MAY 2025

CITY OF MODESTO

Guidance Manual for Development Stormwater Quality Control Measures

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CITY OF MODESTO CALIFORNIA

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1. INTRODUCTION

1.1 PURPOSE & GOALS

The 2025 Guidance Manual for Development Stormwater Quality Control Measures (2025 Development Guidance Manual or Guidance Manual) for the City of Modesto (City) is an update to the 2011 Development Guidance Manual (last revised in 2015). The 2025 update aligns the Development Guidance Manual with:

1) The municipal stormwater National Pollutant Discharge Elimination System (NPDES) permit (Order R5-2016-0040[1]; Regionwide Permit) requirements, which emphasizes low impact development (LID) implementation strategies for new development and redevelopment projects (adopted in 2016); and
2) The Statewide Trash Amendments, which require the implementation of trash full capture systems (FCS) or equivalent trash control measures in certain land use areas (adopted in 2015).

The Guidance Manual and requirements contained herein are applicable to both private and public parcel-based projects and is a "living document", which will be periodically updated to reflect new information, findings, and experience. The overarching goal of the Guidance Manual is to minimize the potential long-term impacts on receiving water quality from new development and redevelopment projects[2] and to streamline the water quality-based design standards with the City's storage-based design standards (**Section 1.4**).

The Manual has been prepared to achieve the following:

- Protect water resources within the City's jurisdiction from the potential adverse impacts associated with runoff from development projects;
- Implement development design standards consistent with the City's municipal stormwater permit and other State requirements, including trash control;
- Integrate and streamline the City's water quality-based development standards with the storage-based development standards;
- Emphasize the implementation of low-impact development (LID)-based strategies;
- Provide clear development standards for developers, engineers, and planners to use in the selection and implementation of appropriate control measures; and
- Provide maintenance procedures to ensure that the selected control measures will be maintained to provide effective, long-term pollution control.

Section 2 of the Manual identifies what requirements apply to which types of projects. A list of the key terms and acronyms used within the Guidance Manual is provided in **Appendix A**.

[1] The Central Valley Regional Water Quality Control Board (Regional Water Board) adopted a Regionwide municipal stormwater NPDES Permit (Regionwide Permit; Order No. R5-2016-0040) in June 2016.
https://www.waterboards.ca.gov/centralvalley/water_issues/storm_water/municipal_permits/#regwidepermit

[2] The City first developed the Development Guidance Manual in January 2001 as required by Order No. 94-163. The 2001 Guidance Manual was updated in 2011 to ensure that it was consistent with Order No. R5-2008-0092.

1.1.1 Hydromodification Requirements

The Regionwide Permit requires the development of a Hydromodification Plan to mitigate the potential impacts of stormwater runoff flows on and within receiving waters. However, Priority Projects may be exempt from the implementation of hydromodification controls where "assessments of downstream channel conditions and proposed discharge hydrology indicate that adverse hydromodification effects to beneficial users of natural drainage systems are unlikely."

Example types of projects that may be exempted include, but are not limited to the following:

1) Redevelopment Projects (e.g., infill) that do not increase the effective impervious area or decrease the infiltration capacity of pervious areas compared to the pre-project conditions.
2) Projects that have any increased discharge directly or via a storm drain to a sump, drainage pump station, lake, area under tidal influence, or into a waterway (e.g., perennial river) that is not susceptible to hydromodification impacts.
3) Projects that discharge directly or via a storm drain into concrete or otherwise engineered (not natural) channels (e.g., channelized or armored with rip rap, shotcrete, concrete lined, etc.), which, in turn, discharge into a receiving water that is not susceptible to hydromodification impacts.

As is described in additional detail in **Section 1.4** and **Figure 2-1**, the City requires new development and most redevelopment projects to retain the stormwater onsite, which protects the receiving waters from potential hydromodification impacts. Alternatively, development projects may be required to discharge into centralized retention or detention basins. These detention basins then typically discharge into engineered channels. As such, the City is exempt from requiring additional hydromodification controls for development projects and is not developing a corresponding Hydromodification Management Plan.[3]

However, this Development Guidance Manual emphasizes the broader concept of LID, which works to replicate pre-project hydrology in a post-project environment through the volume reduction requirement (VRR) as well as requirements to implement best management practices (BMPs) that promote retaining rainfall on-site through infiltration, evapotranspiration, or harvest and use. These requirements will reduce or eliminate the volume of stormwater runoff from a post-project site that is discharged to the receiving water and thereby mitigate potential hydromodification impacts. In cases where the VRR cannot be fully met, the project applicant must apply alternative compliance methods for the remaining stormwater volume that is not retained on-site.

