (Note: use of manufactured percolation tank modules can provide greater porosity than gravel.)

A_{min} = minimum area required (ft^2)

Note: D_{max} should not exceed ten (10) feet. Increase A_{min} as necessary to keep $D_{max} \leq 10$ ft

Step 4 – Design Observation Well

Provide a vertical section of perforated PVC pipe, four (4) to six (6) inches in diameter, installed flush with the top of the Infiltration Trench on a footplate and with a locking, removable cap. The observation well is needed to monitor the infiltration rate in the Infiltration Trench and is useful for marking the location of the Infiltration Trench.

Step 5 – Design Bypass

Provide for bypass or overflow of runoff volumes in excess of the SQDV by means of a screened overflow pipe connected to downstream storm drainage or a grated overflow outlet.

Volume Reduction

Infiltration Trenches may be used to achieve the Volume Reduction Requirement in addition to treatment control requirements. The volume reduction allowed for L-5 Infiltration Trench is equal to the SQDV for the infiltration trench calculated in Step 1 of the design procedure.

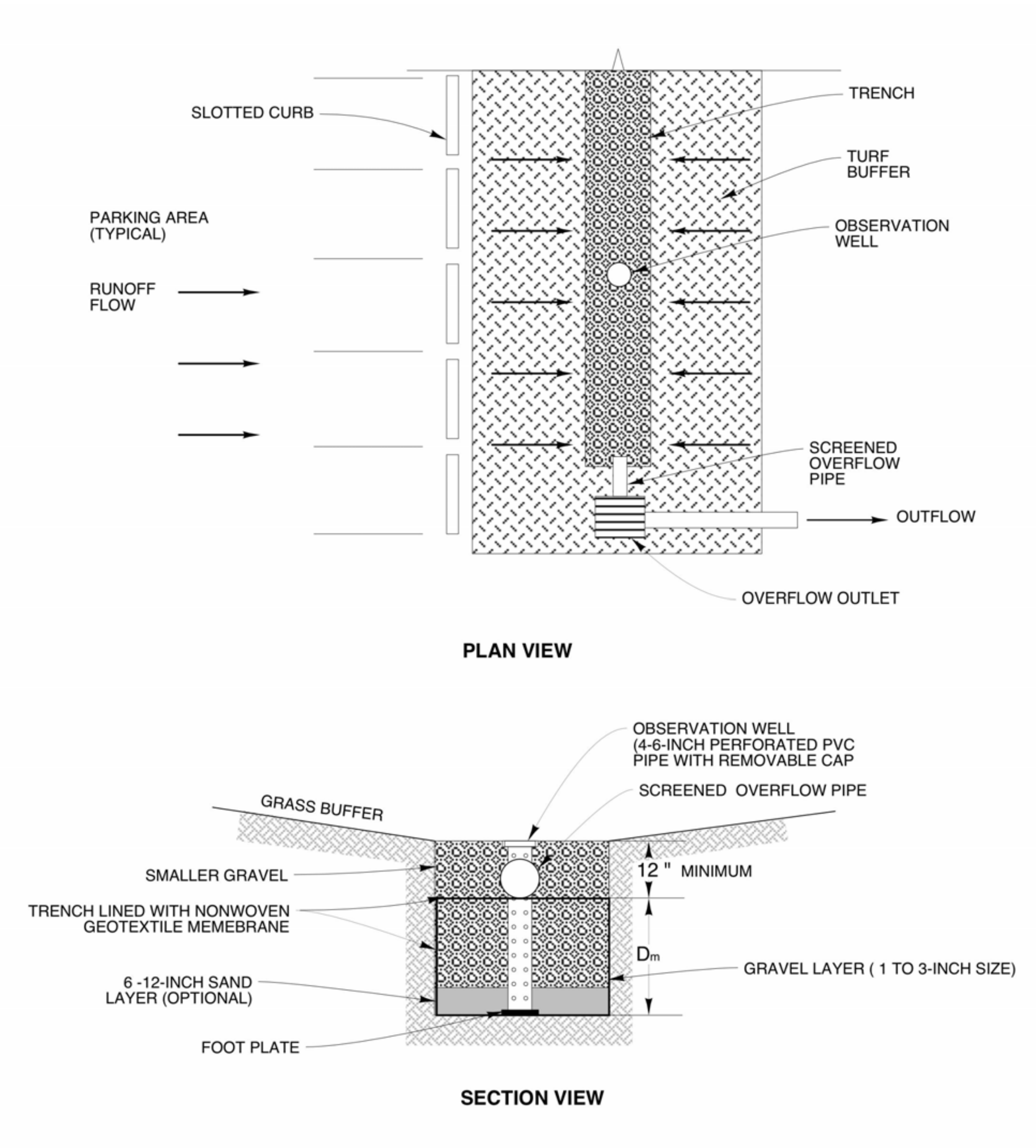


Figure 6-7. Infiltration Trench

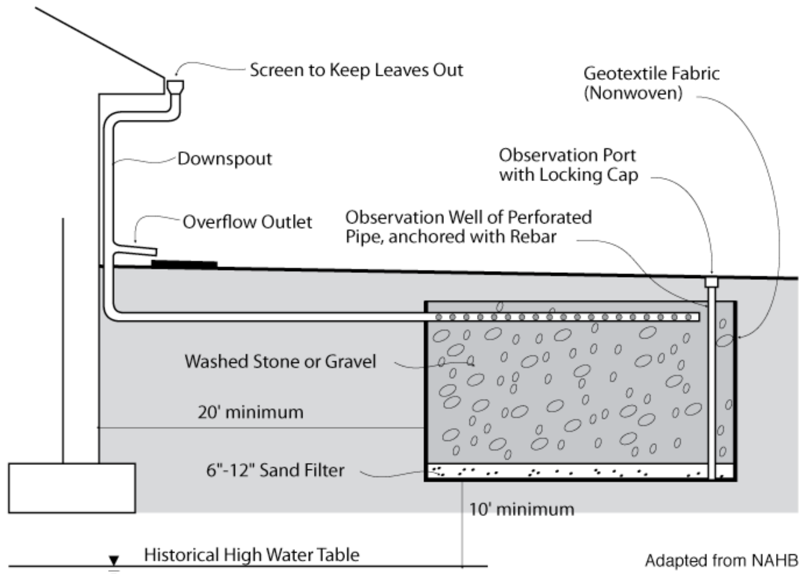


Figure 6-8. Infiltration Vault

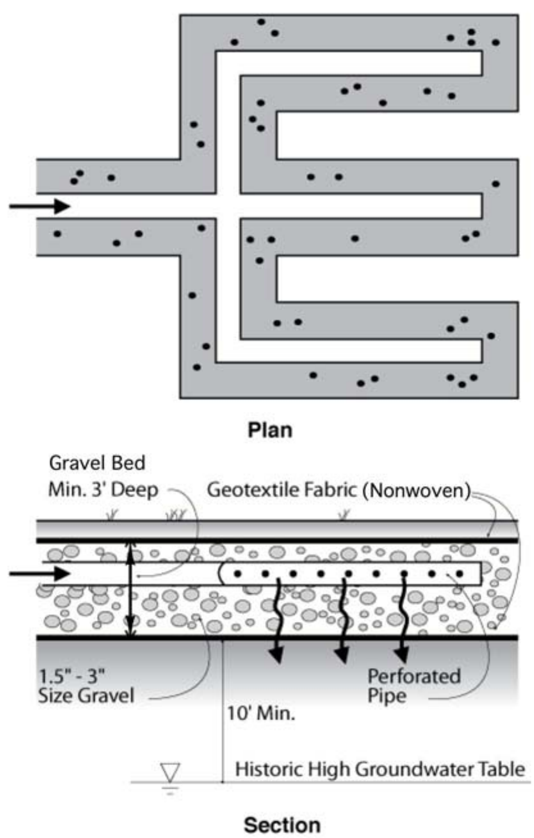


Figure 6-9. Leach Field

Construction Considerations

- If possible, stabilize the entire tributary area to the Infiltration Trench before construction begins. If this is not possible, divert flow around the trench site to protect it from sediment loads during construction.
- Once construction is complete, stabilize the entire tributary area to the trench before allowing runoff to enter the trench facility.
- Install filter fabric on sides, bottom, and one foot below the surface of the trench (see **Figure 6-7**). Provide generous overlap at all seams.
- Store excavated material at least 10 feet from the trench to avoid backsliding and cave-ins.
- Clean, washed gravel should be placed in the excavated trench in lifts and lightly compacted with plate compactor. Use of unwashed gravel can result in clogging.

Long-term Maintenance

The City or County requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Infiltration Trenches. Such agreements will typically include requirements such as those outlined in **Table 6-21**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-21. Inspection and Maintenance Requirements for Infiltration Trenches

Activity	Schedule
If erosion is occurring within the tributary area, re-vegetate immediately and stabilize with erosion control mulch or mat until vegetation cover is established	As required
Monitor the infiltration rate in trench during and after storms by recording the drop in water depth versus time using a calibrated rod or staff gauge.	Several times during first year following installation. During subsequent seasons, near the beginning and end of wet season. Additional monitoring after periods of heavy runoff is desirable.
Clean trench when loss of infiltrative capacity is observed. If infiltration rate is observed to have decreased significantly over the design rate, removal of sediment from the trench and replacement of the upper layer of filter fabric may be necessary. Clogging is most likely to occur near the top foot of the trench, between the upper gravel layer and the protective layer of filter fabric. Cleaning can be accomplished by removing the top layer of gravel and clogged filter fabric, installing a new layer of filter fabric, and replacing the gravel layer with washed gravel. This maintenance activity is expensive, and the need for it can be minimized through prevention of upstream erosion.	As required
Remove pioneer trees that sprout in the vicinity of the trench to prevent root puncture of filter fabric that could allow sediment to enter the trench	As required
Trim adjacent trees to prevent drip lines from extending over surface of trench	As required
Remove litter and debris from trench area	As required
Inspect trench to identify potential problems such as standing water, trash and debris, and sediment accumulation	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
Maintain grassy buffer strip in accordance with requirements listed in the Vegetated Filter Strip Fact Sheet	As required

Description

Porous Pavement Filter consists of an installation of permeable interlocking concrete pavers, pervious concrete, or porous asphalt pavement that is flat in all directions and is provided with a surcharge zone to temporarily store the runoff draining from an adjacent area. Stormwater runoff infiltrates into the porous pavement and the sublayers of sand and gravel and slowly exits through an underdrain.

Permeable interlocking concrete pavement is comprised of a layer of durable concrete pavers or blocks separated by joints filled with small stones. Pervious concrete is made from carefully controlled amounts of water and cementitious materials used to create a paste that forms a thick coating around aggregate particles. Unlike conventional concrete, the mixture contains little or no sand, creating a substantial void content between 15% and 25%. Porous asphalt, or "open-graded" asphalt, pavement contains no fine aggregate particles thereby creating void spaces in the pavement, which allows water to collect within and drain through the pavement. An alternative approach is to use stabilized grassy porous pavement, consisting of grass turf reinforced with plastic rings and filter fabric underlain by gravel. A typical cross section of a Porous Pavement Filter system is shown in **Figure 6-10**.

Advantages

- Reduces runoff volume and peak flows during small storm events.
- Can serve functional and aesthetic purposes.

Limitations

- The cost of restorative maintenance can be somewhat high when the system seals with sediment and can no longer function properly as a permeable pavement.
- Uneven driving surfaces and potential traps for high-heeled shoes are potential limitations.

Planning and Siting Considerations

- Should only be installed on relatively flat surfaces.
- May be used in low vehicle-movement zones. Potential applications include the following:
  - Low vehicle movement airport zones;
  - Parking aprons and maintenance roads;
  - Crossover/emergency stopping/parking lanes on divided highways;
  - Residential street parking lanes;

- o Residential driveways;
- o Maintenance roads and trails; and
- o Emergency vehicle and fire access lanes in apartment/multi-family/complex situations.

- Vehicle movement lanes that lead up to the porous pavement parking pads should be solid asphalt or concrete pavement.
- Grass can be used in the block voids, but it may require irrigation and lawn care.
- In cases when the subsoils are not free draining, an impermeable liner should be provided to contain the water in the gravel pack and to mitigate concerns about expansive soils.
- Should be located far enough from foundations in expansive soils so as to limit damage to potential structures.
- When a commercial or an industrial site may be handling chemicals and petroleum products that may spill to the ground, an impermeable liner with an underdrain is required to prevent groundwater and soil contamination.

Design Criteria

Design Criteria for the Porous Pavement Filter are summarized in **Table 6-22**.

Table 6-22. Porous Pavement Filter Design Criteria

Design Parameter	Criteria	Notes
Drawdown time for SQDV	12 h	Minimum
SQDV	80% annual capture	Use **Figure 6-1** @ 12-hr drawdown
Surcharge storage volume above pavement	SQDV	
Depth of surcharge zone	2 in	Maximum depth above pavement
Imperviousness	<60%	Variable with pavement type
Permeable Paver Infill	ASTM No. 8 crushed aggregate	
Base courses	1-inch ASTM No. 8 over 9-inch ASTM No. 57	

Design Procedure

Step 1 – Determine Stormwater Quality Design Volume (SQDV)

Using the *Fact Sheet T-0*, determine the tributary drainage area and stormwater quality design volume (SQDV) for 12-hour drawdown.

Step 2 – Determine Filter Ponding Zone Storage Volume

The ponding zone storage volume above pavement is equal to 100 percent of the SQDV.

$V_{PZ} = 1.0 \times SQDV$

Step 3 – Determine Filter Surface Area

Calculate minimum required surface area based on surcharge depth of 2 inches above pavement as follows:

Surface Area = SQDV (ft^3)/0.17 (ft)

Step 4 – Select Pavement Type

For permeable pavers, select appropriate modular blocks that have no less than 40 percent of the surface area open. The manufacturer's installation requirements shall be followed with the exception that porous pavement infill material requirements and base course dimension are adhered to.

Step 5 – Porous Pavement Infill

The Modular Block Pavement openings should be filled with ASTM No. 8 crushed stone.

Step 6 – Provide Base Courses

Provide 1-inch ASTM No. 8 crushed stone over 9-inch ASTM No. 57 aggregate base courses as shown in **Figure 6-10.**

Step 6 – Provide Perimeter Wall

Provide a concrete perimeter wall to confine the edges of the Porous Pavement Filter area. The wall should be, at the minimum, 6 inches wide and at least 6 inches deeper than all the porous media and modular block depth combined.

Step 7 – Install Subbase

If expansive soils or rock are a concern or the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the base course. Otherwise install a non-woven geotextile membrane to encourage filtration.

Step 7 – Provide Overflow

Provide an overflow, possibly with an inlet to a storm sewer, set at a maximum of 2 inches above the level of the porous pavement surface. Make sure the 2-inch ponding depth is contained and does not flow out of the area at ends or sides.

Volume Reduction Calculation

Porous Pavement Filters may be used to achieve the Volume Reduction Requirement in addition to treatment control requirements. The volume reduction for a Porous Pavement Filter is less if subsurface drainpipe is provided, because less infiltration will occur. If the Porous Pavement Filter is constructed with an impermeable liner, no volume reduction credit is given. The calculation procedure for volume reduction for Porous Pavement Filter is presented in **Table 6-23**.

Table 6-23. Porous Pavement Filter (PPF) Volume Reduction Calculation

Design Parameter	Criteria	Notes
PPF with Subsurface Drain Pipe		Required for C and D soils
1. Volume Reduction for PPF ($Vol_{reduction}$)		Infiltration allowance for water in ponding zone = 0.25
$Vol_{reduction}$ = (SQDV x 0.25)	$Vol_{reduction}$ = ____________________ ft^3	No volume reduction credit is given for Porous Pavement Filters with impermeable liners
PPF without Subsurface Drain Pipe		Use with A and B soils only
1. Volume Reduction for PPF ($Vol_{reduction}$)		Infiltration allowance for water in ponding zone water = 1.0
$Vol_{reduction}$ = (SQDV x 1.0)	$Vol_{reduction}$ = ____________________ ft^3	

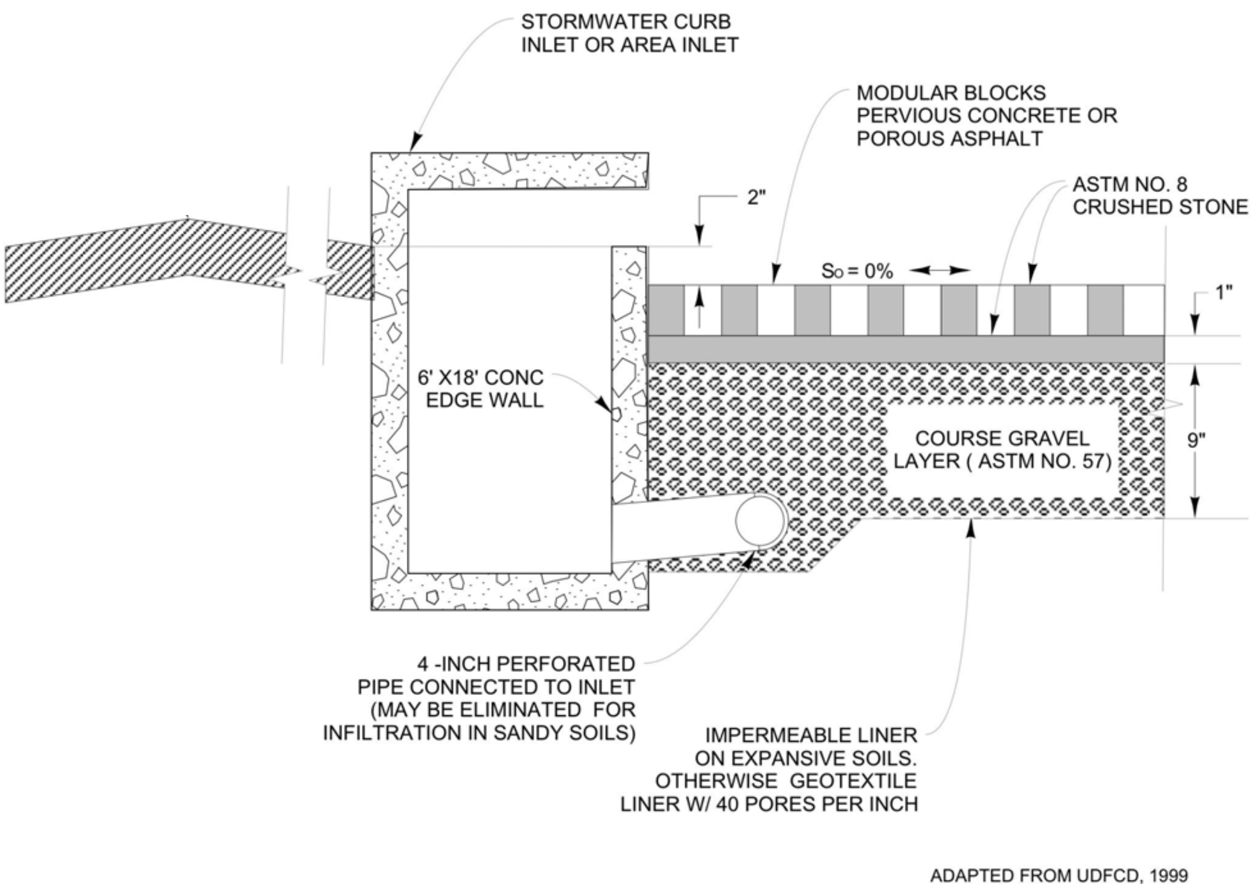


Figure 6-10. Porous Pavement Filter

Construction Considerations

- Before the entire site is graded, the area planned for the Porous Pavement Filter should be roped off to prevent heavy equipment from compacting the underlying soils.
- Both prior to and during construction, diversions should be installed around the perimeter of the Porous Pavement Filter as needed to prevent runoff and sediment from entering the site until the Porous Pavement Filter is in place.

Maintenance Requirements

The City or County requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Porous Pavement Filters. Such agreements will typically include requirements such as those outlined in **Table 6-24**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D.** See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-24. Inspection and Maintenance Requirements for Porous Pavement Filters

Activity	Schedule
Inspect pavements to determine if runoff is infiltrating properly. If infiltration is significantly reduced, remove surface aggregate by vacuuming. Dispose of and replace old aggregate with fresh aggregate.	At least twice during the wet season after significant storms. Additional inspections after periods of heavy runoff are desirable.
If stabilized grassy porous pavement is used, trim vegetation and remove weeds to limit unwanted vegetation.	As required.
Remove litter and debris from the pavement area.	As required.

Photo Credit: American Rivers

Description

Vegetated Swales are long, narrow, landscaped depressions used to collect and convey stormwater runoff. Pollutants are removed via settling and filtration as the water flows over the surface of the swale or infiltrates into the ground. Check dams are provided every 12 to 20 feet to slow flow and pool water to enhance treatment and infiltration. Vegetated Swales reduce the volume of runoff from a site through infiltration into underlying soils. The Vegetated Street Swale variation can be employed in a street setting. This type of swale is constructed between a standard sidewalk and a standard street curb with curb cut spillways and features an underdrain system. See **Figures 6-11** and **6-12** for typical Vegetated Swale configurations.

Advantages

- Relatively inexpensive when integrated into site landscaping.
- Suitable for parking lots and sites with limited open area available for stormwater detention.
- Reduces peak flows during small storm events.
- Enhances site aesthetics.
- Easy to maintain.

> Do not confuse a Vegetated Swale with a Grassy Swale (L-8) or Bioretention (L-1). A Grassy Swale has steeper side slopes and treats runoff via grass filtration. Bioretention areas are level vegetated cells that feature only vertical flow of runoff

Limitations

- Irrigation typically required to maintain vegetation. May conflict with water conservation ordinances for landscape requirements.
- Not appropriate for industrial sites or locations where spills may occur unless infiltration is prevented.
- Not suitable for steeply sloping areas.

Planning and Siting Considerations

- Can receive runoff from parking lots, rooftops, and streets.
- Integrate Vegetated Swales into the overall site design.
- Connection to the storm drain system or another treatment control must be provided at the end of the swale, and possibly at points along the swale, to allow discharge high flows and runoff that does not infiltrate.
- Slopes and depth should be kept as mild as possible to avoid safety risks, and prevent erosion within the Vegetated Swale.

- When Vegetated Street Swales are used, all applicable requirements for other street elements (e.g., curbs, sidewalks, trees) must be met.

Design Criteria

Design criteria for Vegetated Swales are listed in **Table 6-25**. Note that the sizing of the Vegetated Swale is volume-based.

Table 6-25. Vegetated Swale and Vegetated Street Swale Design Criteria

Design Parameter	Criteria	Notes
Design volume	SQDV	Based on 12-hour drawdown. See **Fact Sheet T-0** for calculation of SQDV.
Side slopes	3:1	H:V, Maximum
Flat bottom width	2 ft	Minimum
	4 ft	Minimum (Street Swale)
Top width	5 ft	Minimum
	7 ft	Minimum (Street Swale)
Longitudinal slope	6%	Maximum
Setbacks	5 ft	From centerline of swale to property lines
	10 ft	From building foundations (unless lined with impermeable fabric or approved by City or County
Check Dams		
Length	12 in.	
Width	Width of swale	
Height	3 to 6 in.	Use 12 ft for Street Swale
Spacing interval	12 to 20 ft	
Water storage depth above bottom	6 in.	Minimum
	12 in.	Maximum
Distance from tire stops or curb cut	6 in.	Minimum
Curb cut clear flow area	12 in. x 12 in	Curbs for street swales should be designed for stability by a structural or geotechnical engineer
Topsoil layer	12 in.	Minimum
Permeable filter fabric	–	Optional for Vegetated Swale below top soil layer. Required for Street Swale below topsoil and gravel layers.
Overflow device	–	Required
Underdrain layer		Required for Street Swales and C and D soils
Bottom Slope	10:1	Slope to drain away from street (minimum)
Gravel layer depth	12 in.	Use 3/4” diameter drain rock
Permeable filter fabric	–	Use under gravel layer
Impermeable fabric	–	Use along street edge side of swale
Perforated PVC pipe diameter	6 in.	
Vegetation	No./100 ft^2	Trees, shrubs, grasses, and groundcover. Quantity based on surface area of swale facility. See Design Procedure for minimum quantities.

Design Procedure

Step 1 – Calculate Stormwater Quality Design Volume (SDQV)

Using **Fact Sheet T-0**, determine the stormwater quality design volume, SQDV based on a 12-hour drawdown time, the contributing area, and the imperviousness of the contributing area.

Step 2 – Determine Swale Geometry

Based on criteria in **Table 6-25** and site conditions, determine appropiate values for the following swale geometry design elements:

Bottom width

Side slope

Ponding zone storage depth (D_{PZ})

Top width

Longitudinal slope

Step 3 – Determine Cross-Sectional Area of Swale Storage

$$A_{storage} = D_{PZ} \times \frac{W_{bottom} + W_{top}}{2}$$

Step 4 – Determine Swale Length

$$L_{swale} = \frac{SQDV}{A_{storage}}$$

Step 5 – Design Inlet Controls

For flow introduced along the length of the swale through curb cuts, provide minimum curb cut widths of 12 inches. For swales that receive direct concentrated runoff at the upstream end, provide an energy dissipater, as appropriate, and a flow spreader such as a pea gravel diaphragm flow spreader at the upstream end of the swale. (See **Figure 6-14** in L-9: Grassy Filter Strip for schematic of pea gravel flow spreader.)

Step 6 – Select Vegetation

Choose vegetation to cover the surface area of the swale, including the bottom and side slopes. Turf grass may be used to cover the entire swale surface area. At least 50 percent of the swale surface are shall be planted with grasses or grass-like plants. If plantings are chosen to landscape the swale, the minimum plant material quantities per 100 square feet of swale area should be as follows:

Vegetation Type	Number	Containers	Notes
Large shrubs or small trees	4	3-gallon containers	Or equivalent
Shrubs or large grass-like plants	6	1-gallon containers	Or equivalent
Ground cover plants	1 per foot	4-inch pot (minimum)	On center, triangular spacing, for the ground cover planting area only, unless seed or sod is specified

Wildflowers, native grasses, and ground covers used for Vegetated Swales should be designed to not require mowing. Where mowing is necessary, Vegetated Swales should be designed to require only annual mowing.

Step 7 – Design irrigation system

Provide an irrigation system to maintain viability of Vegetated Swale landscaping.

Volume Reduction

Vegetated Swales may be used to achieve the Volume Reduction Requirement in addition to treatment control requirements. The volume reduction for a bioretention area is less if subsurface drain pipe is provided, because less infiltration will occur. The calculation procedure for volume reduction for bioretention is presented in **Table 6-26.**

Table 6-26. Vegetated Swale Volume Reduction Calculation

Design Parameter	Criteria	Notes
Vegetated Swale with Subsurface Drain Pipe		Required for C and D soils and Street Swale
1. Ponding Zone		Infiltration allowance for water in ponding zone water = 0.25
e. Depth of ponding zone (D_{PZ})	D_{PZ} = ______ ft	
f. Surface Area of ponding zone (A_{PZ})	A_{PZ} = ______ ft^2	
2. Planting Media Layer		Available Water Holding Capacity of planting media layer = 0.1 x volume
e. Depth of planting media layer (D_{PM})	D_{PM} = ______ ft	
f. Area of planting media layer (A_{PM})	A_{PM} = ______ ft^2	
3. Gravel Zone below drainpipe		Porosity of gravel zone = 0.30
c. Depth of gravel below pipe (D_{GZ})	D_{GZ} = ______ ft	Minimum depth below pipe = 6 in
d. Area of gravel below pipe (A_{GZ})	A_{GZ} = ______ ft^2	Minimum width of gravel = 3 ft
4. Volume Reduction for Swale ($Vol_{reduction}$)		
$Vol_{reduction} = (D_{PZ} \times A_{PZ} \times 0.25) + (D_{PM} \times A_{PM} \times 0.1) + (D_{GZ} \times A_{GX} \times 0.3)$	$Vol_{reduction}$ = ______ ft^3	
Vegetated Swale without Subsurface Drainpipe		Recommended for A and B soils
1. Ponding Zone		Infiltration allowance for water in ponding zone water = 1.0
g. Depth of ponding zone (D_{PZ})	D_{PZ} = ______ ft	
h. Area of ponding zone (A_{PZ})	A_{PZ} = ______ ft^2	
2. Planting Media Layer		
g. Depth of planting media layer (D_{PM})	D_{PM} = ______ ft	Minimum depth = 18 inches
h. Area of planting media layer (A_{PM})	A_{PM} = ______ ft^2	
3. Volume Reduction ($Vol_{reduction}$)		
$Vol_{reduction} = (D_{PZ} \times A_{PZ}) + (D_{PM} \times A_{PM} \times 0.10)$	$Vol_{reduction}$= ______ ft^3	Available Water Holding Capacity of planting media layer = 0.1 x volume

Construction Considerations

- Areas to be used for Vegetated Swales should be clearly marked before site work begins to avoid soil disturbance and compaction during construction.
- No vehicular traffic, except that specifically used to construct the Vegetated Swale, should be allowed within 10 feet of swale areas.
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the planter to prevent high sediment loads from entering the planter during ongoing construction activities.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City or County requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Vegetated Swales. Such agreements will typically include requirements such as those outlined in **Table 6-27**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See Appendix E for additional Maintenance Plan requirements and suggested template.