As such, the 2025 Development Guidance Manual is consistent with and meets the requirements for hydromodification within **Attachment J**[4].

[3] Page 2 of Order No. R5-2015-0024.

[4] Finding 16 of the 2016 Regionwide Permit notes "Properly designed, installed, and maintained LID measures are a primary method to address the causes of hydromodification."

1.2 LOW-IMPACT DEVELOPMENT STRATEGIES

Stormwater management has historically consisted of a network of impervious surfaces (e.g., rooftops, walkways, driveways, parking lots, and roads) connected to a storm drain system that was designed to quickly convey stormwater off-site to prevent flooding and protect life and property. Dozens of studies have documented the impacts of connected impervious cover on the natural hydrologic cycle (CWP, 2003). In a natural setting, most rainfall is either infiltrated into the soil or lost to evapotranspiration. However, with urbanization, pervious surfaces (such as forests and meadows) are converted into impervious surfaces such that the rainfall is conveyed off-site. This leads to an increase in the volume and flow of stormwater runoff to downstream water bodies (**Figure 1-1**). If not managed correctly, this increased stormwater runoff may adversely impact local water bodies.

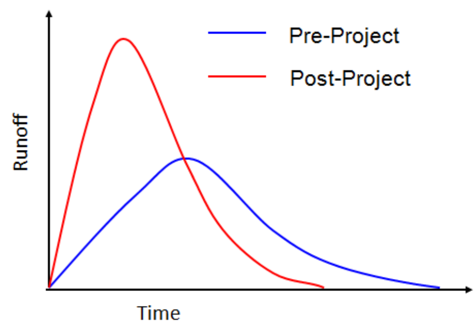


Figure 1-1. Pre vs. Post Project Hydrograph. *Modified from Source: Haltiner, Jeffrey, Philip Williams & Associates, Ltd. Hydromodification: An Introduction and Overview Presentation. (2006, May).*

To mitigate these impacts, conventional BMPs (e.g. detention basins) were implemented to detain stormwater runoff by releasing the volume over a period of time (**Figure 1-2**).

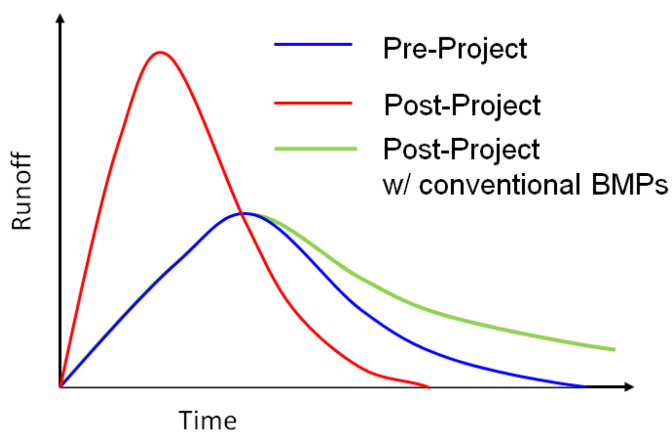


Figure 1-2. Hydrograph with Conventional BMPs. *Modified from Source: Haltiner, Jeffrey, Philip Williams & Associates, Ltd. Hydromodification: An Introduction and Overview Presentation. (2006, May).*

To enhance pollutant removal and groundwater recharge benefits, LID-based strategies have been required and incorporated into an overall stormwater management approach. LID is defined as, "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-project hydrologic functions… LID strategies include retention practices that do not allow runoff, such as infiltration, rain-water harvesting and use, and evapotranspiration."[5]

LID is a decentralized approach to stormwater management that mimics the site's natural hydrology by retaining rainfall onsite. The goal is to eliminate the shaded areas, as shown in **Figure 1-3,** by reducing the peak volume and flow duration through site design and volume reduction measures (VRMs). The benefits of the reduced stormwater volume include reduced pollutant loading and increased groundwater recharge and evapotranspiration rates.

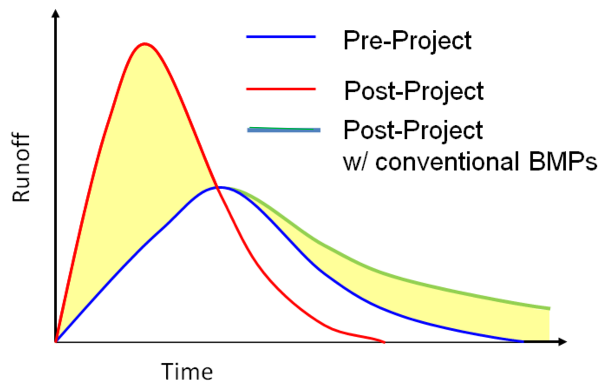


Figure 1-3. Goal of LID is to Mimic Pre-Project Hydrography through Reduction in Peak Runoff Volume and Flow. *Modified from Source: Haltiner, Jeffrey, Philip Williams & Associates, Ltd. Hydromodification: An Introduction and Overview Presentation. (2006, May).*

Additionally, LID strategies can decrease the cost associated with stormwater management and treatment by reducing the number of materials needed for pavement, the need for curbs and gutters, and by reducing stormwater volume, which will correspond to smaller flood-control structures.

1.3 TRASH CONTROL REQUIREMENTS

On April 7, 2015, the State Water Resources Control Board (State Water Board) adopted an Amendment to the Water Quality Control Plan for Ocean Waters of California to Control Trash and Part 1 Trash Provision of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries. Together, they are collectively referred to as "the Trash Amendments."

The Trash Amendments require agencies with regulatory authority over priority land uses (PLUs) to comply with the prohibition of trash discharge to receiving waters. As defined in the Statewide Trash Amendments, PLU areas include high-density residential, industrial, commercial, mixed urban, and public transportation stations (**Section 2**). As such, development and redevelopment projects within these PLU categories will be required to implement trash full capture controls (**Section 7**).

In addition to the State Water Board requirements, the City Engineer may mandate the installation of trash full capture controls at facilities that will be dedicated to the City for

[5] 2016 Regionwide Permit, Attachment C.

maintenance. The specific location of these devices will be determined based on the project design, ensuring ease of maintenance activities.

1.4 FLOOD CONTROL DESIGN STANDARDS

This Development Guidance Manual is intended to assist project proponents understand how to apply the City's stormwater quality-based requirements to new and redevelopment projects. Although not a part of this manual, it is important to understand how the City's flood control design standards (which are focused on storage) also apply to development projects.

The City's Standard Specifications details the multiple criteria for drainage system design (collection, conveyance, storage/disposal) within the City[6]. Any discussion or references to the flood control requirements within this Guidance Manual is provided to assist project proponents in understanding how the flood control and stormwater quality-based requirements are applied. However, this Guidance Manual is **not** intended to provide flood control design criteria. The City Engineer shall be the final authority for all questions that may arise as to the interpretation of this Guidance Manual and City Standard Specifications. Appeals of the City Engineer's decisions may be made to the City Council.

For the purposes of the Flood Control Design Standards:

- Greenfield New Development is considered to be development of buildings or other facilities on undeveloped land with no existing structures or infrastructure.
- Infill Development is considered to be development of buildings or other facilities on land located within the City's existing developed area. Infill development can consist of unused or underutilized land, redevelopment, or new development.

All new development and redevelopment projects are required to provide collection, conveyance and storage/disposal as required by the current City Standard Specifications and stormwater quality-based controls as required by this Guidance Manual.

For infill development, the parcel(s) being improved may currently or have previously been served by the City's stormwater collection system. If the proposed project improvements will be generating more flows than preexisting, it is the project proponent's responsibility to demonstrate adequacy of existing improvements (including downstream conveyance and storage/disposal) or store and dispose of all on-site drainage on-site with an approved method. Infill projects in areas without positive gravity storm drainage system shall utilize horizontal drains for street right-of-way and all on-site drainage shall be stored and disposed of on-site with an approved method.

Once the City's Standard Specifications requirements for stormwater collection, conveyance and storage/disposal have been met, the project proponent must also ensure that the stormwater quality-based requirements detailed within this Development Guidance are also met, as applicable. If the Volume Reduction Requirements are met through the City Standard Specifications by retaining all the stormwater on site, then the project(s) will not need to meet the VRR as specified within this Guidance Manual. Where this is not the case, the projects will

[6] Refer to the current version of the City's Standard Specifications at www.modestogov.com.

need to meet the volume retention and other requirements specified within the Guidance Document.

1.5 IMPLEMENTATION SCHEDULE

Effective September 1, 2025, the 2025 Development Guidance Manual is applicable to all Priority Projects and Priority Land Use Projects or phases of these Projects as described below:

- Tentative maps or vested tentative maps.
- Extensions of approved tentative maps or vested tentative maps.
- Improvement plans approved by the City Engineer.
- Permits for development or construction issued on or after September 1, 2025.
- Infill Priority Projects that require a Use Permit from the City on or after September 1, 2025.

The requirements within this Development Guidance Manual do not apply if approval of a tentative map or vested tentative map was "deemed complete" prior to September 1, 2025. In that case, the design standards within the 2011 Development Guidance Manual apply.

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 projects, the controls that are required for each type of project, and the process that must be used to identify and incorporate stormwater control measures.