Table 6-27. Inspection and Maintenance Requirements for Vegetated Swales

Activity	Schedule
Trim vegetation and remove weeds (as applicable) to limit unwanted vegetation	As required
Remove litter and debris from landscape area	As required
Use integrated pest management (IPM) techniques	As required
Inspect the swale to determine if runoff is infiltrating properly	At least twice per year during storm events. Additional inspections after periods of heavy runoff are desirable.
If infiltration is significantly reduced, remove and replace topsoil and (for Vegetated Street Swale) drain rocks	May be required every 5 to 10 years or more frequently, depending on sediment loads

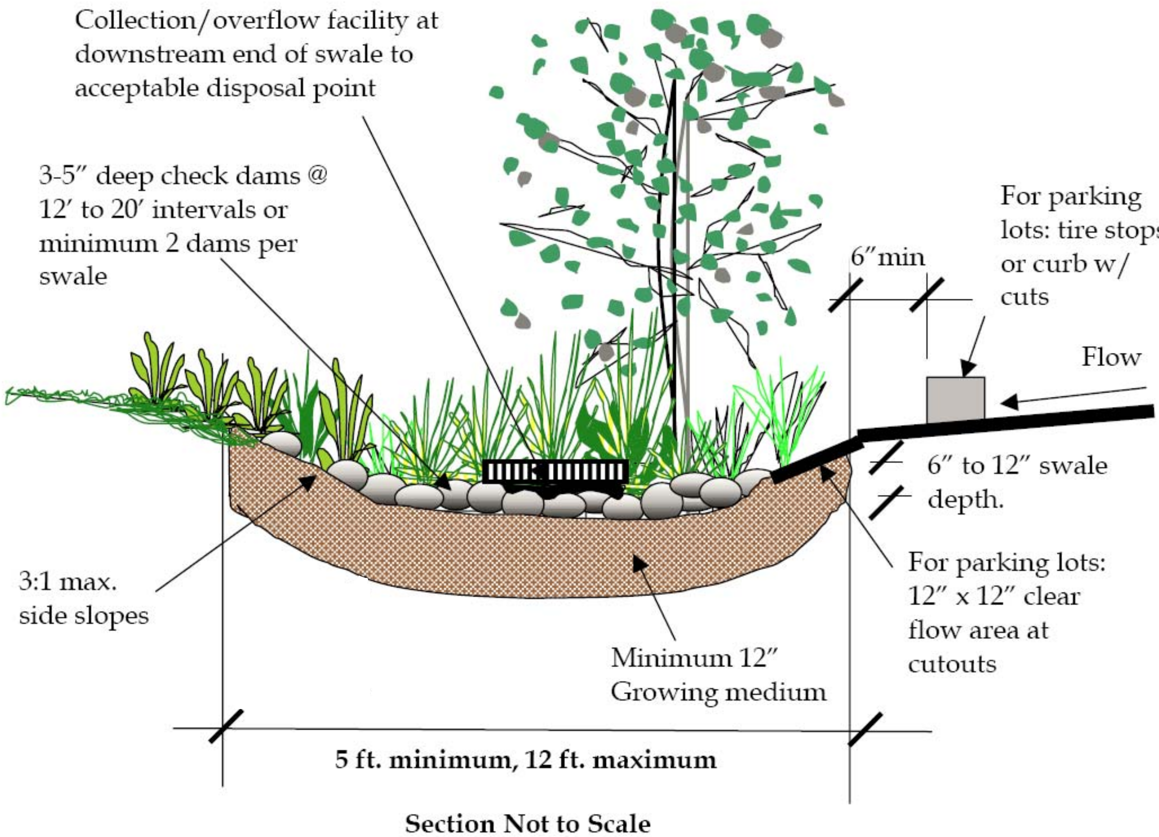


Figure 6-11. Vegetated Swale (Adapted from the City of Portland)

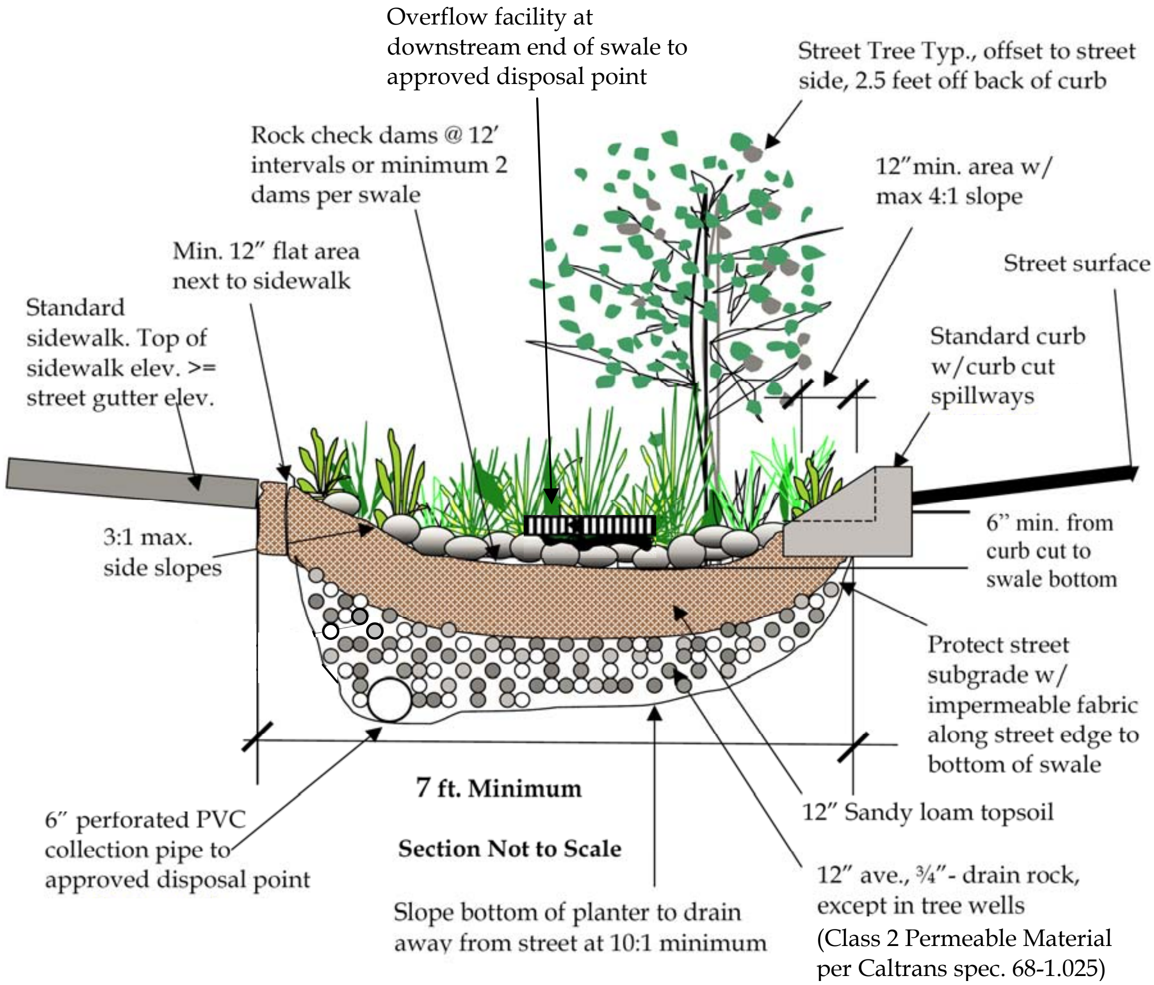


Figure 6-12. Vegetated Street Swale with Underdrain (Adapted from the City of Portland)


Photo Credit: Larry Walker Associates

Description

A Grassy Swale is a shallow, open channel planted with dense, sod-forming vegetation and designed to accept runoff from adjacent surfaces. As the runoff slows and travels through the vegetation and over the soil surface, pollutants are removed by a variety of physical and chemical mechanisms, including sedimentation, filtration, adsorption, precipitation, and microbial degradation and conversion.

A Grassy Swale differs from a conventional drainage channel or roadside ditch due to the incorporation of specific features that enhance stormwater pollutant removal effectiveness. A Grassy Swale is designed to control flow velocities and depth through the vegetation in the swale and to provide sufficient contact time to promote settling and filtration of the runoff flowing through it. Greater surface area and contact time promote greater runoff treatment efficiencies. The volume of runoff can also be reduced through infiltration into underlying soils. See **Figure 6-13** for a typical Grassy Swale configuration.

Other Names: Vegetated Swale, Bioswale

> Do not confuse a Grassy Swale with a *Grassy Filter Strip* (L-9), Vegetated Swale (L-7) or Grassy Channel (V-5), which is used as primarily as volume reduction practice. The latter provides only limited pollutant removal because of higher application rates, and it requires downstream treatment controls.

Advantages

- Relatively inexpensive when used to replace part of a conventional storm drainage system and integrated into site landscaping .
- Provides both stormwater treatment and conveyance.
- Reduces peak flow rates during small storm events.
- Easy maintenance.

Limitations

- May conflict with water conservation ordinances for landscape irrigation requirements.
- May not be appropriate for industrial sites or locations where spills may occur unless liner is provided to prevent infiltration.

Planning and Siting Considerations

- Select location where site topography allows for the design of a channel with sufficiently mild slope (unless small drop structures are used) and enough surface area to maintain non-erosive velocities in the channel.
- Integrate swales into open space buffers, undisturbed natural areas, and other landscape areas when possible.

- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the swale and cars are allowed to overhang the swale.
- The required swale length to meet treatment criteria for a 1-acre project site is typically in the range of 75 to 100 feet. The length will vary depending on several variables, including the geometry of the swale and the runoff coefficient for the site.
- Liners may be required in areas where swales may be impacted by hazardous materials or where spills may occur (e.g., retail gasoline outlets, auto maintenance businesses, processing/manufacturing areas).
- Surface flow into the swale is preferred over underground conveyance.
- Irrigation is typically required to maintain viability of the swale vegetation. Coordinate design of general landscape irrigation system with that of the Grassy Filter Strip, as applicable.
- Vector Considerations: The potential for mosquitoes due to standing water will be greatly reduced or eliminated if the Swale is properly designed, constructed, and operated.

Design Criteria

Design criteria for the Grassy Swale are listed in **Table 6-28**.

Table 6-28. Grassy Swale Design Criteria

Design Parameter	Criteria	Notes
Tributary drainage area	≤ 10 acres	For larger areas, break up into sub-watersheds of 10 acres or less, with a swale for each sub-watershed.
Design flow	SQDF	See *Fact Sheet T-0*
Roughness coefficient (n) for treatment design	0.2	Reflects the roughness associated with shallow flow through dense vegetation.
Roughness coefficient (n) for conveyance design	0.1	Reflects the roughness of swale when depth of flow is above the height of the grass. Used to determine capacity of swale to convey peak hydraulic flows
Minimum contact time for treatment of the SQDF	7 minutes	Provide sufficient length to yield minimum contact time for the WQF
Minimum bottom width	0.5 ft	
Maximum bottom width	10 ft	Swales wider than 10 feet can be divided by internal berms to conform to maximum width criteria.
Maximum side slopes	3:1	Side slopes to allow for ease of mowing. Steeper slopes may be allowed with adequate slope stabilization.
Longitudinal slope	1-4%	
Check dams	As required	For longitudinal slope > 4% and as a means of promoting more infiltration. Space dams as required to maintain maximum longitudinal bottom slope ≤ 4%.
Underdrains	As required	For longitudinal slope < 1%
Maximum depth of flow at SQDF	3-5 in.	1 inch below top of vegetation
Maximum flow velocity (treatment)	1 ft/sec	Based on Manning's n = 0.20. Concentrated inlet flow must be spread
Inlet Design/Curb cuts	≥ 12 in. wide	To prevent clogging and promote flow spreading. Pavement should be slightly higher than swale. Include energy dissipaters.

Design Procedure

Step 1 – Determine the Grassy Swale's Function

The Grassy Swale can be designed to function as both a treatment control for the stormwater quality design flow and as a conveyance system to pass the peak hydraulic design flows, if the swale is located "on-line".

Step 2 – Calculate Stormwater Quality Design Flow (SQDF)

Using the *Fact Sheet T-0*, determine the contributing area and stormwater quality design flow, SQDF.

Step 3 – Provide for peak hydraulic design flows

Using the Standard Calculations Fact Sheet (Appendix H), calculate flows greater than SQDF to be diverted around or flow through the swale. Design the diversion structure, if needed.

Step 4 – Design the Grassy Swale Using Manning's Equation

Swales can be trapezoidal (as illustrated in **Figure 6-13**) or parabolic in shape. While trapezoidal channels are the most efficient channel for conveying flows, parabolic configurations provide good water quality treatment and may be easier to mow since they don't have sharp breaks in slope.

a. Use a roughness coefficient (n) of 0.20 with Manning's Equation to design the treatment area of a swale to account for the flow through the vegetation. To determine the capacity of the swale to convey peak hydraulic flows, use a roughness coefficient (n) of 0.10 with Manning's Equation.

Manning's Equation

$$Q = \frac{1.49}{n}\frac{A^{5/3}}{P^{2/3}} \times s^{1/2}$$

where

Q = SQDF

A = Cross-sectional area of flow

P = Wetted perimeter of flow

s = Bottom slope in flow direction

n = Manning's n (roughness coefficient)

For treatment design of a trapezoidal swale, solve Manning's equation by trial and error to determine a bottom width that yields a flow depth of 3 to 5 inches at the design SQDF and the swale geometry (i.e., side slope and s value) for the site under design. The minimum design bottom width is 0.5 ft.

b. Determine length necessary to provide the desired contact time (7 minutes minimum) for treatment of the SQDF.

$L = (t_c)$ x (flow velocity) x 60

where

L = Length of swale, ft

t_c = Contact time, 7 minutes minimum

Step 5 – Design Inlet Controls

For flow introduced along the length of the swale through curb cuts, provide minimum curb cut widths of 12 inches and avoid short-circuiting the swale by providing the minimum contact time of 7 minutes.

For swales that receive direct concentrated runoff at the upstream end, provide an energy dissipater, as appropriate, and a flow spreader such as a pea gravel diaphragm flow spreader at the upstream end of the swale. (See **Figure 6-14** in L-9: Grassy Filter Strip for schematic of pea gravel flow spreader.)

Step 6 – Select Vegetation

A full, dense cover of sod-forming vegetation is necessary for the Grassy Swale to provide adequate treatment.

Select vegetation that:

- Will be dense and strong enough to stay upright, even in flowing water;
- Has minimum need for fertilizers;
- Is not prone to pests and is consistent with IPM practices;

- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

See **Appendix G** for recommended grasses for Grassy Swales. Do not use bark or similar buoyant material in the swale or around drain inlets or outlets.

Step 7 – Design irrigation system

Provide an irrigation system to maintain viability of Grassy Swale vegetation.

Volume Reduction

Grassy Swales may be used to achieve the Volume Reduction Requirement in addition to treatment control requirements. The calculation procedure for volume reduction for Grassy Swales is presented in **Table 6-29**.

Table 6-29. Grassy Swale Volume Reduction Calculation

Design Parameter	Criteria	Notes
1. SQDV for contributing area	SQDV = ____________ ft^3	See Fact Sheet T-0
2. Volume reduction factor for Grassy Swale (V_{soils})	V_{soils} = ____________	V_{soils} for A and B soils = 0.50 V_{soils} for C and D soils = 0.25
3. Volume Reduction for Grassy Swale ($Vol_{reduction}$) $Vol_{reduction}$ = (SQDV x V_{soils})	$Vol_{reduction}$ = ____________ ft^3	

Construction Considerations

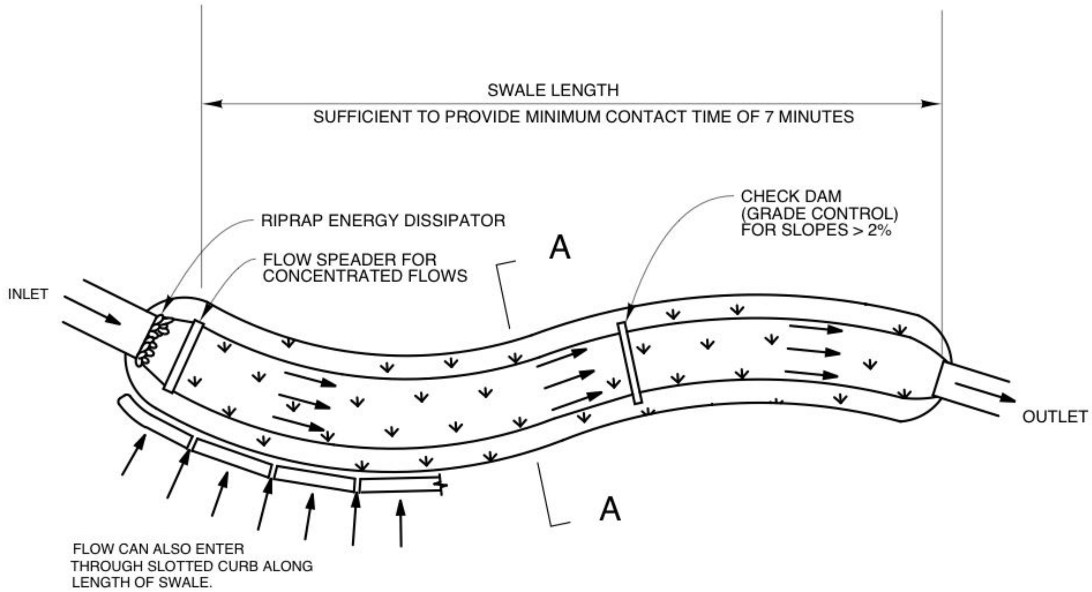
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the swale to prevent high sediment loads from entering the swale during ongoing upstream construction activities.
- Repair, seed, or re-plant damaged areas immediately.
- Apply erosion control measures as needed to stabilize side slopes and inlet areas.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Grassy Swales. Such agreements will typically include requirements such as those outlined in **Table 6-30.** The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

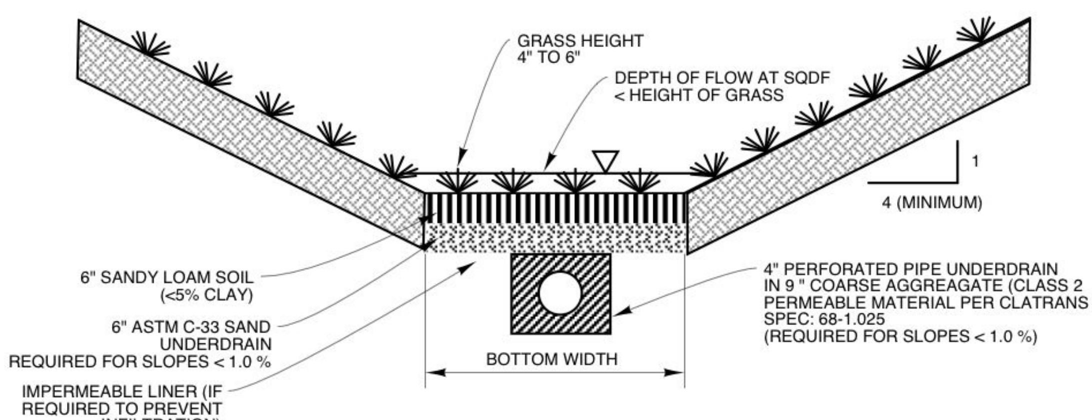
Table 6-30. Inspection and Maintenance Requirements for Grassy Swales

Activity	Schedule
Mow grass to maintain a height of 4 to 6 inches or above depth of flow at SQDF	As required
Remove grass clippings	As required
Use integrated pest management (IPM) techniques	As required
Remove trash and debris from the swale	As required
Inspect swale at for signs of erosion, vegetation damage/coverage, channelization problems, debris build-up, and excessive sedimentation in bottom of channel. Correct problems or remove debris and sediment as soon as possible.	At least twice annually. Schedule one inspection at the end of the wet season so that summer maintenance can be scheduled to prepare swale for wet season. Additional inspections after periods of heavy runoff are desirable.
Remove sediment in inlet areas, the channel, culverts, and outlets whenever flow into the swale is retarded or blocked	As required
Repair ruts or holes in the channel by removing vegetation, adding and tamping suitable soil, and reseeding. Replace damaged vegetation.	As required
Inspect swale for obstructions (e.g., debris accumulation, invasive vegetation) and pools of standing water that can provide mosquito-breeding habitat. Correct observed problems as soon as possible.	At least twice during the wet season after significant storms. Additional inspections after periods of heavy runoff are desirable.



TRAPEZOIDAL GRASS SWALE PLAN

NOT TO SCALE



TRAPEZOIDAL GRASS SWALE SECTION

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Figure 6-13. Grassy Swale

Source: Texas Transportation Institute

Description

A Grassy Filter Strip is a gently sloped soil surface planted with dense, sod-forming vegetation and designed to receive and treat sheet flow runoff from adjacent surfaces. As the runoff flows through the vegetation and over the soil surface at a shallow depth, pollutants are removed by a variety of physical, chemical, and biological mechanisms, including sedimentation, filtration, adsorption, precipitation, and microbial degradation and conversion.

Greater surface area and contact time promote greater runoff treatment efficiencies. The volume of runoff can be reduced through infiltration into underlying soils. See **Figure 6-14** for a typical Grassy Filter Strip configuration.

Other Names: Vegetated Filter Strips, Biofilter

> A Grassy Filter Strip should not be confused with a *Grassy Swale* (L-8) or Vegetated Buffer Strip (V-6), which is used as volume reduction practice. The latter provides only limited pollutant removal because of higher application rates, and, consequently, requires downstream treatment controls.

Advantages

- Relatively inexpensive when used to replace part of a conventional storm drainage system and integrated into site landscaping.
- Reduces peak flows during small storm events.
- Easy to maintain.

Limitations

- Possible conflicts with water conservation ordinances for landscape irrigation requirements.
- Not appropriate for industrial sites or locations where spills may occur.

Planning and Siting Considerations

- Select location where site topography allows for the design of filter strips with proper slopes in flow direction.
- Integrate Grassy Filter Strips into open space buffers, undisturbed natural areas, and other landscape areas when possible.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the filter strip and cars are allowed to overhang the filter strip.
- Irrigation is typically required to maintain viability of the filter strip vegetation. Coordinate design of general landscape irrigation system with that of the Grassy Filter Strip, as applicable.

- Vector Considerations: The potential for mosquitoes due to standing water will be greatly reduced or eliminated if the strip is properly designed, constructed, and operated.

Design Criteria

Design criteria for Grassy Filter Strips are listed in **Table 6-31**.

Table 6-31. Grassy Filter Strip Design Criteria

Design Parameter	Criteria	Notes
Drainage area	≤ 5 acres	For larger areas, break up into sub-watersheds of 5 acres or less with a filter strip for each.
Design flow	SQDF	See *Fact Sheet T-0*
Maximum linear application rate (q_a)	0.005 cfs/ft of width	Rate at which runoff is applied across the top width of filter strip. This rate, combined with the design flow, will define the design width of filter strip.
Minimum slope in flow direction	1%	Gentler slopes are prone to ponding of water on surface
Maximum slope in flow direction	4%	Steeper slopes are prone to channeling. Terracing may be used for slopes > 4%.
Minimum length in flow direction	20 ft	Most treatment occurs in the first 20 feet of flow. Longer lengths will typically provide somewhat higher levels of treatment
Vegetation height (typical)	2 – 4 in.	Vegetation should be maintained at a height greater than the depth of flow at design flow rate but sufficiently low to prevent lodging or shading of the vegetation.

Design Procedure

Step 1 – Calculate Water Quality Flow (SQDF)

Using Fact Sheet T-0, determine the contributing area and stormwater quality design flow, SQDF.

Step 2 – Calculate minimum width of Grassy Filter Strip (W_{GFS})

The design minimum width of the Grassy Filter Strip (W_{GFS}) normal to flow direction is a determined from the design WQF and the minimum application rate (q_a), as follows:

$$W_{GFS} = (SQDF)/(q_a)$$

$$W_{GFS} = (SQDF)/0.005 \text{ cfs/ft (minimum)}$$

Step 3 – Determine the minimum length of Grassy Filter Strip in the flow direction

The length of the filter strip in the flow direction must be a minimum of 20 feet. Greater lengths are desirable, as somewhat better treatment performance can typically be expected.

Step 4 – Determine design slope

Slope of the filter strip surface in the direction of flow should be between one (1) and four (4) percent to avoid ponding and channeling of flow. Terracing may be used to maintain a slope of four (4) percent in steeper terrain.

Step 5 – Design inlet flow distribution

Incorporate a device such as slotted curbing, modular block porous pavement, or other spreader devices at the upstream end of the filter strip to evenly distribute flow along the top width. Concentrated flow delivered to the filter strip must be distributed evenly by means of a level spreader as shown in **Figure 6-14.**

Step 6 – Select vegetation

A full, dense cover of sod-forming vegetation is necessary for the filter strip to provide adequate treatment.

Select vegetation that:

- Will be dense and strong enough to stay upright, even in flowing water;
- Has minimum need for fertilizers;
- Is not prone to pests and is consistent with IPM practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

See **Appendix G** for recommended grasses for Grassy Filter Strips. Do not use bark or similar buoyant material in the filter strip or around drain inlets or outlets.

Step 7 – Design outlet flow collection

Provide a means for outflow collection and conveyance (e.g., grassy channel/swale, storm drain, gutter).

Step 8 – Design irrigation system

Provide an irrigation system to maintain viability of filter strip grass.

Volume Reduction Calculation

Grassy Filter Strip may be used to achieve the Volume Reduction Requirement in addition to treatment control requirements. The calculation procedure for volume reduction for Grassy Filter Strip is presented in **Table 6-32**.

Table 6-32. Grassy Filter Strip Volume Reduction Calculation

Design Parameter	Criteria	Notes
1. SQDV for contributing area	SQDV = ______ ft^3	See Fact Sheet T-0
2. Volume reduction factor for Grassy Filter Strip (VRF)	VRF = ______	VRF for A and B soils = 0.95 – 0.18 = 0.77 VRF for C and D soils = 0.95 – 0.25 = 0.70
3. Volume Reduction for Grassy Filter Strip ($Vol_{reduction}$) $Vol_{reduction}$ = (SQDV x VRF)	$V_{reduction}$= ______ ft^3	

Construction Considerations

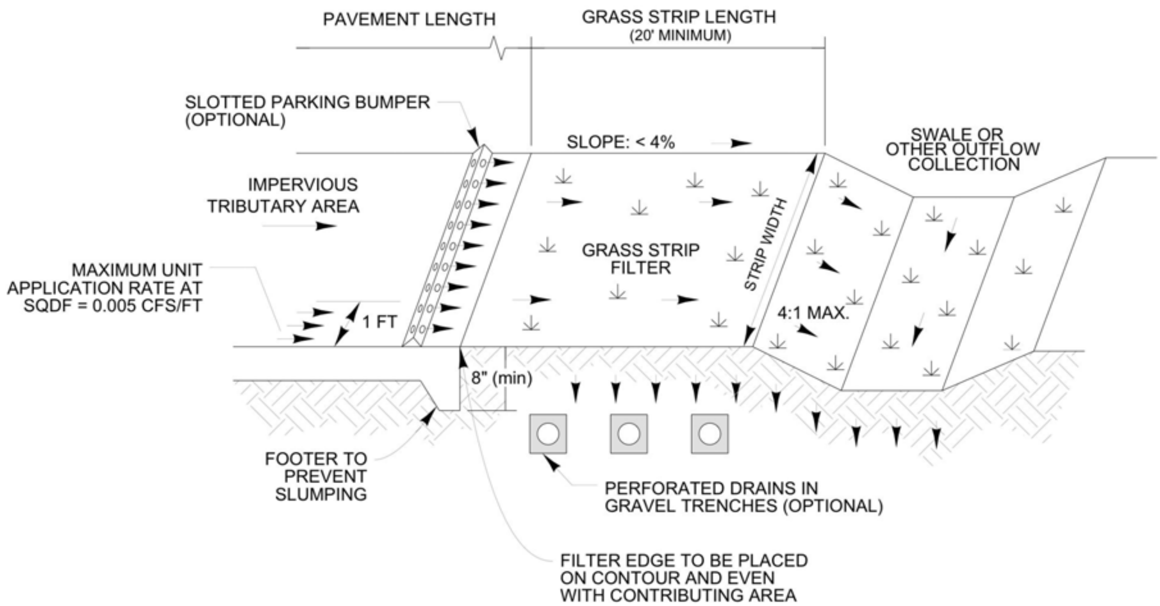
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the filter strip to prevent high sediment loads from entering the filter strip during ongoing upstream construction activities.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City and the County may require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Grassy Filter Strips. Such agreements will typically include requirements such as those outlined in **Table 6-33**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-33. Inspection and Maintenance Requirements for Grassy Filter Strips

Activity	Schedule
Mow grass to maintain a height of 2 to 4 inches (typical)	As required
Remove grass clippings	As required
Use integrated pest management (IPM) techniques	As required
Remove trash and debris from the filter strip	As required
Inspect filter strip for signs of erosion, vegetation damage/coverage, channel formation problems, debris build-up, and excessive sedimentation on the surface of the strip. Correct problems or remove debris and sediment as soon as possible.	At least twice annually. Schedule one inspection at the end of the wet season so that summer maintenance can be scheduled to prepare filter strip for wet season. Additional inspections after periods of heavy runoff are desirable.
Remove sediment in inlet areas, the channel, culverts, and outlets whenever flow into the filter strip is retarded or blocked	As required
Repair ruts or holes in the strip by removing vegetation, adding and tamping suitable soil, and reseeding. Replace damaged vegetation.	As required
Inspect filter strip for obstructions (e.g., debris accumulation, invasive vegetation) and pools of standing water that can provide mosquito-breeding habitat. Correct observed problems as soon as possible.	At least twice during the wet season after significant storms. Additional inspections after periods of heavy runoff are desirable.



SHEET FLOW CONTROL

NOT TO SCALE

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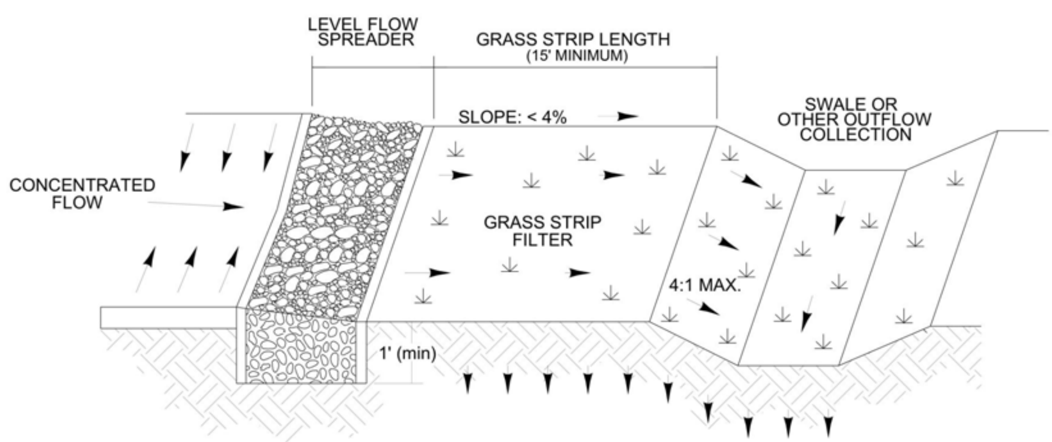


CONCENTRATED FLOW CONTROL

NOT TO SCALE

Figure 6-14. Grassy Filter Strip

Description

A Constructed Wetland is a single-stage treatment system consisting of a forebay and a permanent pool with aquatic plants. Constructed wetlands function similarly to Wet Ponds in that influent runoff flow water mixes with and displaces a permanent pool as it enters the basin. The surcharge volume above the permanent pool is slowly released over a specified period (24 hours for SQDV). Constructed Wetlands require a longer release period for the surcharge volume than Wet Ponds, because the depth and volume of the permanent pool for Constructed Wetlands are less than for Wet Ponds. A base flow is required to maintain the permanent water pool. Constructed Wetlands also differ from Wet Ponds in terms of the extensive presence of aquatic plants. Plants provide energy dissipation and enhance pollutant removal by sedimentation and biological uptake. A conceptual layout of a Constructed Wetland is shown in **Figure 6-15.**

Constructed Wetlands differ from natural wetlands in that they are man-made and are designed to enhance stormwater quality. Diversion of stormwater directly to natural wetlands is not recommended because natural wetlands need to be protected from adverse effects of development. This is especially important because natural wetlands provide stormwater and flood control on a regional scale. Natural wetlands can be incorporated into the constructed wetlands system, but such action requires the approval of federal and state regulators. Constructed wetlands are generally not allowed to be used to mitigate the loss of natural wetlands.

Advantages

- Constructed wetlands can provide substantial wildlife habitat and passive recreation.
- Due to the presence of the permanent wet pool, constructed wetlands can provide significant water quality improvement for many constituents including dissolved nutrients.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to stormwater flow.

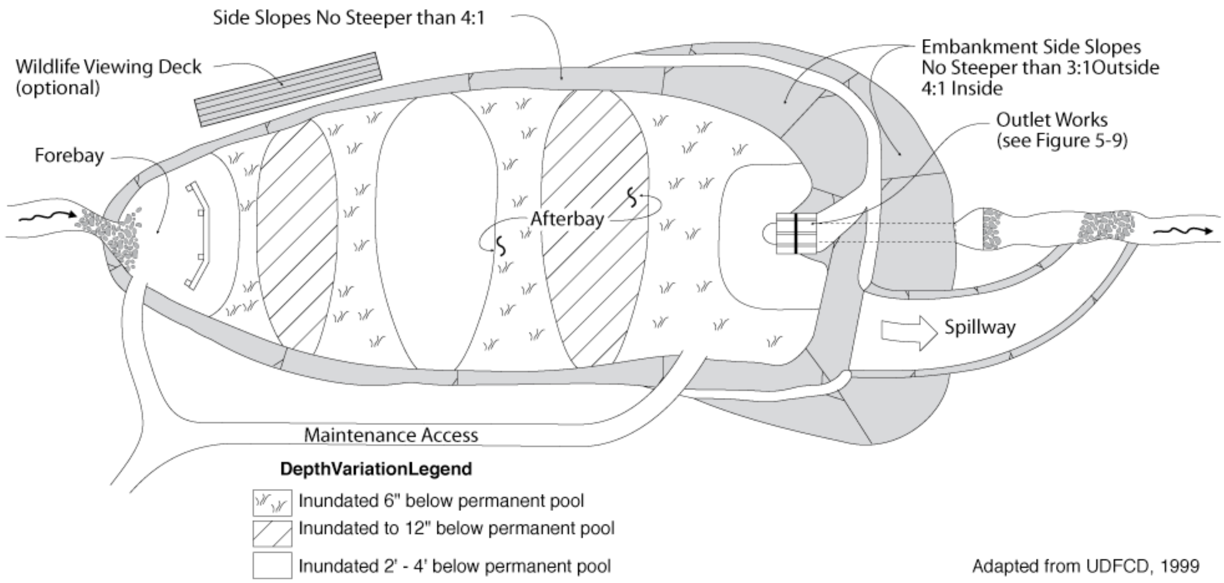
Limitations

- Wetlands must have a continuous base flow to maintain aquatic plants.
- There may be some aesthetic concerns about a facility that looks swampy.
- There are concerns about safety when wetlands are constructed where there is public access.
- Mosquito and midge breeding is likely to occur in wetlands.

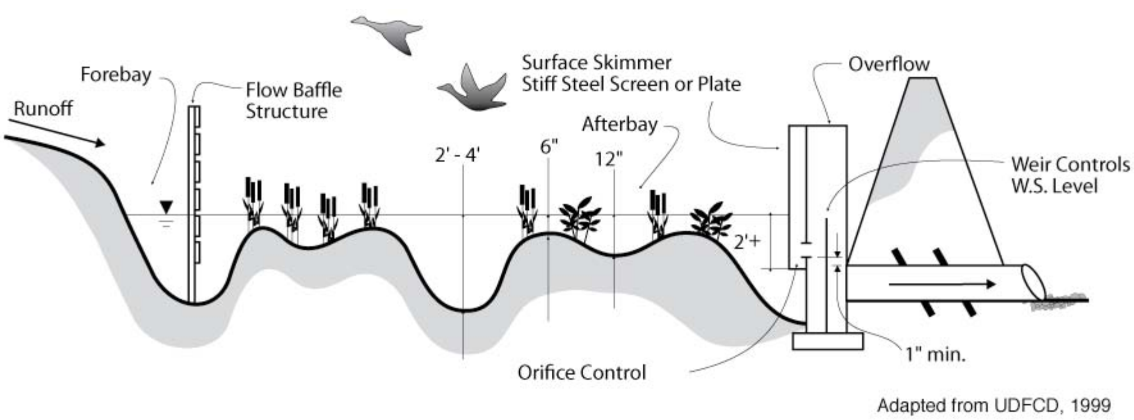
- Wetlands cannot be placed on steep, unstable slopes and require a relatively large footprint.

Planning and Siting Considerations

- Appropriate land uses include large residential developments and commercial, institutional, and industrial areas where incorporation of a green space and a wetland into the landscape is desirable and feasible.
- Can be used effectively in combination with upstream treatment controls, such as vegetated buffer strips and vegetated swales.
- Required relatively large areas (typically four to six percent of the tributary area) and are usually larger than Wet Ponds because the average depth is less.
- Most appropriate for sites with low-permeability soils (type C and D) that will support aquatic plant growth.
- Infiltration through a wetland bottom cannot be relied upon because the bottom is either covered by soils of low permeability or because the groundwater is higher than the wetland bottom.
- Wetland bottom channels require a near-zero slope.
- A base flow of water is required to maintain aquatic conditions.



Plan View



Section View

Figure 6-15. Conceptual Layout of Constructed Wetland

Design Criteria

Design criteria for Constructed Wetland Basins are listed in **Table 6-34**. A Design Data Summary Sheet is provided at the end of this fact sheet.

Table 6-34. Constructed Wetland Basin Design Criteria

Design Parameter	Criteria	Notes
Design volume	SQDV	See standard calculation fact sheet
Maximum drawdown time for SQDV	24 hours	Based on SQDV
Minimum permanent pool volume	75%	Percentage of SQDV
Inlet/outlet erosion control	–	Provide energy dissipaters to reduce velocity
Forebay		
a. Volume	5-10%	Percentage of SQDV
b. Area	5-10%	Percentage of permanent pool surface area
c. Depth	2-4 ft	
Open-water Zone		
a. Area (including forebay)	10-40%	Percentage of permanent pool surface area
b. Depth	2-4 ft	
Wetland Zone		
a. Area	50-70%	Percentage of permanent pool surface area
b. Depth	0.5-1 ft	30 to 50% should be 0.5 ft deep
Outlet Zone		
a. Area	5-10%	Percentage of permanent pool surface area
b. Depth	3 ft	Minimum
Surcharge depth above permanent pool	2 ft	Maximum
Basin length to width ratio	2:1	Minimum (larger preferred)
Basin freeboard	1 ft	Minimum
Wetland zone bottom slope	10%	Maximum
Embankment side slope (H:V)	≥ 4:1	Inside
	≥ 3:1	Outside (without retaining walls)
Maintenance access ramp slope (H:V)	10:1	or flatter
Maintenance access ramp width	16 ft	Minimum – paved with concrete or permeable pavers

Design Procedure

Step 1 – Calculate Water Quality Volume (SQDV)

Using the *Fact Sheet T-0*, determine the tributary drainage area and stormwater quality design volume (SQDV) for 24-hour drawdown.

Step 2 – Determine Basin Minimum Volume for Permanent Pool

The volume of the permanent wetland pool (V_{pp}) shall be not less than 75% of the SQDV.

$V_{pp} \geq 0.75 \times SQDV$

Step 3 – Determine Basin Depths and Surface Areas

Distribution of the wetland area is needed to achieve desired biodiversity. Distribute component areas as follows:

Components	Percent of Permanent Pool Surface Area	Design Water Depth
Forebay	5-10%	2 to 4 feet
Open-water zone	10-40%	2 to 4 feet
Wetland zones with emergent vegetation	50-70%	6 to 12 inches (30% to 50% of this area should be 6 inches deep with bottom slope ≤ 10%)
Outlet zone	5-10%	3 feet (minimum)

a. Estimate average depth of permanent pool (D_{avg}) including all zones

b. Estimate the water surface area of the permanent pool (A_{pp}) based on actual V_{pp}

$A_{pp} = V_{pp} / D_{avg}$

c. Estimate water surface elevation of the permanent pool (WS $Elev_{pp}$) based on site elevations.

Step 4 – Determine Surcharge Depth of SQDV above Permanent Pool and Maximum Water Surface Elevation

The surcharge depth of the SQDV above the permanent pool's water surface (D_{SQDV}) should be ≤ 2.0 feet.

a. Estimate SQDV surcharge depth (D_{SQDV}) based on App.

$D_{SQDV} = SQDV/A_{pp}$

b. If $D_{SQDV} > 2.0$ feet, adjust value of V_{pp} and/or D_{avg} to increase A_{pp} and yield $D_{SQDV} \leq 2.0$.

The water surface of the basin will be greater than A_{pp} when the SQDV is added to the permanent pool.

c. Estimate maximum water surface area (A_{SQDV}) with SQDV based on basin shape.

d. Recalculate Final D_{SQDV} based on A_{SQDV} and A_{pp}. Note: V_{pp} and/or D_{avg} can be adjusted to yield Final $D_{SQDV} \leq 2.0$ feet.

Final $D_{SQDV} = SQDV/((A_{SQDV} + A_{pp})/2)$

e. Calculate maximum water surface elevation in basin with SQDV.

$$WS\ Elev_{SQDV} = WS\ Elev_{pp} + Final\ D_{SQDV}$$

Step 5 – Determine inflow requirement

A net inflow of water must be available through a perennial base flow or supplemental water source. Use the following equation and parameters to estimate the quantity of monthly inflow required at various times of the year. The maximum monthly requirement will govern the design requirement.

$$Q_{inflow} = Q_{E\text{-}P} + Q_{seepage} + Q_{ET}$$

where

$Q_{E\text{-}P}$ = Loss due to evaporation minus the gain due to precipitation (acre-ft/mo.)

$Q_{seepage}$ = Loss or gain due to seepage to groundwater (acre-ft/mo.)

Q_{ET} = Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface) (acre-ft/mo.)

Step 6 – Design Basin Forebay

The forebay provides a location for sedimentation of larger particles and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The forebay is part of the permanent pool and has a water surface area comprising 5 to 10% of the permanent pool water surface area and a volume comprising 5 to 10% of the SQDV. Depth of permanent pool in the forebay should be 2 to 4 feet. Provide forebay inlet with an energy dissipation structure and/or erosion protection. Trash screens at the inlet are recommended to reduce dispersion of large trash articles throughout the basin.

Step 7 – Design Outlet Works

Provide outlet works that limit the maximum water surface elevation to WS $Elev_{SQDV}$. The Outlet Works are to be designed to release the SQDV over a 24 hour period. Protect the outlet from clogging with a trash rack and a skimmer shield that extends below the outlet and above the maximum SQDV depth. A single orifice outlet control is depicted in **Figure 6-18**.

a. For single orifice outlet control or single row of orifices at the permanent pool elevation (WS $Elev_{pp}$) (see **Figure 6-15**), use the orifice equation based on the SQDV (ft^3) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

Orifice Equation

$$Q = C \times A \times \sqrt{2gD}$$

where

Q = Flow rate

C = Orifice coefficient (use 0.61)

A = Area of orifice

g = Acceleration due to gravity (32.2 ft/sec^2)

D = Depth of water above orifice centerline (D_{SQDV})

The equation can be solved for A based on the SQDV and design drawdown time (t) using the following conversion of the orifice equation

$$A = \frac{SQDV}{60.19 \times D^{0.5} \times t}$$

where

t = drawdown period (hrs) = 24 hrs

b. For perforated pipe outlets or vertical plates with multiple orifices, use the following equation to determine required area per row of perforations, based on the SQDV (acre-ft) and depth of water above centerline of the bottom perforation D (ft).

Area/row (in^2) = SQDV/K_{24}

where

$K_{24} = 0.012D^2 + 0.14D - 0.06$ (from Denver UDFCD, 1999)

Select appropriate perforation diameter and number of perforations per row (columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches on center from the bottom perforation. Thus, there will be 3 rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

nr = 1 + (D x 3)

Calculate total outlet area by multiplying the area per row by number of rows.

Total Orifice Area = area/row x nr

Step 8 – Design basin shape

Whenever possible, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. The length to width ratio should be between 2:1 to 4:1, with 3:1 recommended. Internal baffling with berms or modification of inlet and outlet points may be necessary to achieve this ratio.

Step 9 – Design basin side slopes

Side slopes should be stable and sufficiently gentle to limit rill erosion and to facilitate maintenance. Internal side slopes should be no steeper than 4:1; external side slopes should be no steeper than 3:1.

Step 10 – Design Maintenance Access

Provide for all-weather access for maintenance vehicles to the bottom and outlet works. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.

Step 11 – Design Security Fencing

Provide aesthetic security fencing around basin to protect habitat except when specifically waived by the City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division. Fencing design shall be approved by the City or County.

Step 12 – Select Vegetation

Select wetland vegetation appropriate for planting in the wetland bottom. A qualified wetland specialist should be consulted regarding selection and establishment of plants. The shallow littoral bench should have a 4- to 6-inch layer of organic topsoil. Berms and side-sloping areas should be planted with native or irrigated turf grasses. The selection of plant species for a constructed wetland shall take into consideration the water fluctuation likely to occur in the wetland. Permanent pool water level should be controlled as necessary to allow establishment of wetland plants and raised to final operating level after plants are established.

Construction Considerations

- An impermeable liner may be required to maintain permanent pool level in areas with porous soils.
- Install seepage collars on outlet piping to prevent seepage through embankments.

Maintenance Requirements

The City or County requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Constructed Wetland. Such agreements will typically include requirements such as those outlined in **Table 6-35**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-35. Inspection and Maintenance Requirements for Constructed Wetland Basins

Activity	Schedule
Remove litter and debris from Constructed Wetland Basin area.	As required
Inspect basin to identify potential problems such as trash and debris accumulation, damage from burrowing animals, and sediment accumulation.	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
If permitted by the Department of Fish and Game or other agency regulations, stock basin with mosquito fish to enhance natural mosquito and midge control.	As required
Harvest vegetation for vector control and to maintain open water surface area.	Annually or more frequently if required
Remove sediment when accumulation reaches 10 percent of original design depth or if resuspension is observed. (Note: Sediment removal may not be required in the main pool area for as long as 20 years.)	Clean in early spring so vegetation damaged during cleaning has time to reestablish.
Clean forebay to minimize frequency of main basin cleaning.	As required

Description

Extended detention basins are permanent basins formed by excavation and/or construction of embankments to temporarily detain the SQDV of stormwater runoff to allow for the sedimentation of particulates to occur before the runoff is discharged. An extended detention basin serves to reduce peak stormwater runoff rates, as well as provide treatment of stormwater runoff. Extended detention basins are typically dry between storms, although a shallow pool, one to three feet deep, can be included in the design for aesthetic purposes and to promote biological uptake and conversion of pollutants. A bottom outlet provides a controlled slow release of the detained runoff over a specified time period. Extended detention basins can also be used to provide flood control by including additional detention storage. The basic elements of an extended detention basin are shown in **Figure 6-16**. This configuration is most appropriate for large sites.

Advantages

- May be designed to provide other benefits such as recreation (such as playfields), wildlife habitat, and open space. Safety issues must be addressed.
- Relatively easy and inexpensive to build and operate due to its simple design.
- Useful in retrofit situations where their low hydraulic head requirements allow them to be sited within the constraints of the existing storm drain system. Can be designed into flood control basins or sometimes retrofitted into existing flood control basins.

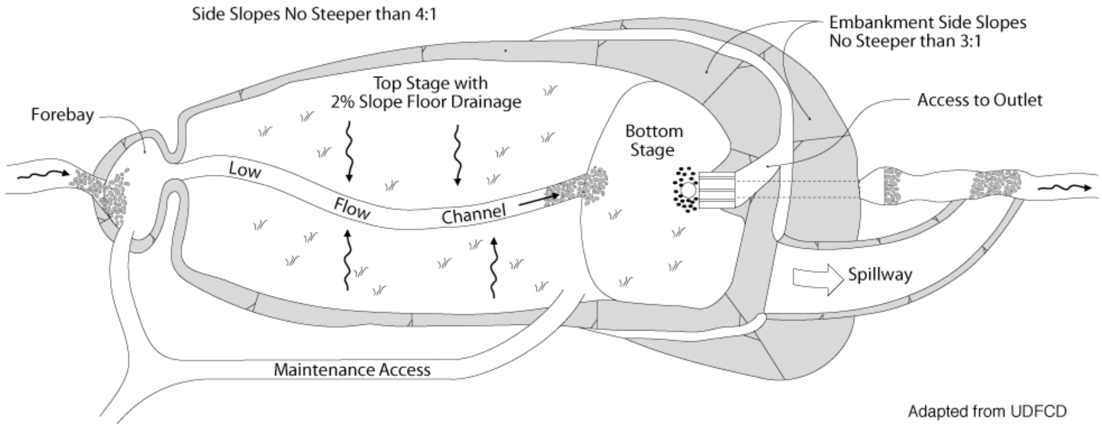
Limitations

- Discharge from Extended Detention Basins may pose a risk to cold-water receiving waters because water retained in the permanent pool is typically heated over time.
- Although wet Extended Detention Basins can increase property values, dry Extended Detention Basins can adversely affect the value of nearby property due to the adverse aesthetics of dry, bare areas and inlet and outlet structures. Appropriate vegetation selection and maintenance can help to mitigate these adverse effects.

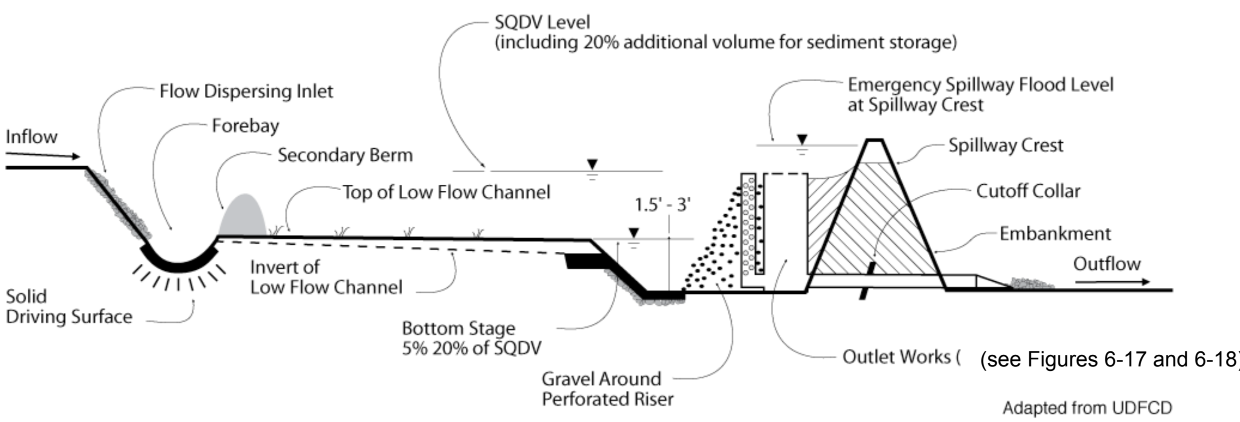
Planning and Siting Considerations

- If constructed early in the land development cycle, can serve as sediment traps during construction within the tributary area.
- Surface basins are typical, but underground vaults may be appropriate in a small commercial development.
- Tributary Drainage Area: Small to medium-sized regional tributary areas with available open space and drainage areas greater than about five (5) acres;
- Land area requirements: Approximately 0.5 to 2 percent of the tributary development area.

- Soil Type: Can be used with almost all soils and geology, with minor adjustments for regions with rapidly percolating soils. In these areas, impermeable liners can be installed to prevent groundwater contamination. The base of the basin should not intersect the groundwater table because a permanently wet bottom can become a vector breeding ground.



Plan View



Section View

Figure 6-16. Extended Detention Basin Conceptual Layout

Design Criteria

Principal design criteria for Extended Detention Basins are listed in **Table 6-36**. A Design Data Summary Sheet is provided at the end of this fact sheet.

Table 6-36. Extended Detention Basin Design Criteria

Design Parameter	Criteria	Notes
Design volume	SQDV	80% annual capture. Use **Figure 6-1** @ 48-hr drawdown
Maximum drawdown time for SQDV	48 h	Based on SQDV
	12 h	Minimum time for release of 50% SQDV
Basin design volume	120%	Percentage of SQDV. Provide 20% sediment storage volume.
Inlet/outlet erosion control	–	Provide energy dissipaters to reduce velocity
Forebay		
a. Volume	5-10%	Percentage of SQDV
b. Drain time	< 45 min	
Low-flow channel		
a. Depth	9 in.	
b. Flow capacity	200%	Percentage of forebay outlet release capacity
Upper stage		
a. Bottom slope	2%	
b. Depth	2 ft	Minimum
c. Width	30 ft	Minimum
Length to width ratio	2:1	Minimum (larger preferred)
Bottom stage		
a. Volume	5-20%	Percentage of SQDV
b. Depth	1.5-3 ft	Deeper than Upper Stage
Freeboard	1 ft	Minimum
Embankment side slope (H:V)	≥ 4:1	Inside
	≥ 3:1	Outside (without retaining walls)
Maintenance access ramp slope (H:V)	10:1	or flatter
Maintenance access ramp width	16 ft	Minimum – approach paved with asphalt concrete

Design Procedure

Step 1 – Calculate Water Quality Volume (SQDV)

Using *Fact SheetT-0*, determine the tributary drainage area and stormwater quality design volume (SQDV) for 48-hour drawdown.

Step 2 – Determine Minimum Basin Storage Design Volume

The volume of the basin (V_{BS}) shall be not less than 120% of the SQDV. The additional 20 percent provides an allowance for sediment accumulation.

V_{BS} = 1.2 x SQDV

Step 3 – Design Outlet Works

The outlet works are to be designed to release the SQDV over a 48-hour period, with no more than 50% released in 12 hours. Protect the outlet from clogging with a trash rack and a skimmer shield that extends below the outlet and above the maximum SQDV depth. Refer to **Figures 6-17** and **6-18** for schematics pertaining to structure geometry; grates, trash racks, and screens; outlet type: perforated riser pipe or orifice plate.

a. For single orifice outlet control or single row of orifices at the basin bottom surface elevation (see **Figure 6-18**), use the orifice equation based on the SQDV (ft^3) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

Orifice Equation

$$Q = C \times A \times \sqrt{2gD}$$

where

Q = Flow rate

C = Orifice coefficient (use 0.61)

A = Area of orifice

g = Acceleration due to gravity (32.2 ft/sec^2)

D = Depth of water above orifice centerline (D_{SQDV})

The equation can be solved for A based on the SQDV and design drawdown time (t) using the following conversion of the orifice equation

$$A = \frac{SQDV}{60.19 \times D^{0.5} \times t}$$

where

t = drawdown period (hrs) = 48 hrs

b. For perforated pipe outlets or vertical plates with multiple orifices (see **Figure 6-17),** use the following equation to determine required area per row of perforations, based on the SQDV (acre-ft) and depth of water above centerline of the bottom perforation D (ft).

Area/row (in^2) = SQDV/K_{48}

where

$K_{48} = 0.013D^2 + 0.22D - 0.10$

Select appropriate perforation diameter and number of perforations per row (columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches on center from the bottom perforation. Thus, there will be 3 rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

nr = 1 + (D x 3)

Calculate total outlet area by multiplying the area per row by number of rows.

Total Orifice Area = area/row x nr

Step 4 – Provide Trash Rack/Gravel Pack

A trash rack or gravel pack around perforated risers shall be provided to protect outlet orifices from clogging. Trash racks are better suited for use with perforated vertical plates for outlet control and allow easier access to outlet orifices for purposes of inspection and cleaning. Trash rack shall be sized to prevent clogging of the primary water quality outlet without restricting with the hydraulic capacity of the outlet control orifices.

Step 5 – Design Basin Shape

Whenever possible, shape the basin with a gradual expansion from the inlet and a gradual contraction from the middle toward the outlet. The length to width ratio should be a minimum of 2:1. Internal baffling with berms or modification of inlet and outlet points may be necessary to achieve this ratio.

Step 6 – Two-Stage Design

A two-stage design, including a pool that fills often with frequently occurring runoff, minimizes standing water and sediment deposition in the remainder of the basin.

a. Upper Stage: The upper stage should be a minimum of 2 feet deep with the bottom sloped at 2 percent toward the low flow channel. Minimum width of the upper stage should be 30 feet.

b. Bottom Stage: The active storage basin of the bottom stage should be 1.5 to 3 feet deeper than the upper stage and store 5 to 20 percent of the SQDV. A micro-pool below the active storage volume of the bottom stage, if provided, should be one-half the depth of the top stage or two (2) feet, whichever is greater.

Step 7 – Design Pond Forebay

The forebay provides a location for sedimentation of larger particles and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The forebay has a volume comprising 5 to 10% of the SQDV. Provide forebay inlet with an energy dissipation structure and/or erosion protection. A berm should separate the forebay from the upper stage of the basin. The outlet pipe from the forebay to the low-flow channel should be sized to drain the forebay volume in 45 minutes. The outlet pipe entrance should be offset from the forebay inlet to prevent short-circuiting.

Step 8 – Low-Flow Channel

The low-flow channel conveys flow from the forebay to the bottom stage. Erosion protection should be provided where the low-flow channel enters the bottom stage. Lining of the low flow channel with concrete is recommended. The depth of the channel should be at least 9 inches. The flow capacity of the channel should be twice the release capacity of the forebay outlet.

Step 9 – Select Vegetation

Bottom vegetation provides erosion protection and sediment entrapment. Basin bottoms, berms, and side slopes may be planted with native grasses or with irrigated turf.

Step 10 – Design Embankment Side Slopes

Design embankments to conform to State of California Division of Safety of Dams requirements, if the basin dimensions cause it to fall under that agency's jurisdiction. Interior slopes should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.

Step 11 – Inlet/Outlet Design

Basin inlet and outlet points should provided with an energy dissipation structure and/or erosion protection.

Step 12 – Design Maintenance Access

Provide for all-weather access for maintenance vehicles to the bottom and outlet works. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.

Step 13 – Provide Bypass

Provide for bypass or overflow of runoff volumes in excess of the SQDV. Spillway and overflow structures should be designed in accordance with applicable standards of the City.

Step 14 – Geotextile Fabric

Non-woven geotextile fabric used in conjunction with gravel packs around perforated risers shall conform to the specifications listed in **Table 6-37**.

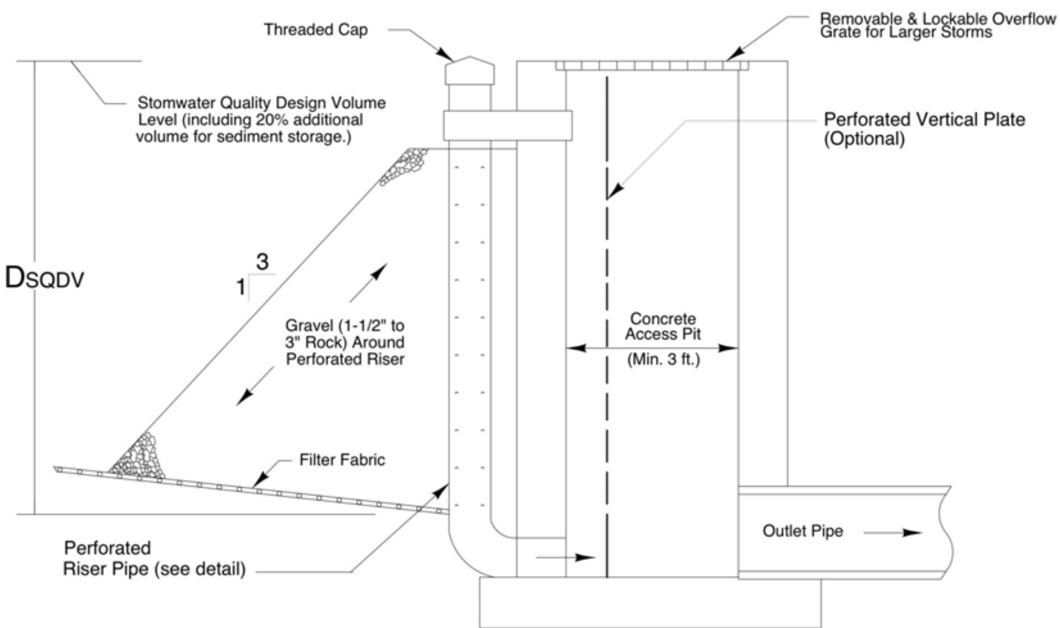
Table 6-37. Non-woven Geotextile Fabric Specifications

Property	Test Reference	Minimum Specification
Grab Strength	ASTM D4632	90 lbs
Elongation at peak load	ASTM D4632	50%
Puncture Strength	ASTM D3787	45 lbs
Permittivity	ASTM D4491	0.7 sec^{-1}
Burst Strength	ASTM D3786	180 psi
Toughness	% Elongation x Grab Strength	5,500 lbs
Ultraviolet Resistance (Percent strength retained at 500 Weatherometer hours)	ASTM D4355	70%

Adapted from SSPWC, 1997.