The standards set forth in the Development Guidance Manual shall apply to all new development and significant redevelopment projects falling under the Priority Project and/or PLU Project categories as specified within this section. Compliance with the Manual should be discussed as early as possible in the design process. The project engineer and other design professionals (including architects) should be involved during the City's Tentative Map stage.

If a project is being developed on a parcel(s) where a previous project was already subject to the City's Stormwater Development Guidance Manual, it is possible that some of the stormwater control measures currently onsite may be able to be used to prevent, infiltrate, or treat stormwater from the new project. However, every project subject to this Manual must show how the required stormwater controls will be incorporated, that the requirements are met, and submit the required documentation.

In addition to the requirements prescribed within this Development Guidance Manual, development projects must also adhere to applicable drainage standards as specified in the most current City Standard Specifications (**Section 1.4**). In the event of a conflict between the requirements of this Guidance Manual and the City's Standard Specifications, the City Engineer will make the determination as to which of the requirements apply and/or how to resolve the conflict.

For applicable projects, the planning permit application submittal must show how the required stormwater controls will be incorporated in the project.

2.1 EXCLUSIONS

Projects that are located outside of the City of Modesto and the following specific types of projects are not required to comply with the City's Development Guidance Manual, however these types of project may be subject to other requirements:

a. Interior remodels and interior tenant improvements which do not include any soil disturbance.

b. Second-story additions that do not increase the building footprint or include any soil disturbance.

c. Roof repairs, exterior wall repairs and foundation repairs.

d. Raised (not built directly on the ground) decks, stairs, or walkways designed with spaces to allow water drainage.

e. Vegetation and landscaping maintenance.

f. Above-ground fuel storage tanks and fuel farms with spill containment system.

g. Public and private projects only replacing curb, gutter, and drive approaches (this exception does not apply to offsite improvements associated with private development).

h. Underground utility projects that replace the ground surface with in-kind material or materials similar runoff characteristics.

i. Electrical and utility vaults, lift station wet wells, backflows and other utility devices. Note: if these types of projects are part of a larger liner utility project (LUP) they will be subject to the Development Guidance Manual if they have a discrete location that has 5,000 square feet or more of a newly constructed contiguous impervious surfaces.

j. Photovoltaic systems installed on/over existing roof or other impervious surfaces, and panels located over pervious surfaces with maintained grass or vegetated groundcover, or panel arrays with a buffer strip at the most down gradient row of panels.

k. Emergency housing projects undertaken by the government agencies for people experiencing unsheltered homelessness, when those projects are constructed pursuant to and consistent with Government Code § 8698.4, including the definition of "homeless shelter" in subdivision (c), and that are temporary[7]. These projects must implement relevant best management practices such as provision of trash collection and sanitary sewage services. In addition, the managing entity of such housing projects assumes full responsibility for the quality and quantity of runoff from these properties.

   The City Engineer reserves the right to impose the provisions of this manual on such projects, depending on factors such as project location, size, and compliance with applicable regulations.

l. Routine maintenance and repair activities that are conducted to maintain original line and grade, hydraulic capacity, or emergency construction activities required to immediately protect public health and safety. If the activity significantly disturbs the soil under the base then it is not considered routine maintenance. Examples of these types of activities include:

   a. Road surface repair including crack sealing, slurry sealing, fog sealing, pavement markings/striping, potholing and square cut patching.

   b. Overlaying existing asphalt or concrete pavement with asphalt or concrete with no increase in area.

   c. Shoulder grading.

   d. Applying pavement treatment such as chip seal or cape seal to existing asphalt or concrete pavement with no increase in area and less than 5,000 cumulative square feet of base repair.

[7] Examples of temporary emergency housing include: formal "community cabin" or tent communities; RV safe parking areas; and homeless "navigation centers" with housing, that are temporary and provide housing for people experiencing unsheltered homelessness.

e. Repair and reconstruction of the road because of slope failures, natural disasters, acts of God or other man-made disaster.

The City Engineer may modify the above listed categories to provide clarity as long as it does not conflict with **Section 2.2**. As needed, the City Engineer will evaluate projects and provide guidelines to follow and to meet all the applicable requirements.

2.2 IDENTIFICATION OF PROJECT TYPE AND PROCESS TO COMPLY WITH CITY STANDARDS

The steps, **Figures 2-1, 2-2 and 2-3**, and process outlined below will assist in determining which requirements apply to a specific project.

In general, all new development and significant redevelopment projects which are determined to be “Priority Projects” must apply all four categories of stormwater pollution controls measures, which include:

- Site Design Control Measures (**Section 3**)
- Source Control Measures (**Section 4**)
- LID-Based Volume Retention Measures (**Section 5**)
- Treatment Control Measures (**Section 6**)

In addition, all Priority Projects and PLU Projects must apply trash control measures (**Section 6**).