Step 15 – Design Security Fencing

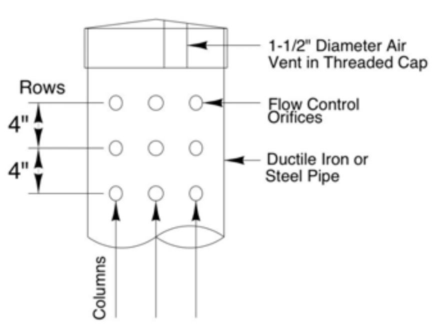
Provide aesthetic security fencing around basin to protect habitat except when specifically waived by the City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division. Fencing design shall be approved by the City or County.



Notes:
1. The outlet pipe shall be sized to control overflow into the concrete riser.
2. Alternate designs include a Hydrobrake outlet (or orifice designs) as long as the hydraulic performance matches this configuration.

OUTLET WORKS
NOT TO SCALE

Notes:
1. Minimum number of holes = 8
2. Minimum hole diameter = 1/4"
3. Maximum hole diameter = 2"



PERFORATED VERTICAL RISER PIPE
NOT TO SCALE

Maximum Number of Perforated Columns

Riser Diameter (in.)	Hole Diameter, in.			
	1/4"	1/2"	3/4"	1"
4	8	8	--	--
6	12	12	9	--
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

Hole Diameter, in.	Area of Hole $(in.)^2$
1/8	0.013
1/4	0.049
3/8	0.110
1/2	0.196
5/8	0.307
3/4	0.442
7/8	0.601
1	0.785

ADAPTED FROM UDFCD, 1999

OUTLET CONFIGURATIONS USING MULTIPLE ORIFICE FLOW CONTROL

Figure 6-17. Perforated Pipe Outlet Structure

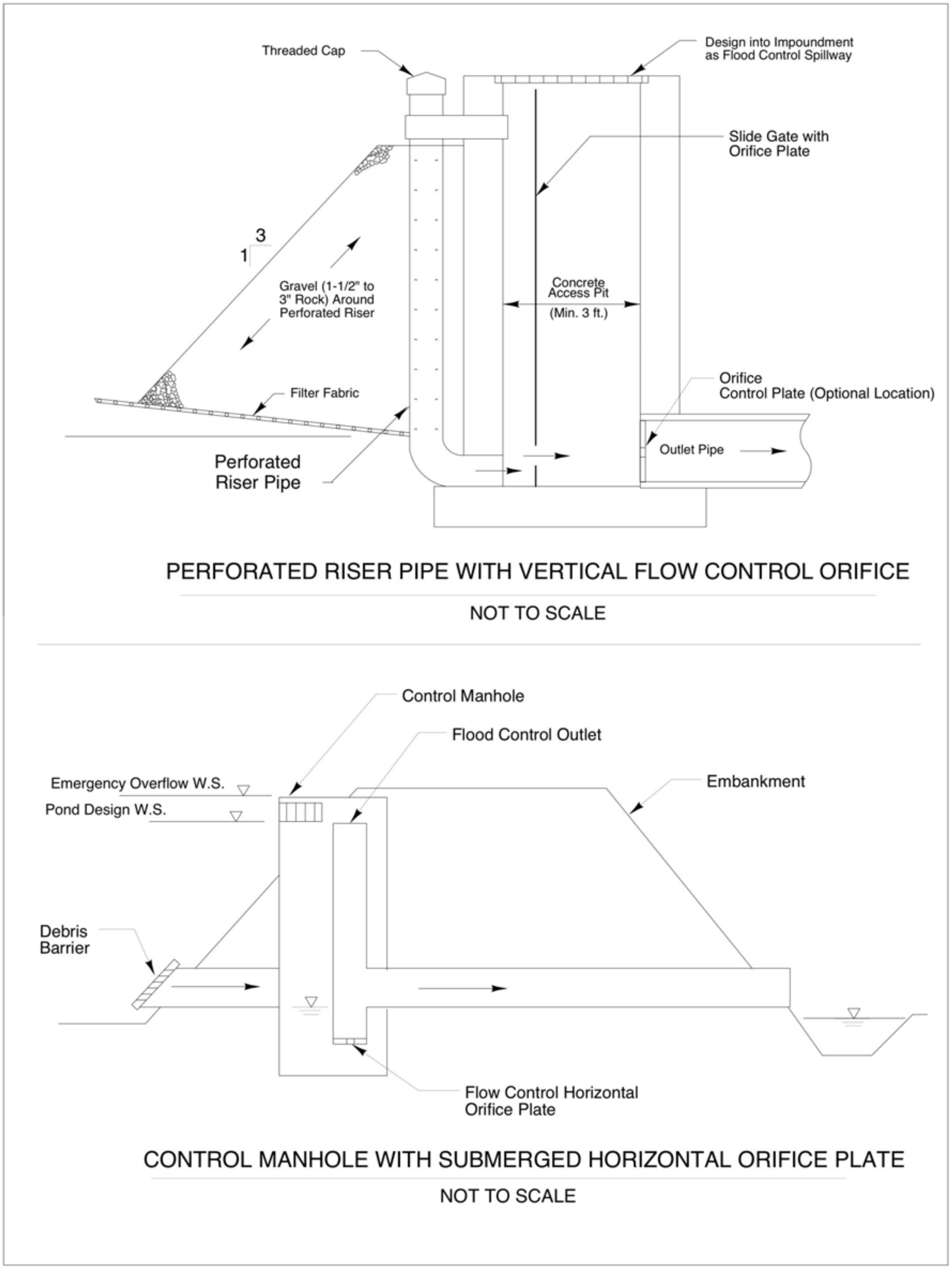


Figure 6-18. Orifice Plate Outlet Configuration

Construction Considerations

- Install seepage collars on outlet piping to prevent seepage through embankments.
- Clearly mark areas to be used for extended detention basins before site work begins to avoid soil disturbance and compaction during construction.

Maintenance Requirements

The City or County requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Extended Detention Basins. Such agreements will typically include requirements such as those outlined in **Table 6-38**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-38. Inspection and Maintenance Requirements for Extended Detention Basins

Activity	Schedule
Remove litter and debris from the banks and basin bottom	As required
Inspect Extended Detention Basin for the following items: clogging of outlet; differential settlement; cracking; erosion; leakage; tree growth on the embankment; the condition of riprap in the inlet, outlet, and pilot channels; sediment accumulation in the basin; trash and debris accumulation; damage from burrowing animals; and the health and density of grass turf on the basin side slopes and floor. Correct observed problems as necessary.	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
If permitted by the Department of Fish and Game or other agency regulations, stock basin with mosquito fish to enhance natural mosquito and midge control.	As required
Remove sediment when accumulation reaches 25 percent of original design depth or if resuspension is observed. (Note: Sediment removal may not be required in the main basin for as long as 20 years.)	Clean in early spring so vegetation damaged during cleaning has time to reestablish.
Clean forebay to minimize frequency of main basin cleaning.	As required
Trim vegetation and inspect monthly to prevent the establishment of woody vegetation and for aesthetic and vector reasons.	At beginning and end of the wet season.
Control mosquitoes	As necessary


Photo Credit: Rachel Terpstra, Larry Walker Associates

Description

Wet Ponds are open earthen basins that feature a permanent pool of water that is displaced by stormwater flow, in part or in total, during storm runoff events. Like Extended Detention Basins, Wet Ponds are designed to temporarily retain the SQDV of stormwater runoff and to slowly release this volume over a specified period (12 hours). Wet Ponds differ from Extended Detention Basins in that the influent runoff flow water mixes with and displaces the permanent pool as it enters the basin. The design drawdown time for Wet Ponds (12 hours) is shorter than for Extended Detention Basins (48 hours), because enhanced treatment is provided in the permanent pool. Wet Ponds differ from constructed wetlands in having a greater average depth. A dry-weather base flow is required to maintain a permanent pool. The primary removal mechanism is settling as stormwater resides in this pool, but pollutant removal, particularly nutrients, also occurs through biological activity in the pond. The basic elements of a Wet Pond are shown in **Figure 6-19**.

Advantages

- Wet ponds can be designed to provide other benefits such as recreation, wildlife habitat, and open space.
- Ponds are often viewed as a public amenity when integrated into a park or open-space setting.
- The permanent pool can provide significant water quality improvement across a relatively broad spectrum of constituents including dissolved nutrients.
- Can serve essentially any size tributary area.

Limitations

- Public safety must be considered with respect to access and use.
- Potential for mosquito and midge breeding exists due to permanent water pool.
- Discharge from Wet Ponds may pose a risk to cold-water receiving waters because water retained in the permanent pool is typically heated over time.
- Base flow or supplemental water is required if water level is to be maintained, although ponds may be allowed to dry out during the dry season if non-stormwater flows are negligible.
- Algae growth may be a potential issue if the permanent water pool is maintained during the summer dry season.
- Ponds require a relatively large footprint.
- Depending on volume and depth, pond designs may require approval from the State Division of Safety of Dams.

Planning and Siting Considerations

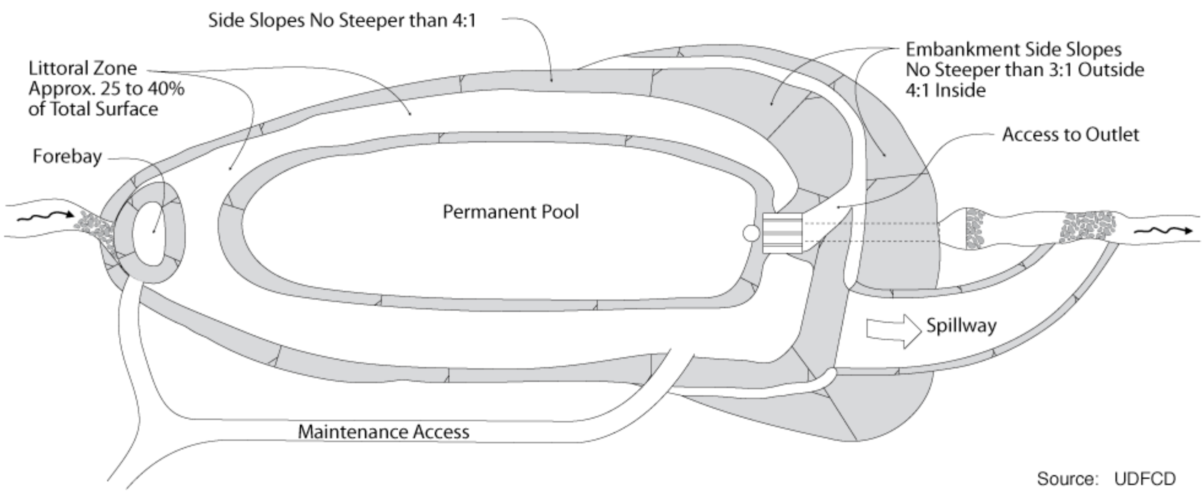
- Wet Ponds are appropriate for use in the following settings:
  - Where there is a need to achieve a reasonably high level of dissolved contaminant removal and/or sediment capture;
  - Where base flow rates or other channel flow sources are relatively consistent year-round; or
  - In residential settings where aesthetic and wildlife habitat benefits can be appreciated and maintenance activities are likely to be consistently undertaken.
- Not suitable for:
  - Dense urban areas;
  - Sites with steep, unstable slopes; or
  - Areas with long dry periods and high evaporation rates without a perennial groundwater base flow or supplemental water supply to maintain the permanent pool.
- Tributary drainage areas are typically small to medium-sized regional areas greater than approximately 10 acres with available open space.
- Land area requirements are approximately two to three percent of the tributary development area.
- Most appropriate for sites with low-permeability soils (types C or D).

Design Criteria

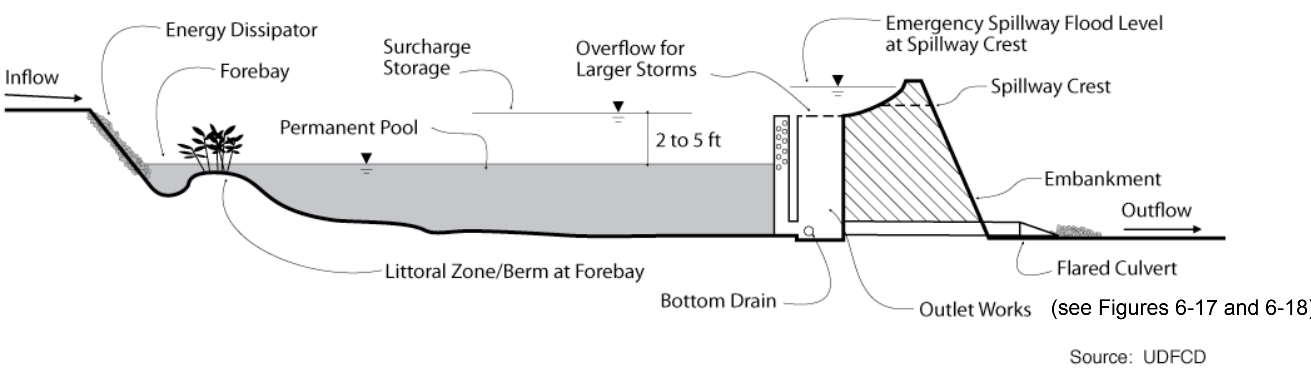
Principal design criteria for Wet Ponds are listed in **Table 6-39**.

Table 6-39. Wet Pond Design Criteria

Design Parameter	Criteria	Notes
Design volume	SQDV	80% annual capture. Use **Figure 6-1** @ 12-hr drawdown
Maximum drawdown time for SQDV	12 h	Based on SQDV
Minimum permanent pool volume	100-150%	Percentage of SQDV
Inlet/outlet erosion control	–	Provide energy dissipaters to reduce velocity
Forebay		
a. Volume	5-10%	Percentage of SQDV
b. Drain time	< 45 min	
c. Depth	2 to 4 ft	
Littoral Zone		
a. Area	25-40%	Percentage of permanent pool surface area
b. Depth	6-18 in	
Deeper Zone		
d. Area (including forebay)	55-65%	Percentage of permanent pool surface area
e. Depth	4-8 ft	Average depth
f. Maximum depth	12 ft	
Pond length to width ratio	2:1	Minimum (larger preferred)
Bottom width	30 ft	Minimum
Pond freeboard	1 ft	Minimum
Embankment side slope (H:V)	≥ 4:1	Inside
	≥ 3:1	Outside (without retaining walls)
Maintenance access ramp slope (H:V)	10:1	or flatter
Maintenance access ramp width	16 ft	Minimum – approach paved with asphalt concrete



Plan View



Section View

Figure 6-19. Conceptual Layout of Wet Pond

Design Procedure

Step 1 – Calculate Water Quality Design Volume (SQDV)

Using the *Calculation of Stormwater Quality Design Flow and Volume Fact Sheet*, determine the tributary drainage area and stormwater quality design volume (SQDV) for 12-hour drawdown.

Step 2 – Determine Minimum Volume for Permanent Pool

The volume of the permanent pool (V_{pp}) shall be not less than 100% and up to 150% of the SQDV.

V_{pp} = 1.0 to 1.5 x SQDV

Step 3 – Determine Depth Zones

Distribution of the permanent pool area is needed to achieve desired biodiversity. In addition to the forebay, two depth zones are required (see **Figure 6-19**). The Littoral Zone provides for aquatic plant growth along the perimeter of the pool. The Deeper Zone covers the remaining pond area and promotes sedimentation and nutrient uptake by phytoplankton. Distribute component areas as follows:

Components	Percent of Permanent Pool Surface Area	Design Water Depth
Forebay	5-10%	2 to 4 feet
Littoral Zone	25-40%	6 to 18 inches
Deeper Zone	55-65%	4 to 8 feet average; 12 foot max

a. Estimate average depth of permanent pool (D_{avg}) including all zones

b. Estimate the water surface area of the permanent pool (A_{pp}) based on actual V_{pp}

$$A_{pp} = V_{pp} / D_{avg}$$

c. Estimate water surface elevation of the permanent pool (WS $Elev_{pp}$) based on site elevations.

Step 4 – Determine inflow requirement

A net inflow of water must be available through a perennial base flow or supplemental water source. Use the following equation and parameters to estimate the quantity of monthly inflow required at various times of the year. The maximum monthly requirement will govern the design requirement.

$$Q_{inflow} = Q_{E-P} + Q_{seepage} + Q_{ET}$$

where

Q_{E-P} = Loss due to evaporation minus the gain due to precipitation (acre-ft/mo.)

$Q_{seepage}$ = Loss or gain due to seepage to groundwater (acre-ft/mo.)

Q_{ET} = Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface) (acre-ft/mo.)

Step 5 – Design Pond Forebay

The forebay provides a location for sedimentation of larger particles and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The forebay is part of the permanent pool and has a volume comprising 5 to 10% of the SQDV. The depth of permanent pool in the forebay should be 2 to 4 feet. Provide forebay inlet with an energy dissipation structure and/or erosion protection. A berm consisting of rock and topsoil mixture should be part of the littoral bench to create the forebay and have a minimum top width of 8 feet and side slopes no steeper than 4:1. Trash screens at the inlet are recommended to reduce dispersion of large trash articles throughout the basin.

Step 6 – Design Outlet Works

The outlet works are to be designed to release the SQDV over a 12-hour period. Protect the outlet from clogging with a trash rack and a skimmer shield that extends below the outlet and above the maximum SQDV depth. An outlet works for a Wet Pond is depicted in **Figure 6-21**.

a. For single orifice outlet control or single row of orifices at the permanent pool elevation (WS $Elev_{pp}$) (see **Figure 6-18**), use the orifice equation based on the SQDV (ft^3) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

Orifice Equation

$$Q = C \times A \times \sqrt{2gD}$$

where

Q = Flow rate

C = Orifice coefficient (use 0.61)

A = Area of orifice

g = Acceleration due to gravity (32.2 ft/sec^2)

D = Depth of water above orifice centerline (D_{SQDV})

The equation can be solved for A based on the SQDV and design drawdown time (t) using the following conversion of the orifice equation

$$A = \frac{SQDV}{61.19 \times D^{0.5} \times t}$$

where

t = drawdown period (hrs) = 12 hrs

b. For perforated pipe outlets or vertical plates with multiple orifices (see **Figure 6-17**), use the following equation to determine required area per row of perforations, based on the SQDV (acre-ft) and depth of water above centerline of the bottom perforation D (ft).

Area/row (in^2) = $SQDV/K_{12}$

where

$$K_{12} = 0.008D^2 + 0.056D - 0.012$$

Select appropriate perforation diameter and number of perforations per row (columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches on center from the bottom perforation. Thus, there will be 3 rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

$$nr = 1 + (D \times 3)$$

Calculate total outlet area by multiplying the area per row by number of rows.

$$\text{Total Orifice Area} = \text{area/row} \times nr$$

Step 7 – Design Basin Shape

Whenever possible, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. The length to width ratio should be between 2:1 to 4:1, with 3:1 recommended. Internal baffling with berms or modification of inlet and outlet points may be necessary to achieve this ratio.

Step 8 – Design Embankment Side Slopes

Side slopes should be stable and sufficiently gentle to limit rill erosion and to facilitate maintenance. Interior slopes should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.

Side slopes above the permanent pool should be no steeper than 4:1, preferably 5:1 or flatter.

The littoral zone should be very flat (40:1 or flatter) with the depth ranging from 6 inches near the shore and extending to no more than 12 inches at the furthest point from the shore.

The side slope below the littoral zone shall be 3:1 or flatter.

Step 9 – Inlet/Outlet Design

Basin inlet and outlet points should provided with an energy dissipation structure and/or erosion protection.

Step 10 – Design Maintenance Access

Provide for all-weather access for maintenance vehicles to the bottom and outlet works. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.

Step 11 – Provide Bypass

Provide for bypass or overflow of runoff volumes in excess of the SQDV. Spillway and overflow structures should be designed in accordance with applicable standards of the City.

Step 12 – Provide Underdrains

Provide underdrain trenches near the edge of the pond. The trenches should be no less than 12 inches wide filled with ASTM C-33 sand to within 2 feet of the pond’s permanent pool water surface, and with an underdrain pipe connected through a valve to the outlet. These underdrains will permit the drying out of the pond when it has to be “mucked out” to restore volume lost due to sediment deposition.

Step 13 – Select Vegetation

Bottom vegetation provides erosion protection and sediment entrapment. Berms, and side slopes may be planted with native grasses or with irrigated turf. The shallow littoral bench should have a 4 to 6 inch thick organic topsoil layer and be vegetated with aquatic species.

Step 14 – Design Security Fencing

Provide aesthetic security fencing around basin to protect habitat except when specifically waived by the City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division. Fencing design shall be approved by the City or County.

Construction Considerations

- An impermeable liner may be required to prevent infiltration and maintain permanent pool level in areas with porous soils.
- Install seepage collars on outlet piping to prevent seepage through embankments.

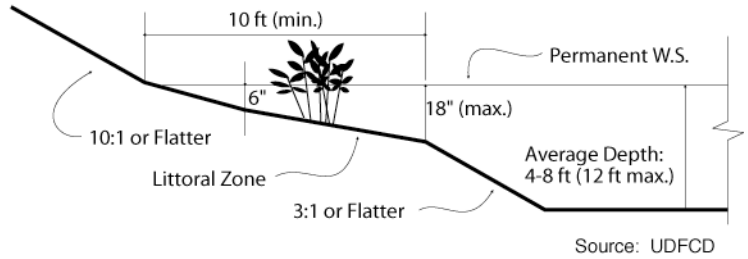
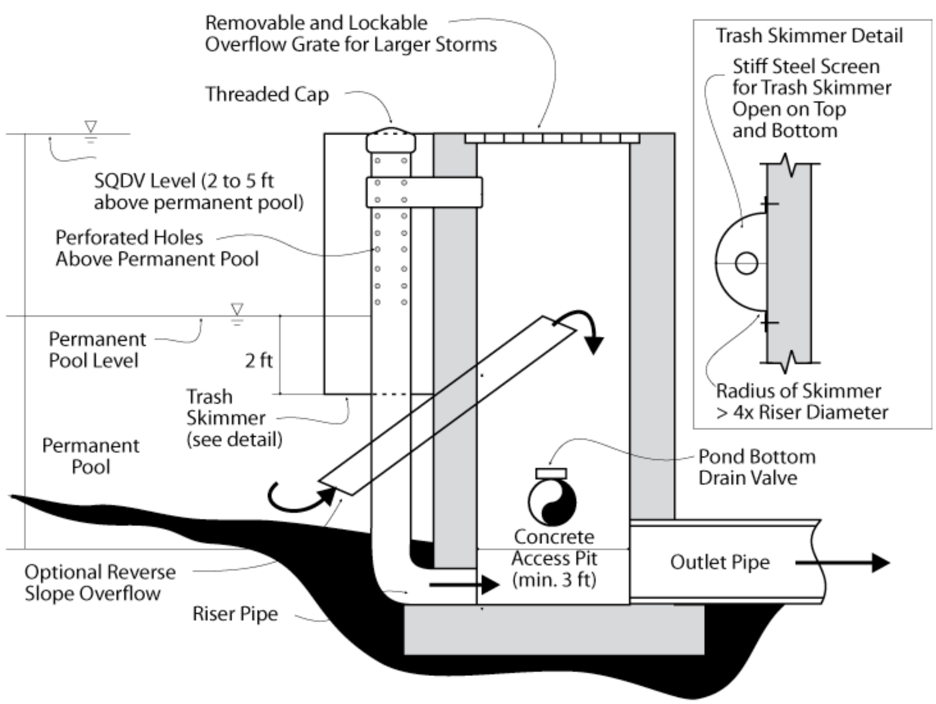


Figure 6-20. Depth Zones for Wet Pond



Notes: 1. Alternate designs are acceptable as long as the hydraulics provides the required emptying times.
2. Use trash skimmer screens of stiff green steel material to protect perforated riser. Must extend from the top of the riser to 2 ft below the permanent pool level.

Source: UDFCD

Figure 6-21. Outlet Works for Wet Pond

Maintenance Requirements

The City or County requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Extended Detention Basins. Such agreements will typically include requirements such as those outlined in **Table 6-40**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-40. Inspection and Maintenance Requirements for Wet Ponds

Activity	Schedule
Remove litter and debris from the banks and pond bottom	As required
Inspect Wet Pond for the following items: clogging of outlet; differential settlement; cracking; erosion; leakage; tree growth on the embankment; the condition of riprap in the inlet, outlet, and pilot channels; sediment accumulation in the basin; trash and debris accumulation; damage from burrowing animals; and the health and density of grass turf on the basin side slopes and floor. Correct observed problems as necessary.	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
If permitted by the Department of Fish and Game or other agency regulations, stock basin with mosquito fish to enhance natural mosquito and midge control.	As required
Harvest vegetation for vector control and to maintain effective permanent pool volume	Annually or more frequently if required
Remove sediment when accumulation reaches 25 percent of original design depth or if resuspension is observed. (Note: Sediment removal may not be required in the main pool area for as long as 20 years.)	Clean in early spring so vegetation damaged during cleaning has time to reestablish.
Clean forebay to minimize frequency of permanent pool cleaning.	As required

The 2009 SWQCCP provides guidance for the selection and design of some of the more common on-site stormwater treatment controls for new development. The standard treatment controls (L-1 through L-9 and C-1 through C-4) included in this Section are non-proprietary (public domain) designs that have been reviewed and evaluated by the City and County and determined to be generally acceptable. Because the performance of these measures has already been demonstrated and reviewed by the City and the County, the plan check review and approval process will be routine for development projects that have selected one or more of these control measures from the 2009 SWQCCP.

The City and the County recognize, however, that these non-proprietary treatment controls may not be appropriate for all projects due to physical site constraints. Thus, if the Volume Reduction Requirement has been met through the use of Volume Reduction Measures (Section 5), the City or the County will allow the use of proprietary control measures that have been approved for general use by the City and County in those projects where the use of non-proprietary treatment controls (L-1 through L-9 and C-1 through C-4) have been demonstrated by the applicant to the satisfaction of the City or County to be infeasible or impractical. Proprietary devices that are approved by the City for general use are listed in **Appendix I** along with the sizing criteria and criteria used for approval. This list will be updated periodically when additional proprietary devices are added to the approved list.

In general, any proprietary device must be designed to treat the SQDV or the SQDF. However, use of alternative sizing criteria is allowed for certain devices as indicated in Appendix I. Procedures to calculate the SQDV and SQDF are provided in Fact sheet T-0. Site runoff in excess of the design capacity may be diverted around or through the treatment device. Any proposed device must include all maintenance, operation, and construction requirements, as indicated in Appendix E and as recommended by the manufacturer.

The City and the County also recognize that in special cases, typically small in-fill projects, the use of City and the County approved general treatment controls, either non-proprietary or proprietary, may not be feasible due to physical site constraints. In these special cases, the City or County will consider the use of substitute proprietary devices in lieu of approved general use control measures. Such substitute devices typically provide a lower level of treatment than the approved general use treatment controls. In such cases where substitute devices are proposed, the applicant must demonstrate to the satisfaction of the City and the County by means of a thorough engineering analysis that use of approved general use control measures are not feasible. Proprietary devices that are approved by the City and the County as substitute devices are listed in **Appendix I** along with the sizing criteria and criteria used for approval. This list will be updated periodically when additional proprietary devices are added to the approved list.

The City and the County encourage the development of innovative stormwater control measures and may consider a limited number of promising alternative control measures that are not on the approved list in Appendix I, including proprietary devices, on a ‘pilot basis.’ In order for a pilot project to be considered for proprietary devices, the manufacturer and/or property owner must commit to participate and fund a monitoring program to verify the device’s performance. Site designers should anticipate additional review time and contact the City or County stormwater staff early in the process to request consideration of pilot installation projects. If unsuccessful, property owner may be required to install additional stormwater control measures.

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SECTION 7
CONTROL MEASURE MAINTENANCE

Continued effectiveness of control measures specified in this SWQCCP depends on diligent ongoing inspection and maintenance. To ensure that such maintenance is provided, the City and County require submittal of a Maintenance Plan and execution of a Maintenance Agreement with the owner/operator of stormwater control measures prior to final acceptance of a private development project, which may include one or more of the control measures detailed in Sections 3,4, 5, and 6. The property owner or his/her designee is responsible for compliance with the agreement. Requirements for the maintenance plan and agreement are presented and discussed in this section. Sample agreements are presented in **Appendix D**.

7.1 MAINTENANCE PLAN

A post-construction Maintenance Plan shall be prepared and submitted to the City or County as part of the Project Stormwater Quality Control Plan submittal. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance.

This section identifies the basic information that shall be included in a maintenance plan. Refer to Fact Sheets for individual control measures regarding device-specific maintenance requirements.

A. Site Map:

1. Provide a site map showing boundaries of the site, acreage, and drainage patterns/contour lines. Show each discharge location from the site and any drainage flowing onto the site. Distinguish between soft and hard surfaces on the map.
2. Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems, and grade breaks for purposes of pollution prevention.
3. With legend, show locations of expected sources of pollution generation (e.g., outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, industrial clarifiers, and wash-racks). Identify any areas having contaminated soil or where toxins are stored or have been stored/disposed of in the past.
4. With legend, indicate types and locations of stormwater controls that will be built to permanently control stormwater pollution. Distinguish between pollution prevention, treatment, sewer diversion, and containment devices.

B. Baseline Descriptions:

1. List the property owners and persons responsible for operation and maintenance of the stormwater control measures on site. Include phone numbers and addresses.
2. Identify the intended method of providing financing for operation, inspection, routine maintenance, and upkeep of stormwater control measures.

3. List all permanent stormwater control measures. Provide a brief description of stormwater control measures selected and, if appropriate, facts sheets or additional information.
4. As appropriate for each stormwater control measure provide:
   a. A written description and checklist of all maintenance and waste disposal activities that will be performed. Distinguish between the maintenance appropriate for a 2-year establishment period and expected long-term maintenance. For example, maintenance requirements for vegetation in a constructed wetland may be more intensive during the first few years until the vegetation is established. The post-establishment maintenance plan shall address maintenance needs (e.g., pruning, irrigation, weeding) for a larger, more stable system. Include maintenance performance procedures for facility components that require relatively unique maintenance knowledge, such as specific plant removal/replacement, landscape features, or constructed wetland maintenance. These procedures shall provide enough detail for a person unfamiliar with maintenance to perform the activity or identify the specific skills or knowledge necessary to perform and document the maintenance.
   b. A description of site inspection procedures and documentation system, including record-keeping and retention requirements.
   c. An inspection and maintenance schedule, preferably in the form of a table or matrix, for each activity for all facility components. The schedule shall demonstrate how it will satisfy the specified level of performance, and how the maintenance/inspection activities relate to storm events and seasonal issues.
   d. Identification of the equipment and materials required to perform the maintenance.
5. As appropriate, list all housekeeping procedures for prohibiting illicit discharges or potential illicit discharges to the storm drain. Identify housekeeping BMPs that reduce maintenance of treatment control measures.

C. Spill Plan:

1. Provide emergency notification procedures (phone and agency/persons to contact).
2. As appropriate for site, provide emergency containment and cleaning procedures.
3. Note downstream receiving water bodies or wetlands which may be affected by spills or chronic untreated discharges.
4. As appropriate, create an emergency sampling procedure for spills. Emergency sampling can protect the property owner from erroneous liability for downstream receiving area clean-ups.

D. Facility Changes:

1. Operational or facility conditions or changes that significantly affect the character or quantity of pollutants discharging into the stormwater control measures may require modifications to the Maintenance Plan and/or additional stormwater controls.

E. Training:

1. Identify appropriate persons to be properly trained and assure documentation of training.
2. Training to include:
   a. Good housekeeping procedures defined in the plan
   b. Proper maintenance of all pollution mitigation devices
   c. Identification and cleanup procedures for spills and overflows
   d. Large-scale spill or hazardous material response
   e. Safety concerns when maintaining devices and cleaning spills

F. Basic Inspection and Maintenance Activities:

1. Create and maintain on site, a log for inspector names, dates, and stormwater control measure devices to be inspected and maintained. Provide a checklist for each inspection and maintenance category.
2. Perform and document annual testing of any mechanical or electrical devices prior to wet weather.
3. Report any significant changes in stormwater controls to the site management. As appropriate, assure mechanical devices are working properly and/or landscaped BMP plantings are irrigated and nurtured to promote thick growth.
4. Note any significant maintenance requirements due to spills or unexpected discharges.
5. As appropriate, perform maintenance and replacement as scheduled and as needed in a timely manner to assure stormwater controls are performing as designed and approved.
6. Assure *unauthorized* low-flow discharges from the property do not bypass stormwater controls (see Permit § D.2.c and Attachment 9, p.1 for a definition of Authorized Non-Stormwater Discharges).
7. Perform an annual assessment of each pollution-generating operation and its associated stormwater controls to determine if any part of the pollution reduction train can be improved.

G. Revisions to Pollution Mitigation Measures:

1. If future correction or modification of past stormwater controls or procedures is required, the owner shall obtain approval from the City or County prior to commencing any work. Corrective measures or modifications shall not cause discharges to bypass or otherwise impede existing stormwater controls.

H. Monitoring & Reporting Program

1. The City or County may require a Monitoring & Reporting Program to ensure the stormwater controls approved for the site are performing according to design.
2. If required by the City or County, the Maintenance Plan shall include performance testing and reporting protocols specified by the City or County.

7.2 MAINTENANCE AGREEMENT

Verification of maintenance provisions is required for all structural controls specified in this Plan, whether Site Design Controls (see **Section 3**), Source Controls (see **Section 4**), Volume Reduction Measures (see **Section 5**) or Treatment Controls (see **Section 6**). Verification, at a minimum, shall include:

1. The owner/developer's signed statement accepting responsibility for inspection and maintenance until the responsibility is legally transferred. A sample Owners Certification statement is provided in **Appendix D**; and either
2. A signed statement from the public entity assuming responsibility for structural control measure inspection and maintenance and certifying that it meets all City or County design standards; or
3. Written conditions in the sales or lease agreement that require the recipient to assume responsibility for inspection and maintenance activities and to conduct a maintenance inspection at least once a year; or
4. Written text in project conditions, covenants, and restrictions for residential properties that assign maintenance responsibilities to the Home Owners Association for the inspection and maintenance of the structural controls; or
5. A legally enforceable maintenance agreement that assigns responsibility for the inspection and maintenance of post-construction structural controls to the owner/operator. A Maintenance Agreement with the City or County must be executed by the owner/operator before occupancy of the project is approved. Sample Maintenance Agreement forms are provided in **Appendix D**.

GLOSSARY OF TERMS

Automotive Repair Shop: a facility that is categorized in any one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 5511, 7532-7534, or 7536- 7539.

Backfill: Earth or engineered material used to refill a trench or an excavation.

Berm: An earthen mound used to direct the flow of runoff around or through a structure.

Best Management Practices (BMPs): methods, measures, or practices designed and selected to reduce or eliminate the discharge of pollutants to surface waters from point and nonpoint source discharges including storm water. BMPs include structural and nonstructural controls, and operation and maintenance procedures, which can be applied before, during, and/or after pollution producing activities.

Buffer Strip or Zone: Strip of erosion-resistant vegetation over which stormwater runoff is directed.

Catch Basin (also known as Inlet or Drain Inlet): Box-like underground concrete structure with openings in curbs and gutters designed to collect runoff from streets and pavements.

Clean Water Act (CWA): (33 U.S.C. 1251 et seq.) requirement of the NPDES program are defined under Sections 301, 307, 402, 318 and 405 of the CWA.

Commercial Development: Any development on private land that is not heavy industrial or residential. The category includes, but is not limited to hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, car wash facilities, mini-malls, business complexes, shopping malls, hotels, office buildings, public warehouses, and light industrial complexes.

Conduit: Any channel or pipe for directing the flow of water.

Construction Activity: Includes clearing, grading, excavation, and contractor activities that result in soil disturbance.

Construction General Permit: An NPDES permit issued by the SWRCB for the discharge of stormwater associated with construction activity from soil disturbance of five (5) acres or more. Threshold lowered to one acre beginning October 10, 2003 (Construction General Permit No. CAS000002).

Conventional Treatment Controls: A subset of Treatment Controls that can be designed to treat the SQDV/SQDF. These controls typically do not reduce runoff volumes and cannot be used to help meet the Volume Reduction Requirement.

Conveyance System: Any channel or pipe for collecting and directing the stormwater.

Culvert: A covered channel or a large diameter pipe that crosses under a road, sidewalk, etc.

Dead-end Sump: A below surface collection chamber for small drainage areas that is not connected to the public storm drainage system. Accumulated water in the chamber must be pumped and disposed in accordance with all applicable laws.

Denuded: Land stripped of vegetation or land that has had its vegetation worn down due to the impacts from the elements or humans.

Designated Public Access Points: Any pedestrian, bicycle, equestrian, or vehicular point of access to jurisdictional channels in the area subject to permit requirements.

Detention: The temporary storage of stormwater runoff to allow treatment by sedimentation and metered discharge of runoff at reduced peak flow rates. The capture and subsequent release of stormwater runoff from the site at a slower rate than it is collected the difference being held in temporary storage.

Development: Any construction, rehabilitation, redevelopment or reconstruction of any public or private residential project (whether single-family, multi-unit or planned unit development); industrial, commercial, retail and other non-residential projects, including public agency projects; or mass grading for future construction. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of facility, nor does it include emergency construction activities required to immediately protect public health and safety.

Directly Adjacent: Situated within 200 feet of the contiguous zone required for the continued maintenance, function, and structural stability of an environmentally sensitive area.

Directly Connected Impervious Area (DCIA): The area covered by a building, impermeable pavement, and/or other impervious surfaces, which drains directly into the storm drain without first flowing across permeable land area (e.g. turf buffers, grass-lined channels).

Directly Discharging: Outflow from a drainage conveyance system that is composed entirely or predominantly of flows from the subject, property, development, subdivision, or industrial facility, and not commingled with the flows from adjacent lands.

Discharge of a Pollutant: any addition of any pollutant or combination of pollutants to waters of the United States from any point source or, any addition of any pollutant or combination of pollutants to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft which is being used as a means of transportation. The term discharge includes additions of pollutants into waters of the United States from: surface runoff which is collected or channeled by man; discharges through pipes, sewers, or other conveyances owned by a State, municipality, or other person which do not lead to a treatment works; and discharges through pipes, sewers, or other conveyances, leading into privately owned treatment works.

Disturbed Area: Area that is altered as a result of clearing, grading, and/or excavation.

Effluent Limits: Limitations on amounts of pollutants that may be contained in a discharge. Can be expressed in a number of ways including as a concentration, as a concentration over a time period (e.g., 30-day average must be less than 20 mg/L), or as a total mass per time unit, or as a narrative limit.

Erosion: The wearing away of land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices relating to farming, residential or industrial development, road building, or timber cutting.

Excavation: The process of removing earth, stone, or other materials, usually by digging.

Filter Fabric: Geotextile of relatively small mesh or pore size that is used to: (a) allow water to pass through while keeping sediment out (permeable); or (b) prevent both runoff and sediment from passing through (impermeable).

Grading: The cutting and/or filling of the land surface to a desired shape or elevation.

Hazardous Substance: (1) Any material that poses a threat to human health and/or the environment. Typical hazardous substances are toxic, corrosive, ignitable, explosive, or chemically reactive; (2) Any substance named by EPA to be reported if a designated quantity of the substance is spilled in the waters of the United States or if otherwise emitted into the environment.

Hazardous Waste: A waste or combination of wastes that, because of its quantity, concentration, or physical chemical, or infectious characteristics, may either cause or significantly contribute to an increase in mortality or an increase in serious irreversible illness; or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed. Possesses at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity) or appears on special EPA or state lists. Regulated under the federal Resource Conservation and Recovery Act and the California Health and Safety Code.

Hydromodification: The change in the natural watershed hydrologic processes and runoff characteristics (i.e., interception, infiltration, overland flow, interflow and groundwater flow) caused by urbanization or other land use changes that result in increased stream flows and sediment transport. In addition, alteration of stream and river channels, installation of dams and water impoundments, and excessive stream bank and shoreline erosion are also considered hydromodification, due to their disruption of natural watershed hydrologic processes.

Illicit Connection: Any man-made conveyance that is connected to the storm drain system without a permit, excluding roof drains and other similar type connections. Examples include channels, pipelines, conduits, inlets, or outlets that are connected directly to the storm drain system.

Illicit Discharge: Any discharge to the storm drain system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term "illicit discharge" includes all non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified in Discharge Prohibitions of this Order, and discharges authorized by the Regional Board.

Impervious Surface/ Cover: A hard surface area that impede the natural infiltration of stormwater and causes water to runoff the surface in greater quantities or at an increased rate of flow from the flow present under pre-project conditions. Impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots, roads or concrete and asphalt paving.

Industrial General Permit: An NPDES Permit (No. CAS000001) issued by the SWRCB for the discharge of Stormwater associated with industrial activity. Board Order 97-03-DWQ.

Infiltration: The downward entry of water into the surface of the soil.

Inlet: An entrance into a ditch, storm sewer, or other waterway.

Integrated Pest Management (IPM): An ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism.

Low Impact Development (LID): A stormwater management and land development strategy that emphasizes conservation and the use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely reflect pre-development hydrologic functions.

LID Treatment Controls: A subset of Treatment Controls that can be designed to treat the SQDV/SQDF and reduce runoff volumes. The runoff reduction achieved by these controls can be used to help meet the Volume Reduction Requirement.

Material Storage Areas: On site locations where raw materials, products, final products, by-products, or waste materials are stored.

Municipal Separate Storm Sewer System (MS4): a conveyance or system of conveyances (including roads with drainage systems, municipal streets, alleys, catch basins, curbs, gutters, ditches, manmade channels, or storm drains) owned by a State, city, county, town or other public body, that is designed or used for collecting or conveying storm water, which is not a combined sewer, and which is not part of a publicly owned treatment works, and which discharges to Waters of the United States.

National Pollutant Discharge Elimination System (NPDES): The national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under CWA §307, 402, 318, and 405.

New Development: Land disturbing activities; structural development, including construction or installation of a building or structure, creation of impervious surfaces; and land subdivision.

Non-Stormwater Discharge: Any discharge to municipal separate storm drain that is not composed entirely of stormwater. Discharges containing process wastewater, non-contact cooling water, or sanitary wastewater are non-stormwater discharges.

Nonpoint Source Pollution: Pollution that does not come from a point source. Nonpoint source pollution originates from diffuse sources that are mostly related to land use.

Non-Structural Best Management Practice (BMP): Low technology procedures or management practices designed to prevent pollutants associated with site functions and activities from being discharged with stormwater runoff. Examples include reducing impervious cover, rain barrels, good housekeeping practices, employee training, standard operating practices, inventory control measures, etc.

Notice of Intent (NOI): A formal notice to SWRCB submitted by the owner/developer of an industrial or construction site that said owner seeks coverage under a General Permit for discharges associated with industrial and construction activities. The NOI provides information on the owner, location, type of project, and certifies that the owner will comply with the conditions of the construction General Permit.

Notice of Termination (NOT): Formal notice to the SWRCB submitted by owner/developer that a construction project is complete.

Outfall: The point where stormwater discharges from a pipe, channel, ditch, or other conveyance to a waterway. The end point where storm drains discharge water into a waterway.

Parking Lot: Land area or facility for the temporary parking or storage of motor vehicles used personally, for business or for commerce with an impervious surface area of 5,000 square feet or more, or with 25 or more parking spaces.

Permeability: A property of soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

Point Source: Any discernible, confined, and discrete conveyance from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural stormwater runoff.

Pollutant: A substance introduced into the environment that adversely affects the usefulness of a resource.

Pollution Prevention (P2): Practices and actions that reduce or eliminate the generation of pollutants.

Post-project: The land use condition as a result of the proposed development activity.

Precipitation: Any form of rain or snow.

Pre-project: The existing land use condition prior to the proposed development activity.

Receiving Stream: (for purposes of this Manual only) any natural or man-made surface water body that receives and conveys stormwater runoff.

Reclamation or Recycling (water reclamation or recycling): Planned use of treated effluent that would otherwise be discharged without being put to direct use.

Redevelopment: Land-disturbing activity that results in the creation, addition, or replacement of 5,000 square feet or more of impervious surface area on an already developed site. Redevelopment includes, but is not limited to: the expansion of a building footprint; addition or replacement of a structure; replacement of impervious surface area that is not part of a routine maintenance activity; and land disturbing activities related to structural or impervious surfaces. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of facility, nor does it include emergency construction activities required to immediately protect public health and safety.

Regional stormwater management facilities: A regional stormwater management facility is defined as a facility that provides detention of stormwater runoff typically for the entire upstream watershed.

Restaurant: means a facility that sells prepared foods and drinks for consumption, including stationary lunch counters and refreshment stands selling prepared foods and drinks for immediate consumption (SIC Code 5812).

Retail Gasoline Outlet: Any facility engaged in selling gasoline and lubricating oils.

Retention: The storage of stormwater to prevent it from leaving the development site; may be temporary or permanent.

Runoff: Water originating from rainfall, melted snow, and other sources (e.g., sprinkler irrigation) that flows over the land surface to drainage facilities, rivers, streams, springs, seeps, ponds, lakes, wetlands, and shallow groundwater.

Run-on: Stormwater surface flow or other surface flow which enters property or area other than that where it originated. Off site stormwater surface flow or other surface flow which enters the site.

Scour: The erosive and digging action in a watercourse caused by flowing water.

Secondary Containment: Structures, usually dikes or berms, surrounding tanks or other storage containers and designed to catch spilled material from the storage containers.

Sedimentation: The process of depositing soil particles, clays, sands, or other sediments that were picked up by runoff.

Sediments: Soil, sand, and minerals washed from land into water, usually after rain, that accumulate in reservoirs, rivers, and harbors, destroying aquatic animal habitat and clouding the water such that adequate sunlight might not reach aquatic plants. Farming, mining, and building activities without proper implementation of BMPs will expose sediment materials, allowing them to be washed off the land after rainfalls.

Significant Materials: Includes, but not limited to, raw materials; fuels; materials such as solvents, detergents, and plastic pellets; finished materials such as metallic products; raw materials used in food processing or production; hazardous substances designed under Section 101(14) of CERCLA; any chemical the facility is required to report pursuant of Section 313 of Title III of SARA; fertilizers; pesticides; and waste products such as ashes, slag, and sludge that have the potential to be released with stormwater discharges.

Significant Quantities: The volume, concentrations, or mass of a pollutant in stormwater discharge that can cause or threaten to cause pollution, contamination, or nuisance that adversely impact human health or the environment and cause or contribute to a violation of any applicable water quality standards for receiving water.

Source Control BMPs: Any schedules of activities, structural devices, prohibitions of practices, maintenance procedures, managerial practices or operational practices that aim to prevent stormwater pollution by reducing the potential for contamination at the source of pollution.

Source Reduction (also Source Control): The technique of stopping and/or reducing pollutants at their point of generation so that they do not come into contact with stormwater.

Spill Guard: A device used to prevent spills of liquid materials from storage containers.

Spill Prevention Control and Countermeasures Plan (SPCC): Plan consisting of structures, such as curbing, and action plans to prevent and respond to spills of hazardous substances as defined in the CWA.

Storm Drains: Above- and below-ground structures for transporting stormwater to streams or outfalls for flood control purposes.

Storm Drain System: Network of above and below-ground structures for transporting stormwater to streams or outfalls.

Storm Event: A rainfall event that produces more than 0.1 inch of precipitation and is separated from the previous storm event by at least 72 hours of dry weather.

Stormwater: Stormwater runoff, snow-melt runoff, surface runoff, and drainage, excluding infiltration and irrigation tailwater. Urban runoff and snowmelt runoff consisting only of those discharges, which originate from precipitation events. Stormwater is that portion of precipitation that flows across a surface to the storm drain system or receiving waters.

Stormwater Discharge Associated with Industrial Activity: Discharge from any conveyance which is used for collecting and conveying stormwater which is related to manufacturing processing or raw materials storage areas at an industrial plant [see 40 CFR 122.26(b)(14)].

Stormwater Pollution Prevention Plan (SWPPP): A written plant that documents the series of phases and activities that, first, characterizes your site, and then prompts you to select and carry out actions which prevent the pollution of stormwater discharges.

Structural BMP: Any structural facility designed and constructed to mitigate the adverse impacts of stormwater and urban runoff pollution (e.g. canopy, structural enclosure). The category may include both Treatment Control BMPs and Source Control BMPs.

Treatment Controls: Any engineered system designed to remove pollutants by simple gravity settling of particulate pollutants, filtration, biological uptake, media adsorption or any other physical, biological, or chemical process. Treatment Controls, for the purposes of this Plan have been divided into two types: LID Treatment Controls and Conventional Treatment Controls.

Treatment: The application of engineered systems that use physical, chemical, or biological processes to remove pollutants. Such processes include, but are not limited to, filtration, gravity settling, media adsorption, biodegradation, biological uptake, chemical oxidation and ultraviolet radiation.

Toxicity: Adverse responses of organisms to chemicals or physical agents ranging from mortality to physiological responses such as impaired reproduction or growth anomalies.

Turbidity: Describes the ability of light to pass through water. The cloudy appearance of water caused by suspended and colloidal matter (particles).

Volume Reduction Measures: BMPs that can be used to direct, retain, reuse and/or infiltrate stormwater runoff (e.g., rain gardens and rain barrels**).**

Volume Reduction Requirement: New Development Priority Projects must reduce post-project runoff volume to pre-project runoff volumes for the 0.51” rainfall event (~85th percentile) using a combination of Volume Reduction Measures and LID Treatment Controls.

LIST OF ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt Concrete
ANSI	American National Standards Institute
APHA	American Public Health Association
APWA	American Public Works Association
ASTM	American Society for Testing Materials
AWWA	American Water Works Association
BAT	Best Available Technology (economically achievable)
BCT	Best Conventional Technology (pollution control)
BMPs	Best Management Practices
BOD	Biochemical Oxygen Demand
CAL-EPA	California Environmental Protection Agency
CAL-OSHA	California Division of Occupational Safety and Health Administration
CASQA	California Stormwater Quality Association
CCR	California Code of Regulations
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
COE	U.S. Army Corps of Engineers
CWA	Clean Water Act (Federal Water Pollution Control Act of 1972 as amended in 1987)
DCIA	Directly Connected Impervious Area
DTSC	California Department of Toxic Substances Control
EIR	Environmental Impact Report
EMC	Event Mean Concentration
EPA	United State Environmental Protection Agency
ESA	Environmentally Sensitive Area
ESC	Erosion and Sediment Control
FHWA	Federal Highway Administration
GIS	Geographical Information System
Hazmat	Hazardous Material
HSG	Hydrologic Soil Groups
IPM	Integrated Pest Management
LID	Low Impact Development
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
MSDS	Material Safety Data Sheet

NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NSF	National Science Foundation
O&G	Oil and Grease
O&M	Operations and Maintenance
OSHA	Occupational Safety and Health Administration
PAHs	Polyaromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCC	Portland Cement Concrete
PPT	Pollution Prevention Team
POTW	Publicly Owned Treatment Works
PSD	Particle Size Distribution
RCRA	Resource Conservation and Recovery Act
RGO	Retail Gasoline Outlet
RWQCB	Regional Water Quality Control Board
SAP	Sampling and Analysis Plan
SIC	Standard Industrial Classification
SPCC	Spill Prevention Control and Countermeasure
SQDF	Stormwater Quality Design Flow
SQDV	Stormwater Quality Design Volume
SWPCP	Stormwater Pollution Control Plan
SWPPP	Stormwater Pollution Prevention Plan
SWQCCP	Stormwater Quality Control Criteria Plan
SWQCP	Stormwater Quality Control Plan
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TSS	Total Suspended Solids
UFC	Uniform Fire Code
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency
WEF	Water Environment Federation

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Volume Reduction Requirement Summary Worksheet

Project:____

Detail:____

Design by:______________________________________

Date:____

1. Project Drainage Area Characteristics: Pre-project			
a. Weighted Runoff Coefficient (C_{rPRE})	C_{rPRE} =	__________	
b. Total Drainage Area (A_{PRE})	A_{PRE} =	__________	ft^2
c. Pre-project Runoff Volume (Vol_{PRE})* $Vol_{PRE} = (0.51/12) \times A_{PRE} \times C_{rPRE}$	Vol_{PRE}=	__________	ft^3
2. Project Drainage Area Characteristics: Post-project			
a. Weighted Runoff Coefficient (C_{ra})	C_{ra} =	__________	
b. Total Drainage Area (A_{POST})	A_{POST} =	__________	ft^2
c. Post-project Runoff Volume (Vol_{POST}) $Vol_{POST} = (0.51/12) \times A_{POST} \times C_{ra}$	Vol_{POST}=	__________	ft^3
d. Volume Reduction Requirement (VRR)* **$VRR = Vol_{POST} - Vol_{PRE}$**	**VRR =**	__________	**ft^3**
3. Volume Reduction Measures (VRMs):			
a. Total number of VRMs in project	No. VRMs =	__________	
b. Total Volume Reduction Credits from VRMs ($\sum Vol_{VRM}$)	$\sum Vol_{VRM}$ =	__________	ft^3
c. Total Tributary Impervious Area Reduction Credits for application to effective area calculation ($\sum Area_{credit}$)	$\sum Area_{credit}$ =	__________	ft^2
d. Remaining Volume Reduction required from LID Treatment Controls (VRR_{TREAT}) $VRR_{TREAT} = VRR - \sum Vol_{VRM}$	**VRR_{TREAT} =**	__________	**ft^3**
4. LID Treatment Controls – Volume Reduction Credits			
a. Total Volume Reduction Credits from LID Treatment Controls ($\sum Vol_{TREAT}$)	$\sum Vol_{TREAT}$ =	__________	ft^3
b. Total Volume Reduction Provided ($VRR_{PROVIDED}$) $VRR_{PROVIDED} = \sum Vol_{VRM}$ (line 3b) + $\sum Vol_{TREAT}$ (line 4a)	$VRR_{PROVIDED}$ =	__________	ft^3
c. Volume Reduction remaining (VRR_{REMAIN}) $VRR_{REMAIN} = VRR - VRR_{PROVIDED}$	**VRR_{REMAIN} =**	__________	**ft^3**

Note: If $VRR_{REMAIN} > 0$, the Volume Reduction Requirement is not fully met. Meeting the Volume Reduction Requirement may be iterative for most sites - designers should return to prior steps to explore alternative combinations of Volume Reduction Measures and LID Treatment Controls. If the meeting the full Volume Reduction Requirement is infeasible, a Volume Reduction Requirement Waiver Application must be submitted (see Section 5-2 and Appendix C).

*Apply reductions to Volume Reduction Requirement as appropriate for Significant Redevelopment as described in Section 5.

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Volume Reduction Requirement Waiver Application

A waiver may be granted if the Volume Reduction Requirement cannot be met due to site constraints, such as a high groundwater table. However, even if the project cannot meet the full Volume Reduction Requirement, the project must still reduce volume to the maximum extent practicable. The burden of proof is on the project applicant to show why the full Volume Reduction Requirement cannot be met. Economic hardship is not an acceptable reason for noncompliance. In general, the City and County do not expect to grant waivers for the Volume Reduction Requirement.

Meeting the Volume Reduction Requirement is an iterative process. Designers should return to prior steps to explore alternative combinations of Volume Reduction Measures and LID Treatment Controls. Projects that cannot fully meet the Volume Reduction Requirement and are located in a watershed with a 303d listed waterbody, must select Treatment Controls with a medium to high removal efficiency for the pollutant of concern (see Table 6-2).

The final determination will be made by City of Stockton Department of Municipal Utilities, Technical Services Division or the San Joaquin County Department of Public Works, Community Infrastructure Division. The City and County have the authority to reject a Volume Reduction Requirement Waiver request if Volume Reduction Measures and/or LID Treatment Controls are considered feasible at the project site.

Consideration of a waiver request requires applicants to:

- Reduce volume to the maximum extent practicable, even if the full Volume Reduction Requirement cannot be met.
- Consider all of the Volume Reduction Measures and LID Treatment Controls. Applicants must show why certain Volume Reduction Measures and/or LID Treatment Controls are not feasible at the development site.
- Submit this application with or prior to preliminary site plan submission.
- Obtain the signature and stamp of the project engineer registered in California.
- Submit the Volume Reduction Design Summary Worksheet (Appendix B) along with this application.

1. **Project Name** ____________________
2. **Project Category** ____________________
(See Section 2 for categories)
3. **Property Description** ____________________
(include location, size, land uses, etc.)
4. **Owner/Developer's Name** ____________________
   Address ____________________
   Phone ____________________
5. **Plan Preparer's Name** ____________________
   Address ____________________
   Phone ____________________

6. Volume Reduction

Volume Reduction Requirement
(Volume Reduction Summary Worksheet, line 2e) ______________________________

Volume Reduction Provided
(Volume Reduction Summary Worksheet, line 4b) ______________________________

Volume Reduction Remaining
(Volume Reduction Summary Worksheet, line 4c) ______________________________

Type and Number of Volume Reduction Measures Proposed:

____ Rain Garden (V-1)
____ Rain Barrel/Cistern (V-2)
____ Vegetated Roof (V-3)
____ Interception Trees (V-4)
____ Grassy Channel (V-5)
____ Vegetated Buffer Strip (V-6)

Type and Number of LID Treatment Controls Proposed:

____ Bioretention (L-1)
____ Stormwater Planter (L-2)
____ Tree-well Filter (L-3)
____ Infiltration Basin (L-4)
____ Infiltration Trench/Dry Well (L-5)
____ Porous Pavement Filter (L-6)
____ Vegetated (Dry) Swale (L-7)
____ Grassy Swale (L-8)
____ Grassy Filter Strip (L-9)

7. Describe Why a Volume Reduction Requirement Waiver is Needed

(please include specifics regarding site constraints – e.g., results of any soil testing that may have been done)

CERTIFICATION

I hereby certify that the information provided in this Application is correct

Application Prepared By: ______________________________

Print Name and Firm

Signed

____

(Signature of Project Engineer in the Firm Named Above)

Title

____

(Affix professional registration stamp of the person named above with signature and expiration date)

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Maintenance Agreements and Forms

This appendix includes the following maintenance agreements and forms:

D-1: Stormwater Treatment Device Access and Maintenance Agreement

D-2: Owner’s Certification Statement

D-3: Sample Engineer’s Report

INSTRUCTIONS TO COMPLETE

STORMWATER TREATMENT DEVICE ACCESS
AND MAINTENANCE AGREEMENT

Please complete the following:

1. Complete the Stormwater Treatment Device Access and Maintenance Agreement (Agreement) with the owner(s) name, mailing address, property address, and assessor parcel number. Enter the date and owners names in the first paragraph. A copy of the Deed must be attached as the last page to verify the ownership and legal description. Complete the **owner acknowledgment** on page 5, and have it notarized.

2. Return one original signed copy of the Agreement to the Municipal Utilities Department, c/o John Wotila, 2500 Navy Drive, Stockton, CA 95206. A recording fee check payable to the San Joaquin County Recorder must be submitted with signed agreement upon filing with the City. The recording fee is currently $8.00 for the first page and $3.00 for each additional page. City staff will record the executed Agreement at the office of the San Joaquin County Recorder.

3. The City will provide one fully-executed copy of Agreement to the Owner for his/her record.

Should you have questions or require other assistance regarding this matter, please do not hesitate to contact John Wotila at (209) 937-8436 in the Permit Center.