Step 1: Determine Project Type and Requirements

Step 1A: Determine if the Project is New Development or Significant Redevelopment

The first step is to determine if the project is categorically “new development” or “significant redevelopment” as defined below (see **Figure 2-1**).

A. **New Development**: Land disturbing activities; structural development, including construction or installation of a building or structure, creation of impervious surfaces; and land subdivision.

   OR

   New Development Infill: development of buildings or other facilities on undeveloped land located within the City’s existing developed area.

B. **Significant Redevelopment**: Land disturbing activity that results in the creation, addition, or replacement of at least 5,000 square feet of impervious surface area on an already developed site, which may include, but is not limited to the following types of projects:

   - 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. Replacement of impervious surfaces includes any activity where impervious materials are removed, exposing underlying soil during construction.

   Significant redevelopment does not include “routine maintenance”, which includes activities that are conducted to maintain original line and grade, hydraulic capacity, or emergency construction activities required to immediately protect public health and safety. If the activity significantly disturbs the soil under the base then it is not considered routine maintenance.

Step 1B: Determine if the Project is Priority Land Use Project, Priority Project or Both

The next step is to determine if the project is, by definition:

A. A Priority Land Use (PLU) Project;
B. A Priority Project; or
C. Both a Priority Project and a PLU Project.

The types of land uses and categories of development for both types of projects are defined below.

A. PLU Projects include the following:

1. **High-density residential** – All land uses with at least 10 developed dwelling units per acre.
2. **Industrial** – Land uses where the primary activities on the developed parcels involve product manufacture, storage, or distribution (e.g., manufacturing businesses, warehouses, equipment storage lots, junkyards, wholesale businesses, distribution centers, or building material sales yards).
3. **Commercial** – Land uses where the primary activities on the developed parcels involve the sale or transfer of goods or services to consumers (e.g., business or professional buildings, shops, restaurants, theaters, vehicle repair shops, etc.).
4. **Mixed urban** – Land uses where high-density residential, industrial, and/or commercial land uses predominate collectively (i.e., are intermixed).
5. **Public transportation stations** – Facilities or sites where public transit agencies' vehicles load or unload passengers or goods (e.g., bus stations and stops).

B. Priority Projects[8] include the following:

1. **Residential subdivision of 10 housing units or more –** This category includes single-family homes, multi-family homes, condominiums, and apartments, as well as the related street and road paved surfaces that are used for the transportation of automobiles, trucks, motorcycles, and other vehicles (not including parking lots, see separate parking lot requirement below). A housing unit is also defined as a dwelling unit.
2. **Commercial and industrial developments greater than or equal to 10,000 square feet of impervious area –** This category is defined as any development on private land that is not for residential uses, where the land area for development is greater than or equal to 10,000 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, office commercial, retail commercial, educational institutions), recreational facilities, commercial retail nurseries, car wash facilities, mini-malls, and other business complexes, shopping malls, hotels, office buildings, public warehouses, and other industrial facilities.

[8] Priority Development Projects are defined within Attachment C of the Regionwide Permit. It should be noted that the Attachment C category "Single-family hillside residences (includes development on any natural slope that is twenty five percent or greater)" does not apply within the City's jurisdictional area.

3. **Automotive repair shops –** This category is defined as a facility that is categorized in any of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, 7536-7539, or 7549.
4. **Retail gasoline outlets (RGOs)** – An RGO is defined as any facility engaged in selling gasoline and lubricating oils.
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 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. For restaurants less than 5,000 square feet, the development must meet all development standards except for treatment control measures and numeric sizing criteria.
6. **Parking lots 5,000 square feet or more or with 25 or more parking spaces and potentially exposed to urban runoff –** A parking lot is defined as a land area or facility for the temporary parking or storage of motor vehicles used personally, for business, or commerce.
7. **Significant redevelopment** – Land disturbing activity that results in the *creation, addition, or replacement of at least 5,000 square feet of impervious surface area* on an already developed site, which may include, but is not limited to the following types of projects:
   - 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[9]. Replacement of impervious surfaces includes any activity where impervious materials are removed, exposing underlying soil during construction.

   Significant redevelopment does not include "routine maintenance"[10], which includes activities that are conducted to maintain original line and grade, hydraulic capacity, or emergency construction activities required to immediately protect public health and safety. If the activity significantly disturbs the soil under the base then it is not considered routine maintenance. In the case of an addition, if the addition constitutes less than 50 percent of the original development, post-construction stormwater requirements only apply to the addition.[11]

[9] Replacement of impervious surfaces includes any activity where impervious materials are removed, exposing underlying soil during construction.
[10] Routine maintenance includes activities that are conducted to maintain original line and grade and/or hydraulic capacity. If the activity significantly disturbs the soil under the base then it is not considered routine maintenance.
[11] For example, if a 6,000 sq-ft addition is built for an existing 15,000 sq-ft building, post-construction stormwater requirements only apply to the 6,000 sq-ft addition.

After reviewing the PLU and Priority Project criteria above, determine if the project is:

A. A Priority Land Use (PLU) Project;

B. A Priority Project; or

C. Both a Priority Project and a PLU Project.

Table 2-1 may assist with this determination.

Table 2-1. Determination of Project Type

Type of Development	Priority Land Use Project	Priority Project Only OR Priority Project AND Priority Land Use Project
Residential	High density (10 dwelling units/acre)	**Priority Project Only** Medium or Low Density (< 10 units)
		Priority Land Use Project and Priority Project High-density (10 dwelling units/acre & ≥10 units)
Industrial	Any size	**Priority Land Use Project and Priority Project** > 10,000 sq ft
Commercial	Any size	**Priority Land Use Project and Priority Project** > 10,000 sq ft or Auto Repair or RGO or Restaurant
Mixed Urban	Any size	**Priority Land Use Project and Priority Project** > 10,000 sq ft
Public Transportation Stations	Any facility or site	---
Parking Lots	---	**Priority Project Only** ≥ 5,000 sq ft or ≥ 25 exposed parking spaces
Significant Redevelopment	---	**Priority Project Only** Creation, addition, replacement ≥ 5,000 sq ft impervious surface

Step 2: Collect Site Information [*Applies to PLU Projects and/or Priority Projects*]

If the project is a PLU and/or Priority Project, site information needs to be collected that is critical for the selection of appropriate stormwater control measures. **Section 3** identifies the types of information that must be documented and submitted to the City at the onset of the application process.

Step 3: Apply Site Design Control Measures [*Applies to Priority Projects*]

The third step is to apply the required Site Design Control Measures 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 reduce runoff volume and is the first step (and possibly the most inexpensive control measure) in meeting the VRR (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 VRMs or LID Treatment Controls is strongly encouraged where the slope and density permit.

Step 4: Apply Source Control Measures [*Applies to Priority Projects*]

All Priority Projects must implement applicable Source Control Measures. Source Control Measures are operational practices that prevent pollution by reducing potential pollutants at the source and/or prevent pollutants from coming into contact with stormwater runoff. The Priority Projects must implement the source control measures specified in **Table 2-2**. Additional Guidance on Source Control Measures can be found in **Section 4**.

Step 5: Apply LID-based Volume Retention Measures [*Applies to Priority Projects*]

*[As noted in **Figure 2-1**, if a project is required to comply with **Section 1.4** of the 2025 Development Guidance Manual consistent with the City Standards by retaining all of the stormwater on site, then the Volume Reduction Requirement Calculations are not required and are considered to have been met.]*

All Priority Projects must apply VRMs (**Table 2-2 and 2-3**). VRMs are BMPs that can direct, retain, reuse, and/or infiltrate stormwater runoff (e.g., rain gardens, rain barrels). Guidance for implementing VRMs is presented in **Section 5**. As a part of Step 5, projects must calculate their VRR, which drives the need for and application of VRMs.

Stormwater Quality-based Design Storm

The **VRR** specifies that post-project runoff volumes must match pre-project runoff volumes for the 0.50-inch storm depth, the average 85th percentile 24-hour storm depth estimated for the City's jurisdictional area[1]. In other words, the **VRR** equals the post-project runoff volume (without VRMs) minus the pre-project runoff volume. New Development Priority Projects can combine VRMs and LID Treatment Controls (see Step 6) to meet the VRR.

Additional information on the VRR is provided in **Section 5**; additional information on the Flood Control Design Standards is provided in **Section 1.4.**

VRMs also provide treatment benefits recognized through tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the water quality volume (WQV) or water quality flow (WQF), which are the primary design criteria used to size Treatment Control Measures. The WQV is calculated by multiplying the effective impervious area by the unit basin volume (measured in inches). The WQF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches

[1] The 85th percentile storm event is the event that has a precipitation total greater than or equal to 85 percent of all storm events over a given period of record in a specific area or location. For example, to determine what the 85th percentile storm event is in a specific location, all 24-hour storms that have recorded values over a 30-year period would be tabulated and a 85th percentile storm would be determined from this record (i.e., 15 percent of the storms would be greater than the number determined to be the 85th percentile storm) [Region-wide Permit pg F-63]. For the City of Modesto this has been determined to be 0.5 inches.

per hour). Implementation of VRMs reduces the effective impervious area and, thereby, the volume of water to be treated.