Stormwater Treatment Device
Access and Maintenance
Agreement

After recorded, return to:
Rebecca King
City of Stockton
Municipal Utilities Department
2500 Navy Drive
Stockton, CA 95206

MUNICIPAL UTILITIES DEPARTMENT
After Recording Transmit Copy to:

___ Owner of Record
___ Municipal Utilities Department
____City Clerk (Original)

OWNER NAME (S)
(as shown on deed) &
MAILING ADDRESS ____

____

O&M CONTACT
PERSON & PHONE # ____

____

FACILITY NAME
AND ADDRESS ____

____

ASSESSOR PARCEL NO. ____

THIS AGREEMENT is made and entered into in ______________________, California, this ____ day of __________________, by and between__________________________________ hereinafter referred to as "Owner" and the CITY OF STOCKTON, a municipal corporation, located in the County of San Joaquin, State of California hereinafter referred to as "CITY";

WHEREAS, the Owner owns real property ("Property") in the City of Stockton, County of San Joaquin, State of California, depicted in Exhibit “A” and intends to install a pollution control system described in Exhibit “B”, both of which are attached hereto and incorporated herein by this reference;

WHEREAS, at the time of initial approval of development project known as ____ within the Property described herein, the City required the project to employ on-site control measures to minimize pollutants in urban runoff;

WHEREAS, the Owner has chosen to install a______________________, hereinafter referred to as "Device", as the on-site control measure to minimize pollutants in urban runoff;

WHEREAS, said Device has been installed in accordance with the requirements of the City of Stockton Stormwater Quality Control Criteria Plan and the Owner’s plans and specifications accepted by the City;

WHEREAS, said Device, with installation on private property and draining only private property, is a private facility with all operation, maintenance and replacement, therefore, the sole responsibility of the Owner in accordance with the terms of this Agreement;

WHEREAS, the Owner is aware that periodic and continuous maintenance, including, but not necessarily limited to, sediment removal, is required to assure peak performance of Device and that, furthermore, such maintenance activity will require compliance with all Local, State, or Federal laws and regulations, including those pertaining to confined space and waste disposal methods, in effect at the time such maintenance occurs;

NOW THEREFORE, it is mutually stipulated and agreed as follows:

1. Owner hereby provides the City or City's designee complete access, of any duration, to the Device and its immediate vicinity at any time, upon reasonable notice, or in the event of emergency, as determined by City's Director of Municipal Utilities with no advance notice, for the purpose of inspection, sampling, testing of the Device, and in case of emergency, to undertake all necessary repairs or other preventative measures at owner's expense as provided in paragraph 3 below. The Owner/Operator shall retain all operation and maintenance records at the facility for City inspection, and a copy shall be provided to the City if requested. City shall make every effort at all times to minimize or avoid interference with Owner's use of the Property.

2. Owner shall use its best efforts to diligently maintain the Device in a manner assuring peak performance at all times. All reasonable precautions shall be exercised by Owner and Owner's representative or contractor in the removal and extraction of material(s) from the Device and the ultimate disposal of the material(s) in a manner consistent with all relevant laws and regulations in effect at the time. When requested from time to time by the City, the Owner shall provide the City with documentation identifying the material(s) removed, the quantity, and disposal destination.

3. In the event Owner, or its successors or assigns, fails to accomplish the necessary maintenance contemplated by this Agreement, within five (5) days of being given written notice by the City, the City is hereby authorized to cause any maintenance necessary to be done and charge the entire cost and expense to the Owner or Owner's successors or assigns,

including administrative costs, attorneys fees and interest thereon at the maximum rate authorized by the Civil Code from the date of the notice of expense until paid in full, and Owner hereby agrees to pay such charge within 30 days of receipt of City's written demand for payment.

4. The City may require the owner to post security in form and for a time period satisfactory to the City of guarantee the performance of the obligations stated herein. Should the Owner fail to perform the obligations under the Agreement, the City may, in the case of a cash bond, act for the Owner using the proceeds from it, or in the case of a surety bond, require the sureties to perform the obligations of the Agreement. As an additional remedy, the Director may withdraw any previous stormwater related approval with respects to the property on which a Device has been installed until such time as Owner repays to City its reasonable costs incurred in accordance with paragraph 3 above.

5. This agreement shall be recorded in the Office of the Recorder of San Joaquin County, California, at the expense of the Owner and shall constitute notice to all successors and assigns of the title to said Property of the obligation herein set forth, and also a lien in such amount as will fully reimburse the City, including interest as herein above set forth, subject to foreclosure in event of default in payment.

6. In event of legal action occasioned by any default or action of the Owner, or its successors or assigns, then the Owner and its successors or assigns agree(s) to pay all costs incurred by the City in enforcing the terms of this Agreement, including reasonable attorney's fees and costs, and that the same shall become a part of the lien against said Property.

7. It is the intent of the parties hereto that burdens and benefits herein undertaken shall constitute covenants that run with said Property and constitute a lien there against.

8. The obligations herein undertaken shall be binding upon the heirs, successors, executors, administrators and assigns of the parties hereto. The term "Owner" shall include not only the present Owner, but also its heirs, successors, executors, administrators, and assigns. Owner shall notify any successor to title of all or part of the Property about the existence of this Agreement. Owner shall provide such notice prior to such successor obtaining an interest in all or part of the Property. Owner shall provide a copy of such notice to the City at the same time such notice is provided to the successor.

9. Time is of the essence in the performance of this Agreement.

10. Any notice or demand for payment to a party required or called for in this Agreement shall be served in person, or by deposit in the U.S. Mail, first class postage prepaid, to addresses listed on Page 1 of this agreement either for the Owner or City. Notice(s) shall be deemed effective upon receipt, or seventy-two (72) hours after deposit in the U.S. Mail, whichever is earlier. A party may change a notice address only by providing written notice thereof to the other party.

IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

CITY OF STOCKTON, a
Municipal corporation

ATTEST: APPROVED AS TO FORM:

By ___________________________________
J. GORDON PALMER JR., CITY MANAGER

OFFICE OF THE CITY ATTORNEY

By_______________________________
Assistant City Attorney

(Name of facility in bold)

By __________________________________
PROPERTY OWNER

Name ________________________________

Title _________________________________

CITY ACKNOWLEDGMENT

STATE OF CALIFORNIA
COUNTY OF SAN JOAQUIN)

On ________________before me, ____
(Insert Name and Title of Officer)

personally appeared ____, who proved to me on the basis of satisfactory evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

____
Signature of Notary

(Seal)

OWNER ACKNOWLEDGMENT

STATE OF CALIFORNIA
COUNTY OF ________________________________)

On ________________before me, ____
(Insert Name and Title of Officer)

personally appeared ____, who proved to me on the basis of satisfactory evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

________________________________ **(Seal)**
Signature of Notary

OWNER ACKNOWLEDGMENT

STATE OF CALIFORNIA
COUNTY OF ________________________________)

On ________________before me, ____
(Insert Name and Title of Officer)

personally appeared ____, who proved to me on the basis of satisfactory evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

________________________________ **(Seal)**
Signature of Notary

OWNER(S)

______________________________ ___________________________________

<u>OWNER ACKNOWLEDGMENT</u>

STATE OF CALIFORNIA)
) ss
COUNTY OF SAN JOAQUIN)

On _______________ before me, ____
(Name, Title of Officer)

personally appeared _________________________, ( ) personally known to me or ( ) proved to me on the basis of satisfactory evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

WITNESS my hand and official seal.

____
Signature of Notary

<u>EXHIBIT A</u>

(Operation & Maintenance Plan)

<u>EXHIBIT B</u>

(Deed Copy)

OWNER'S CERTIFICATION

STOMWATER QUALITY CONTROL PLAN
for
__________(PROJECT NAME)______

This Project Stormwater Quality Control Plan (Plan) was prepared for ___(Project Owner / Developer)___ by _________(Name of Preparing Firm/Individual)______. This Plan is intended to comply with all requirements specified in the City of Stockton Stormwater Quality Control Criteria Plan (SWQCCP) for new development and redevelopment projects.

The undersigned understands that stormwater pollution control measures are enforceable requirements under the SWQCCP. The undersigned, while owning the property on which such control measures are to be implemented, is responsible for the implementation of the provisions of this Plan and for the maintenance of all structural stormwater pollution control measures and agrees to ensure that the conditions on the project site conform to the requirements specified in the SWQCCP.

Once the undersigned transfers its interest in the project property, its successors-in-interest shall bear the aforementioned responsibility to maintain structural stormwater pollution control measures and to implement and amend this Plan.

Name of Owner
Address of Owner
Phone number of Owner

Signature ______________________________________

Print Name ______________________________________

Title ______________________________________

Date ______________________________________

ENGINEER'S REPORT
CANNERY PARK ZONE 2
STOCKTON CONSOLIDATED STORM DRAINAGE MAINTENANCE ASSESSMENT DISTRICT NO. 2005-1
CITY OF STOCKTON
(PURSUANT TO THE MUNICIPAL IMPROVEMENT ACT OF 1913 AND STOCKTON IMPROVEMENT PROCEDURE CODE, PART V)

FISCAL YEAR 2005-06

PREPARED BY:

Thompson-Hysell Engineers,
a division of The Keith Companies, Inc.
1016 12th Street
Modesto, CA 95354

NOVEMBER 1, 2005

ENGINEER'S REPORT
FOR THE 2005-06 FISCAL YEAR

CANNERY PARK ZONE 2
STOCKTON CONSOLIDATED STORM DRAINAGE MAINTENANCE
ASSESSMENT DISTRICT NO. 2005-1
CITY OF STOCKTON
(Pursuant to the Municipal Improvement Act of 1913 and
Stockton Improvement Procedure Code, Part V)

The undersigned respectfully submits the enclosed Engineer's Report as directed by the City Council.

DATED: ____________________, 2005.

Thompson-Hysell Engineers
Engineer of Work

BY:

Michael T. Persak
RCE 44908

I HEREBY CERTIFY that the enclosed Engineer's Report, together with Boundary Map, Assessment, and Assessment Diagram thereto attached, was filed with me on the ________ day of ____________, 2005.

_____________________________, City Clerk, City of Stockton
San Joaquin County, California

BY:

I HEREBY CERTIFY that the enclosed Engineer's Report, together with Assessment and Assessment Diagram thereto attached, was approved and confirmed by the City Council of the City of Stockton, California on the ________ day of _________________, 2005.

_____________________________, City Clerk, City of Stockton
San Joaquin County, California

BY:

I HEREBY CERTIFY that the enclosed Engineer's Report, together with Assessment and Assessment Diagram thereto attached, was filed with the Auditor of the County of San Joaquin on the___________ day of ___________________, 2005.

_____________________________, City Clerk, City of Stockton
San Joaquin County, California

BY:

November 1, 2005

The Honorable Mayor and
City Council of The City of
Stockton, CA

To Whom It May Concern:

This report is prepared pursuant to and in compliance with the requirements of the "Municipal Improvement Act of 1913," as amended, commencing with the Streets and Highways code sections 10000, et seq. and the Stockton Improvement Procedure Code, Part V, commencing with code sections 9-101, et seq, for the creation of a new Zone (Cannery Park Zone 2) in the Stockton Consolidated Storm Drainage Maintenance Assessment District No. 2005-1.

BACKGROUND

The Cannery Park project consists of a 960-lot residential subdivision, one multi-family residential lot, six commercial lots, one light industrial lot, one school site, two park sites, and a fire department site. The development is located in the north portion of the City of Stockton, on the south side of Eight Mile Road and the west side of the Highway 99 frontage road. The development is being pursued by Vascorp Investments Corporation. The Cannery Park project includes amenity improvements of various public areas. This report is relative to the proposed Cannery Park Zone 2 of the City of Stockton Consolidated Storm Drainage Maintenance Assessment District, which provides annual funds for the maintenance of various public storm drainage improvements. Exhibit A, the proposed annexation roll, details how each lot will be assessed.

PHASED DEVELOPMENT

Cannery Park is currently anticipated to be constructed in multiple units. The general nature of the storm drainage improvements for all units is described in the "Description of Facilities to be Maintained." Annually, the additional storm drainage improvements and the additional subdivision developed areas, if any, shall be identified. The costs of the maintenance of the new improvements, if any, shall be added to and included in the next annual storm drainage maintenance budget. Cannery Park, when completed, will include approximately 960 single-family residential lots, one multi-family residential lot, six commercial lots, one light industrial lot, one school site, two park sites, and a fire department site.

ASSESSMENT DISTRICT AREA

The area proposed to be formed into Zone 2 is described as all of the property within the following assessor's parcels identified by assessor's number (APN):

Book	Page	Parcels
092	040	03, 04, 05, 06, 07, 11, 12, 15, 16

A Boundary Map is attached to this Engineer’s Report as Exhibit B. The Assessment Diagram for Cannery Park Zone 2 is attached to the Engineer’s Report as Exhibit C. A County Assessors Map is also included. Exhibit D shows the areas to be maintained.

PLANS AND SPECIFICATIONS

As various phases of this project are developed, plans and specifications for the storm drainage improvements to be maintained by the funds generated by Cannery Park Zone 2 are filed separately with the City of Stockton and are incorporated into this report by reference.

DESCRIPTION OF FACILITIES TO BE MAINTAINED

Certain public storm drainage improvements are to be installed by the developers as part of the Conditions of Approval for the Cannery Park project. Cannery Park Zone 2 was created to provide funding for the continued maintenance of the storm drainage facilities, which are described below. During the installation period for each phase, the developer will maintain the new drainage improvements until the following June 30, at which time the new areas shall be incorporated into the storm drainage improvements already being maintained by the District.

Zone 2 is divided into two sub-zones, Zone 2-A and Zone 2-B. These represent the two separate drainage systems within the Cannery Park development.

The following improvements shall be included in Zone 2-A (Cannery Park Basin) upon their completion.

1. Description of Improvements (Zone 2-A, Cannery Park Basin)

   A. An access road to be maintained.

   B. An extended detention basin to be maintained and inspected semi-annually at the beginning and end of the wet season for: slope stability, sediment accumulation, trash and debris, presence of burrows, mowless grass or approved equivalent.

   C. Inspection and treatment of Vector control.

   D. Inspect and maintain wrought iron fence and gate that surrounds extended detention basin.

The following improvements shall be included in Zone 2-B (SJAFCA Basin #2) upon their completion.

2. Description of Improvements (Zone 2-B, SJAFCA Basin #2)

A. Rip base surface of basin once annually.

B. Manually turn low-flow summer pump on for ripping of surface and turn low-flow summer pump off after ripping of surface is complete.

C. Inspection and treatment of Vector control.

D. Pick up debris and trash in basin on semi-monthly basis.

ALLOCATION OF COSTS

Assessments for the Cannery Park Storm Drainage Maintenance Assessment District are apportioned in a manner intended to fairly distribute the amounts among all assessable developed parcels in proportion to the estimated benefits to be received by each such parcel. The assessment shall be levied on the basis of the adjusted drainage areas of each such lot and/or parcel. A parcel is considered as being developed by reason of having been included as a lot or parcel in the recorded Final Map(s) or being included within the active developed area in the case of an existing parcel. The criteria for apportioning the costs for the maintenance makes use of a dwelling unit equivalent Factor (*dueF*) to calculate the benefit for all uses in terms of equivalent dwelling units. The terms, definitions, and procedures followed to develop the annual assessments are as follows:

1. Calculation of Runoff Coefficient
All developed parcels shall be directly proportional to a single-family residential development, assuming 5 developed single-family lots per acre with a runoff coefficient of 0.35.

Example Calculation:

Determine *dueF* per acre for a developed parcel with a runoff coefficient of 0.65.

$$\frac{\text{Parcel (Developed)}}{0.65} = \frac{\text{5 Single-Family (Developed)}}{0.35}$$

= Parcel (Developed) = 9.3 *dueF* per Acre

2. Dwelling Unit Equivalent Factor (*dueF*)

The *dueF* for each use is as follows:

A. Single-Family Residential
All parcels developed for single-family use shall be determined to have a runoff coefficient of 0.35 and a *dueF* of 1.0 for each parcel.

B. Multi-Family Residential
All parcels determined to be developed for multi-family residential shall be determined to have a runoff coefficient of 0.65 and a *dueF* of 9.3 per acre, which is representative of the increase in storm drainage runoff between a multi-family residential site and a single-family residential development.

C. School Site

All parcels developed for a school site shall be determined to have a runoff coefficient of 0.39 and a *dueF* of 5.56 per acre, which is representative of the increase in storm drainage runoff between a school site and a single-family residential development.

D. Park Site

All parcels developed for a park site shall be determined to have a runoff coefficient of 0.15 and a *dueF* of 2.14 per acre, which is representative of the decrease in storm drainage runoff between a park as compared to a single-family residential development.

E. Industrial/Commercial/Fire Department

All parcels developed for an industrial/commercial/fire department site shall be determined to have a runoff coefficient of 0.90 and a *dueF* of 12.9 per acre, which is representative of the increase in storm drainage runoff between an industrial/ commercial/fire department site as compared to a single-family residential development.

F. Other Uses

All parcels determined to have uses other than identified above shall have a *dueF* established at the time of the first annual budget affecting such areas as determined by the Engineer or other officer appointed by the City of Stockton to prepare the annual cost spread. The determined *dueF* shall follow the character of the factors assigned above as nearly as practicable, but the determination shall be the sole responsibility of the appointed party and the City of Stockton.

G. Zero Dwelling Unit Equivalent Factor (*dueF*)

Certain parcels, by reason of use, size, shape, or state of development, may be assigned a zero *dueF* which will consequently result in a zero assessment for that fiscal year. All parcels having such a zero *dueF* for the previous fiscal year shall annually be reconsidered to determine if the reason for assigning the zero *dueF* is still valid for the next fiscal year. Parcels which may be expected to have a zero *dueF* assigned are typically parcels which are all, or nearly all, publicly landscaped, and remainder parcels too small or narrow for reasonable residential or commercial use, unless actually in use.

3. Compilation

Annually, about May 15, following the determination of the *dueF* for all developed parcels and the determination of the list of developed parcels by APN for the next fiscal year, all single-family or duplex/triplex residential parcels shall have a *due* assigned to each parcel equal to the *dueF* for that parcel. For all parcels other than single-family or duplex/triplex residential parcels, the product of the *dueF* times the area or adjusted usable area of the parcel, as appropriate, shall be calculated and shall be the *due* assigned. For developed parcels, the sum of the *due* assigned to each single-family *due* for each other parcel shall equal the total *due* for the next fiscal year. The total amount of revenue required for the next fiscal year shall then be divided by the total *due* to calculate the assessment per *due* for the next fiscal year. Parcels defined as not developed for the purposes of determining the storm drainage maintenance assessments will all have a zero *dueF* and consequently a zero *due* and a zero assessment.

4. Allocation of Assessments

The assessment for maintenance for the next fiscal year shall then be set for each parcel as the product of the calculated dwelling unit equivalent (*due*) for each parcel, multiplied by the assessment per *due* for the next fiscal year.

METHOD OF ASSESSMENT SPREAD

In compliance with the provisions of Proposition 218, adding Article XIII D to the California Constitution, the benefits conferred on each parcel within Zone 2 of the Stockton Consolidated Storm Drainage Maintenance Assessment District No. 2005-1 are particular and distinct benefits (hereinafter “special benefits”) over and above general benefits conferred on such property or to the public at large, in that the individual number-designated zones in the District each represents a common unit to provide storm drainage quality control for the development of the property within the individual number-designated zones in the District generally for residential and related urban uses. Benefits are determined to be 100% special benefits and 0% general benefits. Also, in keeping with the requirements of Proposition 218, no annual individual assessments shall be increased above the amounts assessed under the established criteria for each zone for the preceding fiscal year without an election approval, except as provided by the annual escalation factor.

The assessments are to be levied on the basis of the adjusted drainage areas of each of such lots and/or parcels.

Pursuant to Article XIII D, Section 4, of the California Constitution, publicly owned properties which receive special benefit from the improvements must be assessed a proportionate share of the costs thereof.

The base objective of the assessment spread is to distribute costs in accordance with the benefits received. Costs will be spread equally to each residential lot, school site, park site, and industrial/ commercial/fire department site *due* as follows:

Zone 2-A

A. Lots A, B, C, D, F, and Y.

Zone 2-B

A. Village A, lots 1-51; Village B, lots 1-36; Village C, lots 1-47; Village D1, lots 1-86; Village D2, lots 1-87; Village E1, lots 1-129; Village E2, lots 1-102; Village F, lots 1-146; Village G1, lots 1-154; Village G2, lots 1-122; Lot E, school site, park sites, and fire department site.

As improvements are constructed in subsequent units of said subdivision, the cost of maintaining such additional improvements will be added to the cost of maintaining entire district improvements during each fiscal year following the completion of such additional improvements, and the total cost of such maintenance shall be assessed equally against all lots within the respective district.

ANNUAL ESCALATION

The maximum assessment amount for each fiscal year shall be increased in an amount equal to the greater of: 1) three percent (3.0%), or 2) the percentage increase of the Local Consumer Price Index (CPI). Consumer Price Index applied is for the San Francisco-Oakland-San Jose County Area for All Urban Consumers, as developed by the U.S. Bureau of Labor Statistics for a similar period of time.

ADMINISTRATION

It is intended that the City of Stockton, either directly or by subcontract, shall have the responsibility to establish an ongoing Storm Drainage Maintenance Management entity to be known as the Storm Drainage Maintenance District Manager which shall be responsible to establish the annual budget, keep an accounting of the maintenance and operational administrative costs, administer and perform the storm drain maintenance either directly or by subcontract, pay all fees, utility costs, taxes, and any and all other operating costs.

ESTIMATE OF COSTS

The estimated costs are for public storm drainage maintenance only. All initial improvements will be installed by the developer, at no cost to the Storm Drainage Maintenance Assessment District. The cost of maintaining the improvements will be paid by the developer to the District through the end of the fiscal year (June 30) and until such time as sufficient funds (not to exceed the total maximum assessment) are available from the District's annual assessments.

Items considered in the maintenance cost include, but are not limited to: regularly scheduled maintenance, and facility repair and replacement at the end of its useful life.

The Cannery Park development is required to ensure that all property owners within the subdivision pay their proportionate share of the cost to maintain the storm drainage quality control facilities within the service area for the subdivision or serving the subdivision.

The annual costs estimated to be collected with the 2005-06 taxes for the initially developed area are as follows. Refer to the cost breakdowns which follow the estimated costs for detailed information on the items marked with an asterisk (*).

ZONE 2-A

OPERATION COSTS	**MAXIMUM ANNUAL ASSESSMENT**	**FY 2005-06 ACTUAL ASSESSMENT**
Cannery Park Extended Detention Basin (Zone 2-A)		
Maintenance/Repair*	$8,640.00	$0.00
Watering Mowless Sod*	$600.00	$0.00
Replacement Reserve*	$2,000.00	$0.00
Subtotal Extended Detention Basin Costs	*$11,240.00*	*$0.00*
Wrought Iron Fence and Gate Maintenance (Zone 2-A)		
Maintenance/Graffiti Control*	$2,400.00	$0.00
Replacement Reserve*	$500.00	$0.00
Subtotal Wrought Iron Fence and Gate Costs	*$2,900.00*	*$0.00*
Inspection/Management*	$1,680.00	$0.00
Total Operation Costs	$15,820.00	$0.00

OPERATION COSTS		MAXIMUM ANNUAL ASSESSMENT	FY 2005-06 ACTUAL ASSESSMENT
DISTRICT ADMINISTRATION COSTS (Split Equally Between Zones 2-A and 2-B)			
Attorney Fees	($1,500.00)	$750.00	$750.00
Annual Engineers' Report	($2,000.00)	$1,000.00	$1,000.00
Publication	($200.00)	$100.00	$100.00
City Administration Fee	($5,000.00)	$2,500.00	$2,500.00
County Administration Fee	($1,000.00)	$500.00	$500.00
Total Administration Costs		$4,850.00	$4,850.00
Total Operation and Administration Costs		**$20,670.00**	**$4,850.00**
Estimated Contingency (10±%)		**$2,078.62**	**$485.00**
Total Estimated Revenue Required for 2005-06 Fiscal Year		**$22,748.62**	**$5,335.00**
Total Appropriation Required from Existing Fund Balance		**$0.00**	**$0.00**
Total Estimated Assessment for 2005-06 Fiscal Year		**$22,748.62**	**$5,335.00**
Developer's Contribution		**$0.00**	**$5,335.00**
Total *dueF*		**1,999**	**0**
Estimated Assessment per *dueF*		**$11.38**	**$0.00**

ZONE 2-A COST BREAKDOWN

Cannery Park Extended Detention Basin
***Maintenance/Repair*: 12 site visits for trash pickup, mowless sod check and repair, slope check and repair, berm check and repair, low-flow channel check and repair, sprinkler check and repair at $470.00 per site visit (including materials for repair) = $5,640.00; Vector Control inspection and spraying (including materials) = $3,000.00**
Watering Mowless Sod: $600.00
***Replacement Reserve*: $2,000.00 (x 50 years = $100,000.00 + 3% interest rate)**

Wrought Iron Fence and Gate Maintenance
***Maintenance/Graffiti Control*: 12 site visits to remove graffiti at $200.00 per site visit = $2,400.00**
***Replacement Reserve*: $500.00 (x 50 years = $25,000.00 + 3% interest rate)**

***Inspection/Management*:** 2 hours per month x 12 months per year x $70.00 per hour = $1,680.00

ZONE 2-B

OPERATION COSTS		**MAXIMUM ANNUAL ASSESSMENT**	**FY 2005-06 ACTUAL ASSESSMENT**
SJAFCA Basin #2 (Zone 2-B)			
Vector Control*		$3,000.00	$3,000.00
Rip Basin Bottom*		$7,000.00	$7,000.00
Low Flow Pump Operations*		$500.00	$500.00
Debris/Trash Maintenance*		$1,680.00	$1,680.00
Subtotal SJAFCA Basin #2 Costs		*$12,180.00*	*$12,180.00*
Inspection/Management*		$1,680.00	$1,680.00
Total Operation Costs		$13,860.00	$13,860.00
DISTRICT ADMINISTRATION COSTS (Split Equally Between Zones 2-A and 2-B)			
Attorney Fees	($1,500.00)	$750.00	$750.00
Annual Engineers' Report	($2,000.00)	$1,000.00	$1,000.00
Publication	($200.00)	$100.00	$100.00
City Administration Fee	($5,000.00)	$2,500.00	$2,500.00
County Administration Fee	($1,000.00)	$500.00	$500.00
Total Administration Costs		*$4,850.00*	*$4,850.00*
Total Operation and Administration Costs		**$18,710.00**	**$18,710.00**
Estimated Contingency (10±%)		**$1,867.66**	**$1,867.66**
Total Estimated Revenue Required for 2005-06 Fiscal Year		**$20,577.66**	**$20,577.66**
Total Appropriation Required from Existing Fund Balance		**$0.00**	**$0.00**
Total Estimated Assessment for 2005-06 Fiscal Year		**$20,577.66**	**$20,577.66**
Developer's Contribution		**$0.00**	**$19,866.86**
Total *dueF*		**1,158**	**40**

Estimated Assessment per *dueF* **$17.77** **$17.77**

ZONE 2-B COST BREAKDOWN

SJAFCA Basin #2
Vector Control: **Vector Control inspection and spraying (including materials) = $3,000.00**
Rip Basin Bottom: Excavate temporary swale from north inlet along west base to inlet of pump station; Rip surface approximately 4-5 feet = $7,000.00
Low Flow Pump Operations: Turn summer pump on for approximately one week to drain basin for maximum surface dry out; Turn summer pump off = $500.00
Debris/Trash Maintenance: (Semi-monthly visits) 2 hours per visit x 2 visits per month = 4 hours per month x 12 months x $35.00 per hour = $1,680.00

***Inspection/Management**:* 2 hours per month x 12 months per year x $70.00 per hour = $1,680.00

ASSESSMENT ROLLS

The assessment roll for proposed Zone 2-A for the fiscal year 2005-06 is as follows:

Assess-ment No.	APN No.	Cannery Park Future Lot Nos.	Owner	No. of *dueF's*	Maximum Annual Assessment	FY 2005-06 Actual Assessment
1	092-040-03	Lot A (20.49 acres) (*264 dueF's);* Basin	Vascorp Investments Corporation	264	$3,004.32	$0.00
2	092-040-04	Lot A (21.1 acres) (*272 dueF's)*, Lot B (11.3 acres) *(146 dueF's)*; Basin	Vascorp Investments Corporation	418	$4,756.84	$0.00
3	092-040-05	Lot B (2.0 acres) *(26 dueF's)*	Vascorp Investments Corporation	26	$295.88	$0.00
4	092-040-06	Lot B (10.0 acres) *(129 dueF's)*; Lot C (7.9 acres) *(102 dueF's)*; Lot D (37.4 acres) *(482 dueF's)*; Lot F (12.2 acres) *(157 dueF's)*; Lot Y (5.5 acres) *(71 dueF's)*	Vascorp Investments Corporation	941	$10,708.58	$0.00
5	092-040-16	Lot A (27.1 acres) *(350 dueF's)*	Vascorp Investments Corporation	350	$3,983.00	$0.00
Developer's Contribution				0	$0.00	$5,335.00
Total				1,999	$22,748.62	$5,335.00

The assessment roll for proposed Zone 2-B for the fiscal year 2005-06 is as follows:

Assess-ment No.	APN No.	Cannery Park Future Lot Nos.	Owner	No. of *dueF's*	Maximum Annual Assessment	FY 2005-06 Actual Assessment*
1	092-040-03	Village E1, Lots 20-34, 97-129; Village E2, Lots 1-6, 40-69 *(84 dueF's)*; Park (1.12 acres) *(2 dueF's)*	Vascorp Investments Corporation	86	$1,528.22	$0.00
2	092-040-04	Village E1, Lots 1-19, 35-96; Village A, Lots 1-51; Village B, Lots 1-36 *(168 dueF's)*	Vascorp Investments Corporation	168	$2,985.36	$0.00
3	092-040-06	Village C, Lots 1-47 *(47 dueF's)*; Lot E (11.7 acres) *(109 dueF's)*	Vascorp Investments Corporation	156	$2,772.12	$0.00
4	092-040-11	Village D1, Lots 1-86; Village D2, Lots 1-87; Village F, Lots 4-41, 49-73; Village G1, Lots 9-50 *(278 dueF's)*; Fire Department (2.17 acres) *(28 dueF's)*	Vascorp Investments Corporation	306 ***Unit D1 – Lots 1-40**	$5,437.62	$710.80
5	092-040-12	Village F, Lots 1-3, 42-48, 74-146; Village G1, Lots 1-8, 51-154; Village G2, Lots 1-49, 59-81, 84-122 *(306 dueF's)*; Park (6.45 acres) *(14 dueF's)*; School (8.07 acres) *(45 dueF's)*	Vascorp Investments Corporation	365	$6,486.05	$0.00
6	092-040-15	Village G2, Lots 50-58, 82, 83 *(11 dueF's)*	Vascorp Investments Corporation	11	$195.47	$0.00
7	092-040-16	Village E2, Lots 7-39, 70-102 *(66 dueF's)*	Vascorp Investments Corporation	66	$1,172.82	$0.00
Developer's Contribution				0	$0.00	$19,866.86
Total				1,158	$20,577.66	$20,577.66

The parcels in the Cannery Park subdivision are expected to subdivide upon and subsequent to the proposed formation of Zone 2. The proposed subdivision will yield approximately 960 residential lots *(960 dueF's)*, 1 multi-family residential lot *(109 dueF's)*, 7 commercial/light industrial parcels *(1,999 dueF's)*, 2 park sites *(16 dueF's)*, a school site *(45 dueF's)*, and a fire department site *(28 dueF's)*, and will have a proposed assessment roll, based on the above criteria and budget, as set forth in Exhibit A for Zones 2-A and Zone 2-B.

The foregoing Engineer's Report and the estimate of costs, as well as the Boundary Map, Assessment Diagram, and Assessment Roll which are attached hereto, are presented for your approval by resolution dated this __________ day of _________________, 2005.

THOMPSON-HYSELL ENGINEERS
Engineer of Work
BY:

Michael T. Persak
RCE 44908

Appendix E
Submittal Guidance

This appendix includes the following maintenance agreements and forms:

E-1: Project Stormwater Quality Control Plan Guidance

E-2: Maintenance Plan Guidance

Project Stormwater Quality Control Plan Guidance

This appendix identifies the basic information that shall be included and format that shall be followed in a Project Stormwater Quality Control Plan (SWQCP) pursuant to the City of Stockton and County of San Joaquin SWQCCP.

A. Cover page including:

- Project Name
- Owner/Developer's name and contact information
- Plan Preparer's name and contact information
- Date submitted (first submittal)
- Date revised (subsequent submittals, as required)

B. Owner's Certification Statement (see Appendix D-2 for sample statement)

C. Project Description

1. Project Category (see Section 2)
2. Narrative description of project – size, location, pollutants of concern, land uses, etc.
3. Site maps
   a. Provide a vicinity map showing the location of the project relative to principal landmarks.
   b. Provide a site map showing boundaries of the site, acreage and drainage patterns/contour lines. Show each discharge location from the site and any drainage flowing onto the site.
   c. Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.
   d. With legend, show locations of expected sources of pollution generation (outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, industrial clarifiers, wash-racks, etc). Identify any areas having contaminated soil or where toxins are stored or have been stored/disposed of in the past.
   e. With legend, indicate types and locations of structural stormwater control measures that will be built to permanently control stormwater pollution.

D. Stormwater Pollution Control Measures

1. Provide summary matrix indicating each type of control measure provided (see Section 2).
2. Site Design Controls
   a. Describe the controls provided under each Site Design Control (G-1 through G-4). Indicate how site design will conform to design criteria listed in SWQCCP.

b. If a Site Design Control is not applicable to the project, provide a statement of justification describing why the control measure is not applicable to the project.

c. If implementation of a Site Design Control is not feasible due to project site conditions, provide a statement of justification describing why implementation is not feasible.

3. Source Controls

   a. Describe the source controls to be provided (Note: Source Control S-1 is required for all projects). Indicate how design of source controls will conform to design criteria listed in SWQCCP.

4. Volume Reduction Measures

   a. Describe the volume reduction measures to be provided.

   b. Use the summary sheet in Appendix B to track compliance with the Volume Reduction Requirement.

   c. If implementation of Volume Reduction Measures is not feasible and/or the Volume Reduction Requirement cannot be met, use the Waiver Application in Appendix to justify why implementation is not feasible. All Volume Reduction Measures must be taken into consideration.

5. Treatment Control Measures

   a. Describe the treatment control measures to be provided.

   b. If the Volume Reduction Requirement was not fully met through the use of Volume Reduction Measures, LID Treatment Controls must be used and the summary sheet in Appendix B should be used to continue tracking compliance with the Volume Reduction Requirement. If implementation of Volume Reduction Measures is not feasible and/or the Volume Reduction Requirement cannot be met, use the Waiver Application in Appendix to justify why implementation is not feasible. All Volume Reduction Measures must be taken into consideration.

   c. Summarize design data for treatment control measures on appropriate design procedure forms (see Appendix I for forms). Provide detailed supporting calculations for design data values in a clear and organized manner.

E. Maintenance Plan and Responsibility

1. Provide a summary of structural control measures to be provided and parties responsible for maintenance of each control. Indicate any anticipated transfer of responsibility due to future transfer of ownership or annexation.

2. Provide complete contact information for each listed responsible party

3. Provide a statement that a detailed Maintenance Plan will be prepared in accordance with SWQCCP requirements (see Appendix D for guidance).

Maintenance Plan Guidance

This appendix identifies the basic information that shall be included in a maintenance plan. Refer to Fact Sheets for individual control measures regarding device-specific maintenance requirements.

A. Site Map:

1. Provide a site map showing boundaries of the site, acreage and drainage patterns/contour lines. Show each discharge location from the site and any drainage flowing onto the site. Distinguish between soft and hard surfaces on the map.
2. Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.
3. With legend, show locations of expected sources of pollution generation (outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, industrial clarifiers, wash-racks, etc). Identify any areas having contaminated soil or where toxins are stored or have been stored/disposed of in the past.
4. With legend, indicate types and locations of stormwater control measures that will be built to permanently control stormwater pollution. Distinguish between pollution prevention, treatment, sewer diversion, and containment devices.

B. Baseline Descriptions:

1. List the property owners and persons responsible for operation and maintenance of the stormwater control measures on site. Include phone numbers and addresses.
2. Identify the intended method of providing financing for operation, inspection, routine maintenance and upkeep of stormwater control measures.
3. List all permanent stormwater control measures. Provide a brief description of stormwater control measures selected and if appropriate, facts sheets or additional information.
4. As appropriate for each stormwater control measure provide:
   a. A written description and check list of all maintenance and waste disposal activities that will be performed. Distinguish between the maintenance appropriate for a 2-year establishment period and expected long-term maintenance. For example, maintenance requirements for vegetation in a constructed wetland may be more intensive during the first few years until the vegetation is established. The post-establishment maintenance plan shall address maintenance needs (e.g. pruning, irrigation, weeding) for a larger, more stable system. Include maintenance performance procedures for facility components that require relatively unique maintenance knowledge, such as specific plant removal/replacement, landscape features, or constructed wetland maintenance. These procedures shall provide enough detail for a person unfamiliar with maintenance to perform the activity, or identify the specific skills or knowledge necessary to perform and document the maintenance.

b. A description of site inspection procedures and documentation system, including record-keeping and retention requirements.

c. An inspection and maintenance schedule, preferably in the form of a table or matrix, for each activity for all facility components. The schedule shall demonstrate how it will satisfy the specified level of performance, and how the maintenance/inspection activities relate to storm events and seasonal issues.

d. Identification of the equipment and materials required to perform the maintenance.

5. As appropriate, list all housekeeping procedures for prohibiting illicit discharges or potential illicit discharges to the storm drain. Identify housekeeping BMPs that reduce maintenance of treatment control measures.

C. Spill Plan:

1. Provide emergency notification procedures (phone and agency/persons to contact).
2. As appropriate for site, provide emergency containment and cleaning procedures.
3. Note downstream receiving water bodies or wetlands which may be affected by spills or chronic untreated discharges.
4. As appropriate, create an emergency sampling procedure for spills. (Emergency sampling can protect the property owner from erroneous liability for down-stream receiving area clean-ups).

D. Facility Changes:

1. Operational or facility changes which significantly affect the character or quantity of pollutants discharging into the stormwater control measures will require modifications to the Maintenance Plan and/or additional stormwater control measures.

E. Training:

1. Identify appropriate persons to be trained and assure proper training.
2. Training to include:
   a. Good housekeeping procedures defined in the plan.
   b. Proper maintenance of all pollution mitigation devices.
   c. Identification and cleanup procedures for spills and overflows.
   d. Large-scale spill or hazardous material response.
   e. Safety concerns when maintaining devices and cleaning spills.

F. Basic Inspection and Maintenance Activities:

1. Create and maintain on site, a log for inspector names, dates and stormwater control measure devices to be inspected and maintained. Provide a checklist for each inspection and maintenance category.
2. Perform annual testing of any mechanical or electrical devices prior to wet weather.

3. Report any significant changes in stormwater control measures to the site management. As appropriate, assure mechanical devices are working properly and/or landscaped BMP plantings are irrigated and nurtured to promote thick growth.
4. Note any significant maintenance requirements due to spills or unexpected discharges.
5. As appropriate, perform maintenance and replacement as scheduled and as needed in a timely manner to assure stormwater control measures are performing as designed and approved.
6. Assure *unauthorized* low-flow discharges from the property do not by-pass stormwater control measures.
7. Perform an annual assessment of each pollution generation operation and its associated stormwater control measures to determine if any part of the pollution reduction train can be improved.

G. Revisions to Pollution Mitigation Measures:

1. If future correction or modification of pass stormwater control measures or procedures is required, the owner shall obtain approval from the governing stormwater agency prior to commencing any work. Corrective measures or modifications shall not cause discharges to by-pass or otherwise impede existing stormwater control measures.

H. Monitoring & Reporting Program

1. The governing stormwater agency may require a Monitoring & Reporting Program to assure the stormwater control measures approved for the site are performing according to design.
2. If required by local agency, the Maintenance Plan shall include performance testing and reporting protocols.

Hydrologic Soil Groups

This appendix includes information on the Hydrologic Soil Groups in San Joaquin County to use in designing various stormwater control measures:

Relevance of Hydrologic Soil Groups Information

The hydrologic soil groups of a development area are pertinent to design of controls that involve infiltration and for identifying sites appropriate for detention basins. The predominant soil group will control the effectiveness of infiltration facilities or the suitability of an area for impounding water. Hydrologic soil group information should be used for preliminary siting studies only. Actual design should be based on in-situ soil investigations and testing by a qualified engineer or geologist.

Table F-1. Typical Infiltration Rates

Soil Type (Hydrologic Soil Group)	***Infiltration Rate (in/hr)***
A	1.00 – 8.3
B	0.5 – 1.00
C	0.17 – 0.27
D	0.02 – 0.10

Infiltration rates shown represent the range covered by multiple sources, e.g. ASCE, BASMAA, etc.

Hydrologic Soil Groups

The hydrologic soil groups are classified by the USDA Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service. There are four hydrologic soil groups: A, B, C and D. Soils may be classified by two groups. Soil groups A and B have the highest infiltration rates, unless the soils under consideration have been compacted during construction. Soil groups A and B are typically the best candidate soils for construction of infiltration facilities. Sites with soil groups C and D are usually more appropriate for detention basins.

Soils in group A have a low runoff potential and high infiltration rate, as the soils typically are sands and gravel. Soil group B includes soils with moderate infiltration rates when completely wetted. Group B soils are sandy loam soils with moderately fine to moderately coarse textures. Soils in group C have slow infiltration rates when thoroughly wetted and these soils typically are silty-loam soils with an impeding layer or soils with moderately fine to fine texture. Group D soils have a high runoff potential and very slow infiltration rate when thoroughly wetted. Group D soils include clay soils with high swelling potential, soils in a permanent high water table and shallow soils over nearly impervious material.

The hydrologic soil information presented here should be used as a general overview. For more specific information, consult the *San Joaquin County Soil Survey* (USDA, NRCS) or contact the NRCS at (530) 662-3986.

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Plants Suitable for Vegetative Control Measures

Vegetation serves primarily to maintain soil porosity and prevent erosion. The effectiveness and aesthetic appeal of control measures are enhanced by selection of appropriate vegetative cover. Turf grass is preferred, and some other ground covers also may be appropriate. An important maintenance consideration in the selection of appropriate vegetation is whether irrigation is planned for the site. Consult with City stormwater staff regarding selection of appropriate vegetation.

Table G-1 provides a sample list of appropriate vegetative covers. Additional suggested vegetative species are listed in Table F-2. The tables are intended as guides in selecting vegetative covers. For specific species suitability and care information, refer to the sources listed for these tables. Contact the Natural Resources Conservation Service for additional information.

Table G-1. Sample List of Appropriate Vegetative Covers

Plant Name Common (Latin)	Appropriate Species	Maintenance and Usage Notes*
Bermuda Grass (Cynodon)	Santa Ana hybrid Common	Moderate maintenance. Dormant (brown) in winter. Heat tolerant. Erosion control, swales.
Fescue (Festuca)	Red fescue (F. rubra)	Low to moderate maintenance. Tolerates some shade and poor soil. Lawns, swales, erosion control.
	“Kentucky 31" Tall Fescue (F. elatior)	Low maintenance. Tolerate shade and compacted soils. Rapid germination. Lawns, swales, erosion control. Useful as overseed for Bermuda grass during dormant (winter) season.
Ryegrass (Lolium)	Perennial (L. perenne)	Moderate maintenance. Heat intolerant. Fast sprouting. Useful as overseed for Bermuda grass during dormant (winter) season. Swales.
	Annual (L. multiflorum)	Annual (may live several seasons in mild climate). Moderate maintenance. Heat intolerant. Fast growing. Useful as overseed for winter-dormant species. Swales.

*Generally, these species will require supplemental irrigation.
Sources: ASCE, MWCG, Sunset

Table G-2. Additional Suggested Vegetative Covers

Plant Name Common (Latin)	Appropriate Species	Usage Notes
Kentucky Bluegrass	(Poa pratensis)	Irrigated Sites
Orchard grass (Dactylis)	“Akaroa” or “Berber” (D. glomerata)	Irrigated and Non-irrigated Sites
Wheatgrass (Agropyron)	“Luna” or “Topar” pubescent (A. intermedium trichophorum)	Irrigated and Non-irrigated Sites
Zorro Fescue (Vulpia)	(V. myuros)	Irrigated and Non-irrigated Sites
Creeping wild Rye (Leymus)	(L. triticoides)	Nonirrigated Sites
Brome (Bromus)	Blando (B. mollis)	Nonirrigated Sites
	California or “Cucamonga” (B. carinatus)	Nonirrigated Sites

Sources: NRCS-FOTG. Manual of Standards for Erosion and Sediment Control Measures, Association of Bay Area Governments, 1995.

Introduction

Stormwater runoff in excess of the water quality flow or volume is to be diverted around or through the treatment control measure. The following paragraphs provide equations and design criteria necessary to design diversion structures to divert runoff in excess of the SQDV or SDQF around or through the treatment control measures.

Diversion Structure Design

Capture or isolation of the SQDV is typically achieved by employing one of the following techniques:

- Divert the SQDV into the treatment control measure from the on-site storm drain system using weirs or orifices at or upstream of the point of entrance to the treatment control measure.
- Bypassing flows in excess of the SQDV within the treatment control measure using weirs and pipes for channel or pipe storm drain systems or routing excessive flows through a vegetated swale.

By employing diversion techniques, the water quality flow or volume is treated and discharged to the storm drain system and runoff that exceeds the water quality flow or volume is diverted or bypassed, untreated, directly to the downstream storm drain system.

Equations and criteria to design a diversion structure are provided below. Alternative designs may be considered subject to approval.

All diversion structures are designed using the on-site storm design event. The drainage design storm is established by the governing agency and is not the same as the stormwater quality design flow or volume. The drainage design storm is used to design the conveyance system, i.e. pipes, swales, etc. of the site without regard for treatment. The design engineer must ensure sufficient head room in the on-site system above the diversion to accommodate overflows.

Diverting Flows at the Inlet or Upstream of the Treatment Control Device

Diverting flow at the inlet to the treatment control is the more common approach to divert excess runoff. Figure H-1 illustrates the more commonly used diversion structures. The height of the weir to divert the flow is determined a follows:

<u>Treatment Control Measures Designed Based on the SQDV</u>

1. Determine the SQDV (see Section 6)
2. Utilizing design techniques provided in the treatment control measure fact sheets, determine the maximum height of the water level in the treatment control measure when the entire SQDV is being held,
3. Set the height of the diversion weir to the maximum height of the water level.
4. Determine weir dimensions needed to divert peak flows of the drainage design storm using the following equation for a rectangular sharp-crested weir

$$Q_d = C \times L \times h^{1.5} \qquad \textit{eqn H-1}$$

Where: Q_d = Peak flow rate for drainage design storm, cfs

L = Effective length of weir, ft

C = Weir discharge coefficient

h = Depth of the flow above the crest of the weir, ft

The discharge coefficient "C" accounts for many factors, such as velocity of approach, in the weir equation. The height of the weir (H) and the height of the flow over the weir (h) are two characteristics of the sharp-crested weir that affect the value of C. Table H-1 can be used to approximate C for rectangular sharp-crested weirs without end contractions.

5. Provide sufficient head room in the treatment control to accommodate depth of flow over the weir.

Table H-1. Weir Discharge Coefficient (C) for Rectangular Sharp-crested Weirs Without End Contractions[1]

H/h	Head (h) over weir, ft						
	0.2	**0.4**	**0.6**	**0.8**	**1.0**	**2.0**	**5.0**
0.5	4.18	4.13	4.12	4.11	4.11	4.10	4.10
1.0	3.75	3.71	3.69	3.68	3.68	3.67	3.67
2.0	3.53	3.49	3.48	3.47	3.46	3.46	3.45
10.0	3.36	3.32	3.30	3.30	3.29	3.29	3.28
∞	3.32	3.28	3.26	3.26	3.25	3.25	3.24

1. From Lindsay and Franzini , (1979)

<u>Treatment Control Measures Designed Based on the SQDF</u>

1. Establish the size of the on-site drainage system (pipe diameter or dimensions) based on the drainage design storm
2. Determine the SQDF (see Section 6)
3. Determine the depth of flow in the on-site drainage system when carrying the SQDF using Manning's equation (eqn H-2)

$$SQDF = \frac{1.49}{n}(A)(R)^{\frac{2}{3}}(s)^{\frac{1}{2}} \qquad \textit{eqn H-2}$$

Where: SQDF = Water Quality Flow, cfs

n = Manning's roughness coefficient

A = Cross sectional area of drainage pipe or channel, ft^2

R = Hydraulic radius, ft

S = Slope of pipe or channel, ft/ft

4. Using nomographs or computer programs, determine the depth of flow at SQDF. Set the

weir height at this depth.

5. Using Equation H-1, establish weir dimensions. Provide sufficient head room in treatment control to accommodate flows over the weir.

Bypassing Excess Flows within the Treatment Control Measure

For certain site conditions, bypassing runoff in excess of the SQDV must be achieved in the treatment control measure. When this occurs, the control measure must be designed to ensure the bypass system can be accommodated in the unit, i.e. sufficient depth, width and length to accommodate pipes, length of weirs, etc. The following discusses design considerations for the different treatment control measures.

<u>Bypassing Flows through Infiltration and Sedimentation/Filtration Treatment Control Measures</u>

Weirs, orifices or pipes in treatment control measures are used to bypass runoff in excessive of the SQDV and SQDF. Design of these measures is similar to the approach described above under diverting flows at the inlet to the treatment control measure. Bypass for filtration devices occurs in the sedimentation chamber.

Weirs

Weirs are commonly used to bypass excess storm events. Determining the height of the weir is based on the maximum water elevation in a treatment control device when holding the entire SQDV. To design the weir, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV.

Orifices

Orifices can be considered in place of weirs or pipes. To avoid drawing floatables into the bypass, a hooded orifice (see Figure H-2) should be designed using the equation H-3:

$$Q_d = C \times A \times (2gh)^{0.5} \qquad \textit{eqn H-3}$$

Where:

Q_d = Peak flow rate for drainage design storm, cfs

C = Orifice discharge coefficient, (use 0.6)

A = Area of orifice, ft^2

h = Depth of the water above midpoint of orifice, ft

g = 32.2 ft/sec^2

Hoods should extend into one-third of the permanent pool depth or one-foot whichever is greater. Commercial catch basin traps can be used in lieu of a hood.

Determining the elevation of the orifice is based on determining the maximum water elevation in a treatment control device when holding the entire SQDV. Use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV to establish the elevation of the mid-point of the orifice opening.

The size of the orifice is determined by using Equation H-3 for the orifice to bypass the peak flow of the on-site storm.

Ensure sufficient head room in the treatment unit to accommodate flows through orifice.

Pipes

Pipes can also be employed to bypass excess runoff. Determining the invert elevation of the bypass inlet is based on determining the maximum water elevation in a treatment control device when holding the entire SQDV. To do this, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV to design a diversion weir.

For filtration control measures, a hooded inlet using a 90° elbow should be considered at the inlet to the bypass pipe to prevent drawing floatables into the bypass (see Figure H-2). Hoods should extend into one-third of the permanent pool depth or one-foot whichever is greater. Commercial catch basin traps can be used in lieu of a hood.

For infiltration control measures (see Figure H-3) bypass pipes are perforated and wrapped with filter fabric to avoid drawing sediment and small particles into the bypass pipe. Hoods are not necessary for these overflow pipes.

Bypass pipes are sized using the Manning's equation (Equation H-4) and sized to pass the peak flow of the drainage design storm, and assume the bypass pipes are flowing full. With this assumption, the Manning's equation, Equation H-4, reduces to:

$$D = \left(\frac{2.159 Q_d n}{s^{\frac{1}{2}}} \right)^{\frac{3}{8}} \qquad \textit{eqn H-4}$$

Where: D = Diameter of pipe, ft

Q_d = Peak flow rate for drainage design storm, cfs

n = Manning's coefficient for pipe material

s = Slope of pipe, ft/ft (0.5% minimum required)

Provide sufficient head room in the treatment control to accommodate flows.

<u>Routing Excess Runoff Through a Vegetated Swale</u>

The depth of flow in a Vegetated Swale at SQDF is determined using a roughness coefficient of 0.2. If additional flows beyond the SQDF are to be directed to the vegetated swale, the roughness coefficient for these flows will be lower (approximately 0.03), because the flows exceeding the SQDF do not flow through the swale and are only influenced by surface friction/roughness. Swales with distinctly different roughness coefficients can be designed using an equivalent roughness coefficient that is determined based on the roughness associated with the wetted perimeters (P). For most on-site Vegetated Swale designs, there will be two different "n" values. An equivalent "n_e" value can be determined using equation H-5:

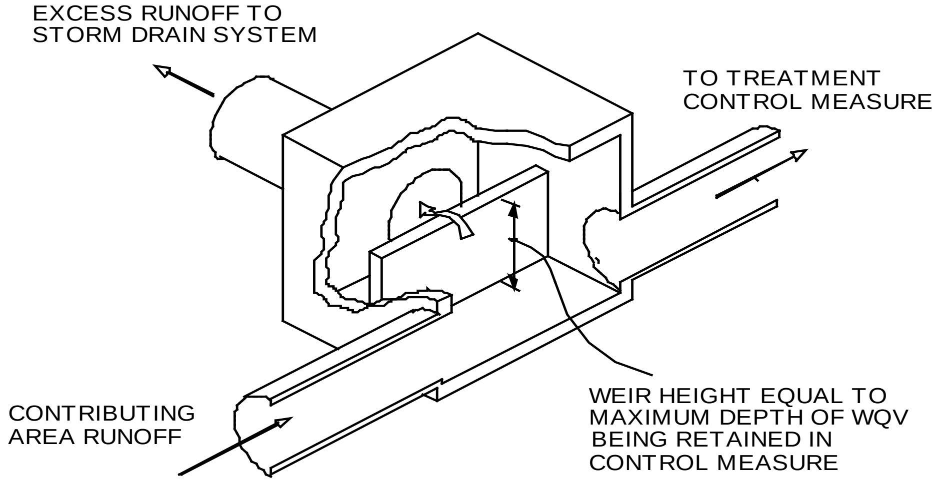
$$n_e^{\frac{3}{2}} = \frac{P_1 n_1^{\frac{3}{2}} + P_2 n_2^{\frac{3}{2}}}{P} \qquad \textit{eqn H-5}$$

An iterative approach is used to develop an equivalent "n_e", that can be calculated with most computer hydraulic program applications:

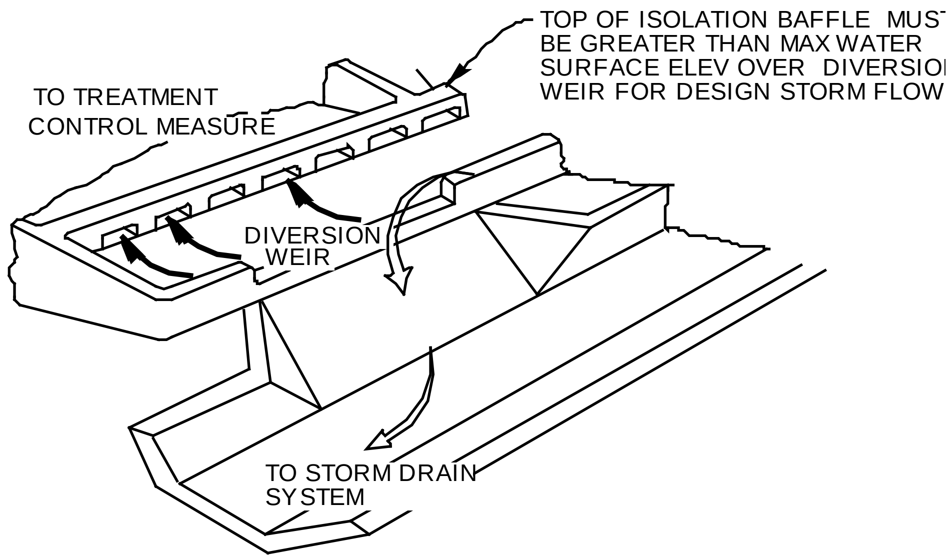
1. Estimate an equivalent roughness coefficient (estimated "n_e");

2. Use the estimated roughness coefficient to determine the depth of flow using trial and error solution of Equation H-2 substituting the peak flow of the drainage design storm for the SQDF;
3. Use the calculated depth to determine the wetted perimeter for the drainage system;
4. Use the wetted perimeter associated with each "n" for the drainage system and using Equation H-5 to calculate the equivalent roughness coefficient (calculated "n_e"), and compare to the estimated "n_e"; and
5. Continue the process until the calculated "n_e" equals the estimated "n_e". This value is the equivalent roughness coefficient and used to design the Vegetated Swale according to recommendations provided in Fact Sheet L-7.

Note - This approach results in conservative n values. High flows in the swale may cause some vegetation to bend resulting in a lower n_1 and lower equivalent "n_e".



PIPE INTERCEPTOR ISOLATION/DIVERSION STRUCTURE



SURFACE CHANNEL DIVERSION STRUCTURE

Figure H-1. Common Diversion Structures at Inlets

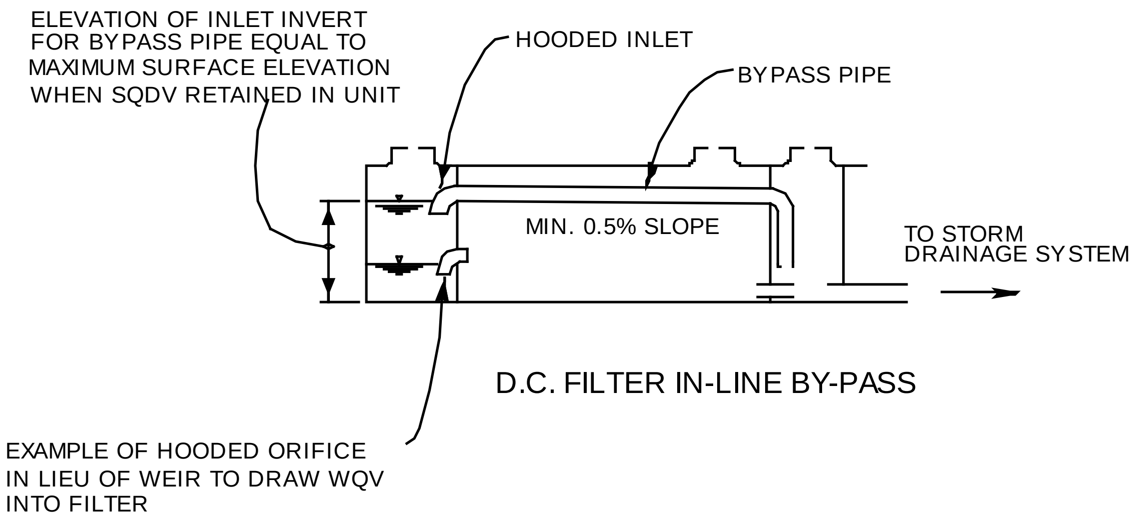


Figure H-2. Illustration of Pipe Bypass in a Filtration Device

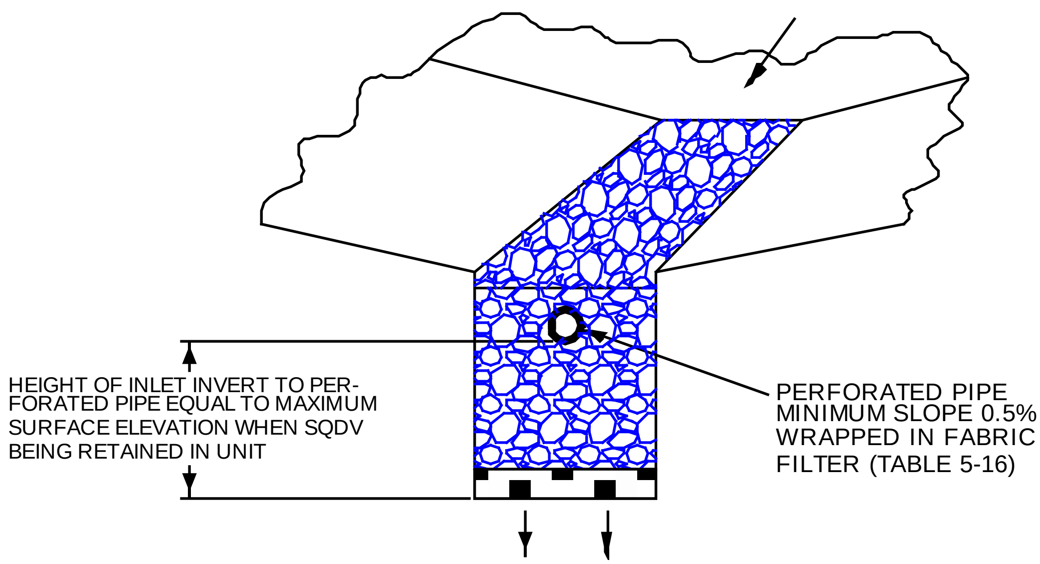


Figure H-3. Illustration of Pipe Bypass in Infiltration Trench

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Approved Proprietary Stormwater Treatment Devices

This appendix identifies proprietary stormwater treatment devices (proprietary devices) that have been approved by the City of Stockton (City) and the County of San Joaquin (County) for general use in new development and significant redevelopment projects within the Stockton Urbanized Area (SUA). In order to use proprietary devices, projects must first demonstrate that the Volume Reduction Requirement is met through the use of Volume Reduction Measures (Section 5).