The VRM fact sheets (**Section 5**) detail how volume retention 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**.

Volume Retention Requirement Credit for Significant Redevelopment

Significant Redevelopment Priority Projects must also comply with the VRR; however, an incentive in the form of credits may be applied based on the type of redevelopment. A maximum credit of 0.25 inch from the 0.50-inch VRR may be applied to any of the following types of redevelopment. Credits are issued in 0.05-inch increments based on five criteria:

- Significant Redevelopment (as defined in Step 1);
- Brownfield redevelopment;
- High density (≥22 units per acre);
- Vertical Density (2 or more stories); or
- Mixed-use and Transit Oriented Development (within ½ mile of public transit, such as a bus stop)

Step 6: Apply Treatment Control Measures ***[Applies to PLU Projects and/or Priority Projects]***

Treatment control measures are required for all Priority Projects and PLU Projects (**Table 2-2 and 2-3**). Treatment controls are engineered technologies designed to remove pollutants from stormwater runoff and must be designed to treat the WQF or WQV. All Treatment Controls, except those controls specifically implemented for trash, are designed to treat the runoff from the smaller storms and the first flush of large storms, which comprise 80-85 percent of annual runoff volumes.

For trash, the following types of controls may be implemented as long as they are designed to treat the peak flow rate from a one-year, one-hour storm for the Modesto area (0.32 inches[2]):

- Full Capture Systems (FCS)[3];
- Multi-Benefit Projects[4]; and
- Other Treatment Controls[5].

[2] This value was determined by using Basin Sizer, which is a software tool developed by Caltrans to determine what the 1-year, 1-hour storm size is for different areas within California. This information is used for the sizing of full trash capture devices. The value may be modified over time due to changing climate or other conditions. https://svctenvims.dot.ca.gov/basinsizer/

[3] Full Capture System: A treatment control, or series of treatment controls, including but not limited to, a Multi-Benefit project or a LID control that traps all particles that are 5 mm or greater and has the design treatment capacity that is either: a) of not less than the peak flow rate, Q, resulting from a one-year, one-hour storm in the sub-drainage area, or b) appropriately sized to, and designed to carry at least the same flows as the corresponding storm drain.

[4] Multi-Benefit Project: A treatment control project designed to achieve any of the benefits set forth in section 10562, subdivision (d) of the Water Code.

[5] Treatment Controls: Structural BMPs to either (a) remove pollutants and/or solids from stormwater runoff, wastewater, or effluent, or (b) capture, infiltrate or reuse stormwater runoff, wastewater, or effluent. Treatment Controls include FCS and LID controls.

Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets located within the parcel's boundaries and operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public Right of Way (RoW) if the City has agreed to enter into a maintenance agreement with the property owner.

The volume or flow in excess of the treatment design values is typically bypassed. Guidance on sizing the Treatment Controls is provided in **Section 6**. The selection of Treatment Controls should be based on their ability to reduce runoff volumes and remove the pollutants of concern. See **Table 6-2** for the typical removal efficiency of treatment controls.

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

If the VRR cannot be fully met due to site constraints, see “Alternative Compliance Option” in **Section 5**. Priority Projects that cannot fully meet the VRR must select Treatment Controls with a medium to high removal efficiency for the pollutants of concern (**Tables 2-2 and 6-2**).

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

Step 7: Select Additional Treatment Controls as Needed to Meet Treatment Requirement [*Applies to Priority Projects*]

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

Regional Stormwater Facilities

Priority Projects that discharge stormwater runoff to City-approved, regional stormwater treatment control facilities that comply with the WQV/WQF requirements are not required to provide separate treatment controls. However, such projects are required to meet the VRR and provide site design, source, and VRMs consistent with the Development Guidance Manual.

Step 8: Submit Project Stormwater Quality Control Measures Plan and Maintenance Plan [*Applies to PLU Projects and/or Priority Projects*]

Priority and PLU Projects are required to submit a Project Stormwater Quality Control Measures Plan (SWQCP) that adequately demonstrates that the proposed project will conform to all requirements of the Development Guidance Manual.

The SWQCP must be approved by the City prior to the issuance of building or use permits for the project. The SWQCP must be submitted in addition to any other required submittals such as a Stormwater Pollution Prevention Plan (SWPPP), which is required for all construction projects subject to the State Construction General Stormwater Permit.