In order to provide a rationale for approval of proprietary devices, the City and County have elected to recognize those proprietary devices that are approved for general, conditional, or pilot use by selected municipal stormwater programs that have established and are actively conducting a comprehensive testing protocol and approval process. Currently, the City and County recognize the proprietary devices approved for general, conditional, or pilot use from the following stormwater programs:

- Sacramento Stormwater Quality Partnership
  http://www.beriverfriendly.net/newdevelopment/propstormwatertreatdevice/
- State of Washington Department of Ecology (DOE) Stormwater Program
  http://www.ecy.wa.gov/programs/wq/stormwater/newtech/technologies.html

The City and County may recognize proprietary devices from other municipal stormwater programs in the future and will update Appendix I accordingly.

Basic Treatment[1]: General, Conditional, and Pilot Use Designations

The proprietary devices currently approved for general, conditional, or pilot use by the City and County are listed in **Table I-1** along with the manufacturer, basis of approval, and sizing criteria. This list will be updated periodically as additional proprietary devices are approved.

Table I-1. Proprietary Stormwater Treatment Devices Approved for General and Conditional Use for Basic Treatment by the City of Stockton and the County of San Joaquin

	Proprietary Device	Manufacturer	Approval Basis	Sizing Criteria
General Use				
1	BayFilter®	BaySaver Technologies, Inc www.BaySaver.com	Washington DOE general use designation for basic treatment	Stormwater Quality Design Flow (see Section 6, T-0) @ 30-75 gpm /cartridge (depending on cartridge) using Silica Sand, Perlite, Zeolite, and Activated Alumina

[1] The proprietary devices approved for basic treatment are intended to achieve the following:

- A goal of 80% removal of total suspended solids (TSS) for influent concentrations between 100 – 200 mg/L
- An effluent goal of 20 mg/L TSS for influent concentrations less than 100 mg/L
- For influent concentrations greater than 200 mg/L TSS, a higher treatment goal is intended

	Proprietary Device	Manufacturer	Approval Basis	Sizing Criteria
2	Compost-Amended Biofiltration Swale	WSDOT www.wsdot.wa.gov/Environment/waterquality	Washington DOE general use designation for basic treatment	Stormwater Quality Design Flow (see Section 6, T-0)
3	ecoStorm plus	Royal Environmental Systems www.watertectonics.com	Washington DOE general use designation for basic treatment	Stormwater Quality Design Flow (see Section 6, T-0) per Standard concrete filter
4	Filterra® Bioretention System	Americast www.filterra.com	Washington DOE general use designation for basic treatment; Sacramento Stormwater Quality Partnership "accepted devices"	Based on water quality design hydraulic loading rates @100 in/hr
5	FloGard Perk Filter®	Kristar/Oldcastle Precast, Inc. www.kristar.com	Washington DOE general use designation for basic treatment	Stormwater Quality Design Flow (see Section 6, T-0) @ no greater than 1.5 gpm/ft^2 of media surface area
6	Jensen Precast StormVault®	Jensen Precast http://www.jensenstormwater.com/stormvault	Sacramento Stormwater Quality Partnership "accepted devices"	Stormwater Quality Design Volume (see Section 6, T-0)
7	Media Filter Drain	WSDOT www.wsdot.wa.gov/Environment/waterquality	Washington DOE general use designation for basic treatment	Stormwater Quality Design Flow (see Section 6, T-0)
8	Media Filtration System (MFS)	CONTECH Engineered Solutions, LLC. http://www.conteches.com/	Washington DOE general use designation for basic treatment	Stormwater Quality Design Flow (see Section 6, T-0) @ 1 gpm for every 2.44 inches of cartridge height
9	MWS-Linear Modular Wetland	Bio Clean Environmental Services, Inc. www.biocleanenvironmental.com	Washington DOE general use designation for basic treatment	Sized at a hydraulic loading rate of 1 gpm/ft^2 of wetland cell surface area. For moderate pollutant loading rates (low to medium density residential basins), size the Prefilters at 3.0 gpm/sq ft of cartridge surface area. For high loading rates (commercial and industrial basins), size the Prefilters at 2.1 gpm/sq ft of cartridge surface area.

	Proprietary Device	Manufacturer	Approval Basis	Sizing Criteria
10	Stormfilter using ZPG™ Media	CONTECH Engineered Solutions, LLC. http://www.conteches.com/	Washington DOE general use designation for basic treatment Sacramento Stormwater Quality Partnership "accepted devices"	Hydraulic loading rate of 1 gpm/ft^2 of media surface area, dependent on effective cartridge height and flow rate; using ZPG™ media
11	Stormfilter using ZPG™ Media	CONTECH Engineered Solutions, LLC. http://www.conteches.com/	Sacramento Stormwater Quality Partnership "accepted devices"	Hydraulic loading rate of 2 gpm/ft^2 of media surface area, dependent on effective cartridge height and flow rate; using ZPG™ media
Conditional Use				
1	Aqua-Swirl System	AquaShield™, Inc. www.aquashieldinc.com	Washington DOE conditional use designation for basic treatment	Stormwater Quality Design Flow (see Section 6, T-0), but no greater than 23 gpm/ft^2
2	Aquip	StormwateRx, LLC http://www.stormwaterx.com/	Washington DOE conditional use designation for basic treatment **[Expires 01/01/2017]**	Hydraulic loading rate of no greater than 1 gpm/ft^2 of media surface area; using enhanced (sorptive) media; influent by pump station or gravity flow
3	Enpurion®Metals Treatment	Lean Environment, Inc. http://www.leanenvironment.com/	Washington DOE conditional use designation for basic treatment **[Expires 02/29/2016]**	Hydraulic loading rate of no greater than 50 gpm per series of columns
4	Jellyfish™ Filter	Imbrium Systems http://www.imbriumsystems.com/	Washington DOE conditional use designation for basic treatment **[Expires 06/30/2015]**	Cartridge length dependent on Stormwater Quality Design Flow (see Section 6, T-0) and sediment load
5	StormFilter using Perlite Media at 2 gpm	CONTECH Engineered Solutions, LLC. http://www.conteches.com/	Washington DOE conditional use designation for basic treatment **[Expires 09/30/2015]**	Hydraulic loading rate of no greater than 2 gpm/ft^2 of media surface area; using CONTECH's perlite media
6	StormFilter using PhosphoSorb™ Media at 1.67 gpm/sq ft	CONTECH Engineered Solutions, LLC. http://www.conteches.com/	Washington DOE conditional use designation for basic treatment **[Expires 12/31/2014]**	Hydraulic loading rate of no greater than 1.67 gpm/ft^2 of media surface area; using CONTECH's PhosphoSorb™ media

	Proprietary Device	Manufacturer	Approval Basis	Sizing Criteria
7	Stormwater Management StormFilter® using MetalRx™ Media	CONTECH Engineered Solutions, LLC. http://www.conteches.com/	Washington DOE conditional use designation for basic treatment **[Expires 06/30/2016]**	Hydraulic loading rate of no greater than 1 gpm/ft^2 of media surface area; using CONTECH's MetalRx™ media
8	Up-Flo™ Filter	Hydro International http://www.hydro-int.com/us	Washington DOE conditional use designation for basic treatment **[Expires 03/01/2016]**	Hydraulic loading rate of no greater than 22.7 gpm/ft^2 per filter module (given a filter module surface area of 1.1 ft^2 containing 2 filter bags with combined filter media depth of 8 inches); Using a carbon-peat-zeolite (CPZ Mix™) filter media
Pilot Use				
1	Aqua-Filter System	AquaShield™, Inc. www.aquashieldinc.com	Washington DOE pilot use designation for basic treatment **[Expires 02/01/2015]**	Stormwater Quality Design Flow (see Section 6, T-0) @ 5.0 gpm/ft^2 cartridge
2	Maxwell Plus Drainage System	Torrent Resources	Washington DOE pilot use designation for basic treatment **[Expires 04/01/2017]**	Sized at a hydraulic loading rate of no greater than 0.25 cubic feet per second (cfs) per system

Any device listed in **Table I-1** proposed for use in the SUA must be designed, installed, and maintained in accordance with conditions stipulated by the approving program and must include all maintenance, operation, and construction requirements as indicated in Appendix D and as recommended by the manufacturer. Any proprietary device proposed for use within the SUA must have a currently valid use designation by the approving program at the time of approval by the City or County.

If the device is the first of its kind to be installed in the SUA, the performance of the unit must be monitored in accordance with the performance monitoring protocols stipulated by the approving program.

Conditional and pilot use designations are subject to expiration and/or removal without notice. If a project is delayed and, during the time of delay, a particular device's conditional use designation has expired and/or has been removed, then the project proponent must resubmit plans incorporating necessary changes, including, but not limited to, a currently approved proprietary device.

Pretreatment[2]: General, Conditional, and Pilot Use Designations

The City and County recognize that, in special cases (typically small in-fill projects) the use of basic treatment control measures, either non-proprietary or proprietary, may not be feasible due to physical site constraints. In these cases, the City and County will consider the use of substitute proprietary pretreatment devices in lieu of approved basic treatment devices where it can be demonstrated, by means of an engineering analysis to the satisfaction of the City or County, that use of the approved proprietary devices is not feasible.

Proprietary devices that are approved by the City and County as substitute pretreatment devices are listed in **Table I-2** along with the manufacturer, approval basis, and sizing criteria. This list will be updated periodically as additional proprietary devices are approved.

Table I-2. Proprietary Stormwater Treatment Devices Approved as Substitute Pretreatment Devices by the City of Stockton and the County of San Joaquin[A]

	Proprietary Device	Manufacturer	Approval Basis	Sizing Criteria
General Use				
1	AquaSwirl System	AquaShield™, Inc. www.aquashieldinc.com	Washington DOE general use designation for pretreatment	Stormwater Quality Design Flow (see Section 6, T-0), but no greater than 23 gpm/ft^2
2	CDS™ Stormwater Treatment System	CONTECH Engineered Solutions, LLC. http://www.conteches.com/	Washington DOE general use designation for pretreatment	Stormwater Quality Design Flow (see Section 6, T-0) or manufacturer's recommendation if greater
3	Vortechs System	CONTECH Engineered Solutions, LLC. http://www.conteches.com/	Washington DOE general use designation for pretreatment	Stormwater Quality Design Flow (see Section 6, T-0) or manufacturer's recommendation if greater
4	Downstream Defender	Hydro-International www.hydro-international.biz	Washington DOE general use designation for pretreatment	Stormwater Quality Design Flow (see Section 6, T-0) or manufacturer's recommendation if greater

[2] Pretreatment is generally applied to:

- Project sites using infiltration treatment
- Treatment systems where needed to assure and extend performance

Pretreatment devices are intended to achieve:

- 50% removal of fine (50 micron-mean size) and 80% removal of coarse (125-micron-mean size) total suspended solids for influent concentrations between 100 mg/L - 200 mg/L.
- For influent concentrations less than 100 mg/L, the devices are intended to achieve effluent goals of 50 mg/L of fine and 20 mg/L of coarse total suspended solids.

	Proprietary Device	Manufacturer	Approval Basis	Sizing Criteria
General Use				
5	Stormceptor	Imbrium Systems http://www.imbriumsystems.com/	Washington DOE general use designation for pretreatment	Stormwater Quality Design Flow (see Section 6, T-0) or manufacturer's recommendation if greater
Conditional Use				
	None			
Pilot Use				
	None			

Note:

A. Devices considered only in cases where it can be satisfactorily demonstrated that use of approved basic treatment control measures are not feasible, or for use in combination with approved downstream treatment measures.

Any device listed in **Table I-2** proposed for use in the SUA must be designed, installed, and maintained in accordance with conditions stipulated by the approving program and must include all maintenance, operation, and construction requirements as indicated in Appendix D and as recommended by the manufacturer. Any proprietary device proposed for use within the SUA must have a currently valid use designation by the approving program at the time of approval by the City or County.

Example Calculation

This Appendix provides an example calculation to illustrate the application of the Volume Reduction Requirement, Volume Reduction Measures, tributary impervious area credit and LID Treatment Controls. The calculation begins at Step 5, Apply Volume Reduction Measures. Real world development applications should also adhere to Steps 1 – 4 as described in Section 2.

SITE CONDITIONS

A commercial site design (**Figure J-1**), is used for the example calculation. This is a new development scenario and it is assumed that the pre-project conditions primarily consisted of disturbed soils with some undisturbed open space and no impervious cover elements.

STEP 5: APPLY VOLUME REDUCTION MEASURES

The substeps for Step 5 as described in Section 5 are as follows:

- Calculate the Volume Reduction Requirement (post - pre)
- Select Volume Reduction Measures
- Determine volume reduction
- Determine remaining Volume Reduction Requirement
- Determine tributary impervious area credits

Calculate Volume Reduction Requirement

Pre-Project Volume

Site element	Element Area ft^2	Fraction of Total Area	Runoff Coefficient	Weighted Runoff Coefficient (Fraction of Total Area * Runoff Coefficient)	0.51-inch Storm Volume, ft^3 (Total Project Area * Total Weighted Runoff Coefficient)
Disturbed soils	76,750	0.91	0.25	0.23	
Undisturbed open space /trees	7,250	0.09	0.05	0.00	
Total	84,000			**0.23**	**831**

Post-Project Volume

Site element	Element Area ft^2	Fraction of Total Area	Runoff Coefficient	Weighted Runoff Coefficient (Fraction of Total Area * Runoff Coefficient)	0.51-inch Storm Volume, ft^3 (Total Project Area * Total Weighted Runoff Coefficient)
Permeable pavers	2,410	0.03	0.60	0.02	
Roofs	15,200	0.18	0.95	0.17	
Parking lot	22,961	0.27	0.95	0.26	
Driveway	14,531	0.17	0.95	0.16	
Plaza	4,755	0.06	0.95	0.05	
Walkways	5,607	0.07	0.95	0.06	
Amended soils	11,286	0.13	0.05	0.01	
Undisturbed open space /trees	7,250	0.09	0.05	0.00	
Total	84,000			0.74	**2,647**
Pre-project Volume					831
Volume Reduction Requirement (post – pre)					**1,816**

Select Volume Reduction Measures & Determine Volume Reduction

Thirty-four evergreen, interception trees were selected as the Volume Reduction Measures for this site. Additional details on interception trees can be found in Fact Sheet V-4.

Parameter	Unit	Value
No. of trees	ea	34
Avg. canopy diameter	ft	20
Unit projected canopy area (area of tree projected over impervious area)	ft^2	314
Total canopy area (unit projected canopy area * no. of trees)	ft^2	10,676
Percent interception	%	40%
Volume reduction (0.51" * Total canopy area * Percent interception / 12 in/ft)	ft^3	**181**

Determine Remaining Volume Reduction Requirement

Remaining Volume Reduction Requirement (Volume Reduction Requirement – Interception Tree Volume Reduction):
1,816 ft^3 – 181 ft^3 = 1,635 ft^3

Determine Tributary Impervious Area Credits

Each Volume Reduction Measure fact sheet describes how impervious area credits are calculated. See Fact Sheet V-4 for details on calculating the credits associated with interception trees.

Site Element	Area of Canopy Coverage ft^2	Impervious Area Credit ft^2 (Area of Canopy Coverage * Percent Interception)
Parking lot	5,018	2,007
Plazas	3,737	1,495
Walkways	1,921	768
Total	10,676	4,270

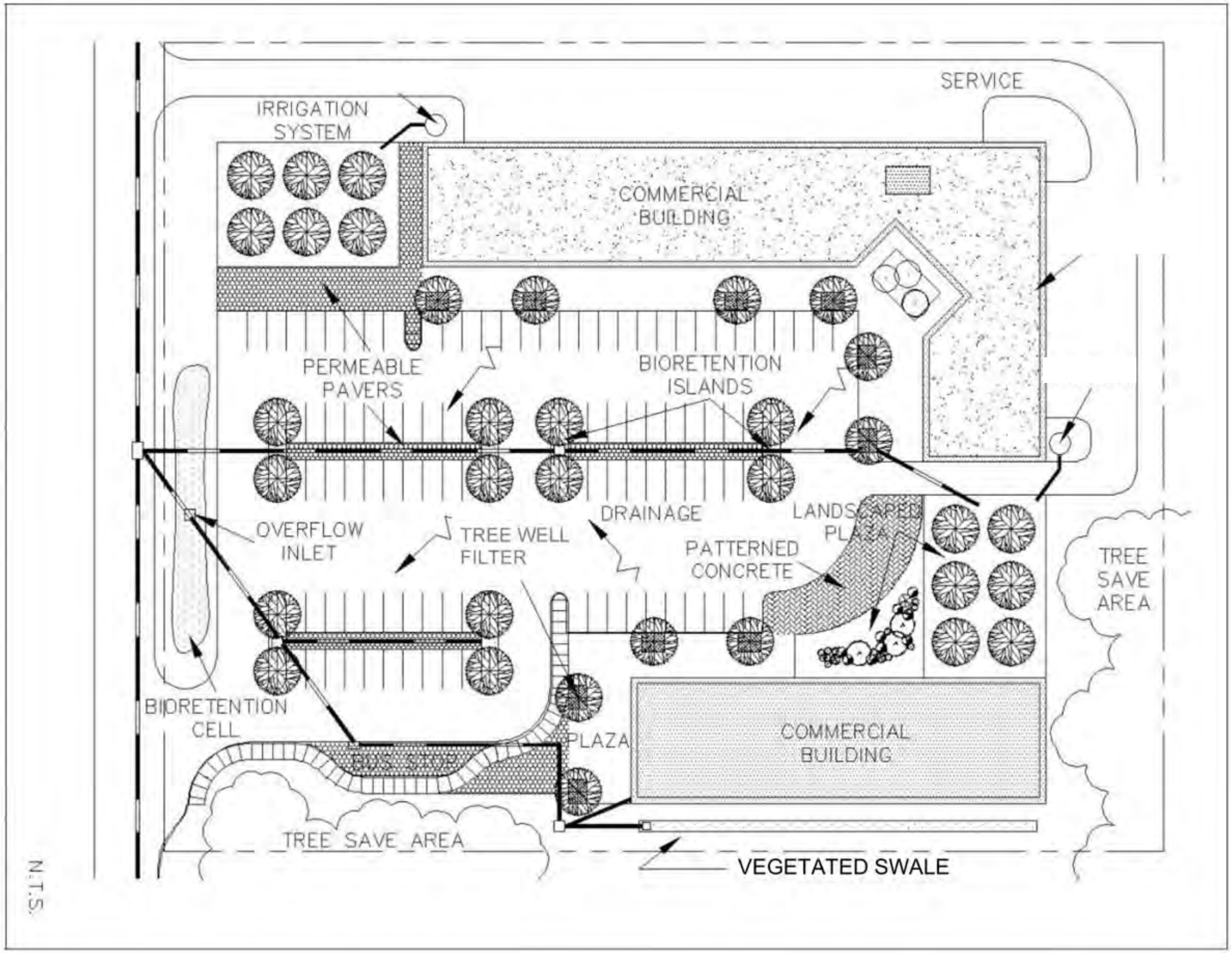

Figure J-1. Example Commercial Site Design (modified from LID Center

STEP 6: APPLY LID TREATMENT CONTROLS

If Volume Reduction Requirement was not met through use of Volume Reduction Measures (Step 5), LID Treatment Controls must be used to further reduce volume. Treatment controls must be designed to treat the SQDF or SQDV.

In this example calculation, the Volume Reduction Requirement was not fully met through the use of Interception Trees as a result, the development will also apply the following LID Treatment Controls:

- Parking Lot Bioretention
- Vegetated Swale
- Bioretention Cell
- Tree-well Filter

Calculations for each of the LID Treatment Controls are provided in the tables below.

Parking Lot Bioretention	Unit	Value
Tributary area (Area draining to parking lot bioretention)	ft^2	22,961
Tributary impervious area credit (see Tributary Impervious Area Credits in Step 5)	ft^2	2,007
Effective tributary area (Tributary area – Tributary impervious area credit)	ft^2	20,954
SQDV[1] (Unit Basin Storage Volume[2] * Effective tributary area * 1ft/12in)	ft^3	559
Bioretention area	ft^2	1,563
Depth of ponding zone	ft	0.50
Depth of planting zone	ft	1.50
Treatment volume provided[1] (Bioretention area * Depth of ponding zone)	ft^3	782
Volume reduction (Depth of ponding zone * Bioretention area * 0.25) + (Depth of planting zone * Bioretention area * 0.1)	ft^3	430

1: SQDV is treatment volume required; Treatment volume provided is the amount of treatment actually provided by parking lot bioretention
2: See Figure 6-1

Vegetated Swale	Unit	Value
Tributary area (Area draining to vegetated swale)	ft^2	5,188
Tributary impervious area credit (see Tributary Impervious Area Credits in Step 5)	ft^2	-
Effective tributary area (Tributary area – Tributary impervious area credit)	ft^2	5,188
SQDV[1] (Unit Basin Storage Volume[2] * Effective tributary area * 1ft/12in)	ft^3	138
Swale area	ft^2	798
Depth of ponding zone	ft	0.67
Depth of planting zone	ft	1.50
Treatment volume provided[1] (Swale area * Depth of ponding zone)	ft^3	535
Volume reduction (Depth of ponding zone * Swale area * 0.25) + (Depth of planting zone * Swale area * 0.1)	ft^3	253

1: SQDV is treatment volume required; Treatment volume provided is the amount of treatment actually provided by vegetated swale
2: See Figure 6-1

Bioretention Cell	Unit	Value
Tributary area (Area draining to bioretention cell)	ft^2	32,560
Tributary impervious area credit (see Tributary Impervious Area Credits in Step 5)	ft^2	768
Effective tributary area (Tributary area – Tributary impervious area credit)	ft^2	31,792
SQDV[1] (Unit Basin Storage Volume[2] * Effective tributary area * 1ft/12in)	ft^3	848
Bioretention area	ft^2	2,272
Depth of ponding zone	ft	1.00
Depth of planting zone	ft	1.50
Treatment volume provided[1] (Bioretention area * Depth of ponding zone)	ft^3	2,272
Volume reduction (Depth of ponding zone * Bioretention area * 0.25) + (Depth of planting zone * Bioretention area * 0.1)	ft^3	909

1: SQDV is treatment volume required; Treatment volume provided is the amount of treatment actually provided by bioretention cell
2: See Figure 6-1

Tree-well Filters	Unit	Value
Tributary area (Area draining to tree-well filter)	ft^2	4,755
Tributary impervious area credit (see Tributary Impervious Area Credits in Step 5)	ft^2	1,495
Effective tributary area (Tributary area – Tributary impervious area credit)	ft^2	3,260
SQDV[1] (Unit Basin Storage Volume[2] * Effective tributary area * 1ft/12in)	ft^3	87
No. of filters	ea	12
Unit filter area	ft^2	16
Total filter area (No. of filters * Unit filter area)	ft^2	192
Depth of ponding zone	ft	0.75
Depth of planting zone	ft	1.50
Treatment volume provided[1] (Total filter area * Depth of ponding zone)	ft^3	144
Volume reduction (Depth of ponding zone * Total filter area * 0.25) + (Depth of planting zone * Total filter area * 0.1)	ft^3	65

1: SQDV is treatment volume required; Treatment volume provided is the amount of treatment actually provided by bioretention cell
2: See Figure 6-1

SUMMARY OF VOLUME REDUCTION

Control Measure	Units	Volume Reduction
Tree Interception	ft^3	181
Parking Lot Bioretention	ft^3	430
Vegetated Swale	ft^3	253
Bioretention Cell	ft^3	909
Tree-well Filters	ft^3	65
Total Volume Reduction	ft^3	**1,838**
Volume Reduction Requirement	ft^3	1,816

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References

Alameda Countywide Clean Water Program October 1996. Final Monitoring Report, Grassed Swales at the ADVO Facility, Newark, prepared by Woodward-Clyde Consultants.

Association of Bay Area Governments May 1995. Manual of Standards for Erosion and Sediment Control Measures, Second Edition.

Bay Area Stormwater Management Agencies Association (BASMAA), 1999. Start at the Source, Design Guidance for Stormwater Quality Protection.

California Stormwater Quality Task Force, March 1993. California Storm Water Industrial/Commercial Best Management Practice Handbook, prepared by Camp Dresser & McKee, Larry Walker Associates, Uribe and Associates, Resource Planning Associates.

California Stormwater Quality Association, January 2003. California Stormwater Best Management Practices Handbooks, prepared for by Camp Dresser & McKee, Larry Walker Associates, et.al.

Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Ellicott City, MD.

Center for Watershed Protection (CWP). 2007. Urban Stormwater Retrofit Practices. Manual 3 of the Urban Subwatershed Restoration Manual Series. Ellicott City, MD.

Chow, Ph.D., V.T., 1959. Open-Channel Hydraulics, McGraw-Hill, Inc., New York.

City of Alexandria Department of Transportation and Environmental Services 1992. Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filters BMPs.

City of Alexandria Department of Transportation and Environmental Services, February 1992. Supplement to the Northern Virginia BMP Handbook.

City of Austin, 1991. Environmental Binder, Section 1, Water Quality Management.

City of Modesto, Operations and Maintenance Department, January 2001. Guidance Manual for New Development Stormwater Quality Control Measures.

City of Portland. 2008. Stormwater Management Manual. Portland, OR.

City of Sacramento Department of Utilities and County of Sacramento Water Resources Division, January 2000. Guidance Manual for On-Site Stormwater Quality Control Measures.

County of San Diego. 2007. Low Impact Development Handbook. Department of Planning and Land Use. San Diego, CA.

Denver Colorado Urban Drainage and Flood Control District (UDFCD), 1999. Urban Drainage Criteria Manual, Volume 3 – Best Management Practices Stormwater Quality.

Denver Colorado Urban Drainage and Flood Control District(UDFCD), 1992. Urban Drainage Criteria Manual, Volume 3 – Best Management Practices Stormwater Quality.

Federal Highway Administration, August 1989. Retention, Detention, and Overland Flow for Pollutant Removal from Highway Stormwater Runoff, Volume II Design Guidelines, Draft, Report No. FHWA/RD-89/203.

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. "Stream Corridor Restoration: Principles, Processes, and Practices." Federal Interagency Stream Restoration Working Group (FISRWG). GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3.

Goldman S.J., Jackson K., Bursztynsky, P.E., T.A., 1986. Erosion and Sediment Control Handbook, McGraw-Hill Inc., New York.

Haltiner J. 2006. Hydrograph Modification: An Introduction and Overview. Philip Williams & Associates. Powerpoint Presentation.

Metropolitan Washington Council of Governments, March 1992. A Current Assessment of Urban Best Management Practices, Techniques for Reducing Non-Point Source Pollution in the Coastal Zone.

North Carolina 1993. Storm Water Management Guidance Manual, North Carolina.

Northern Virginia Planning District, Engineers and Surveyors Institute, January 1996, Northern Virginia BMP Handbook Addendum, Sand Filtration Systems.

Puget Sound Action Team & Washington State University Piece County Extension. 2005. Low Impact Development: Technical Guidance Manual for the Puget Sound.

Retail Gasoline Outlet Work Group, March 1997. Best Management Practice Guidelines Retail Gasoline Outlets.

Roesner L., Urbonas B., Sonnen M., July 1988. Design of Urban Runoff Quality Controls, American Society of Civil Engineers, New York.

Schueler, T.R. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, Metropolitan Washington Council of Governments, Department of Environmental Programs.

Seattle Engineering Department Drainage and Wastewater Utility 1993. Dayton Avenue W. Swale Biolfiltration Study.

U.S. Environmental Protection Agency (EPA). 2007. Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices. EPA 841-F-07-006.

U.S. EPA. 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, Chapter 4. EPA 840-B-92-002.

U.S. EPA. 1993. Handbook Urban Runoff Pollution Prevention and Control Planning, EPA/625/R-93/004.

U.S. EPA. 1992. Storm Water Management for Industrial Activities, Developing Pollution Prevention Plans and Best Management Practices, EPA 832-R-92-006.

Uribe & Associates, Larry Walker Associates, October 1994. Action Plan Demonstration Project, Demonstration of Gasoline Fueling Station BMPs, prepared for US EPA Region IX.

Ventura County Flood Control and Water Resources Department, 1991. Hydrology Manual.

Washington State Department of Ecology, October 1992. Biofiltration Swale Performance, Recommendations, and Design Considerations, Publication 657, Grant Tax. No. 89-136.

Water Environment Federation and American Society of Civil Engineers 1992. Design and Construction of Urban Stormwater Management Systems.

Watershed Management Institute, Inc., August 1997. Operation, Maintenance and Management of Stormwater Management Systems.

Woodward-Clyde Memorandum June 1995 to City of Fresno Metropolitan Flood Control District, Vegetated Swale Guidelines.

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