Project SWQCPs should conform to the content and format requirements pursuant to the Development Guidance. The City's review and approval process is as follows:

- Receive Project SWQCP from applicant.
- Send Project SWQCP to plan reviewer.
- Send comment letter, as needed, to applicant outlining steps needed to be taken to obtain plan approval.
- Receive requested item(s) from applicant.
- Check resubmittal.
- Send second comment letter to applicant, if necessary.
- Approve Project SWQCP through the City's permitting system.
- Send approved Project SWQCP to the City Environmental Compliance Section for use by inspectors.

The City also requires the submittal of a Maintenance Plan and execution of a Maintenance Agreement with the owner/operator of stormwater control measures prior to the final acceptance of a private project for projects using any of the Structural Source Controls that require maintenance (**Section 4**), VRMs (**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** provides additional information and guidance on compliance with maintenance requirements.

Review **Figures 2-1, 2-2, and 2-3** to determine what water quantity and water quality requirements apply to the project.

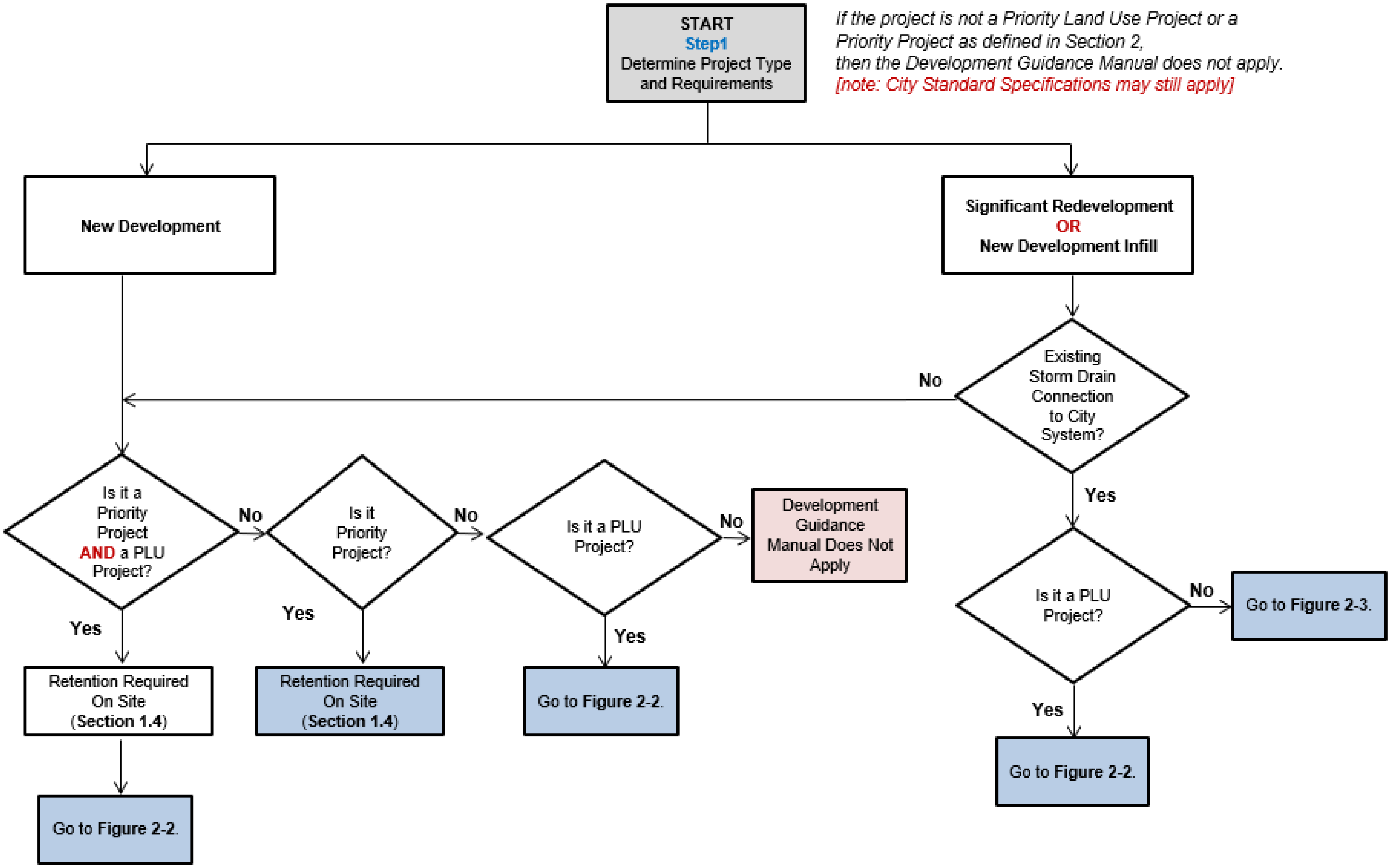
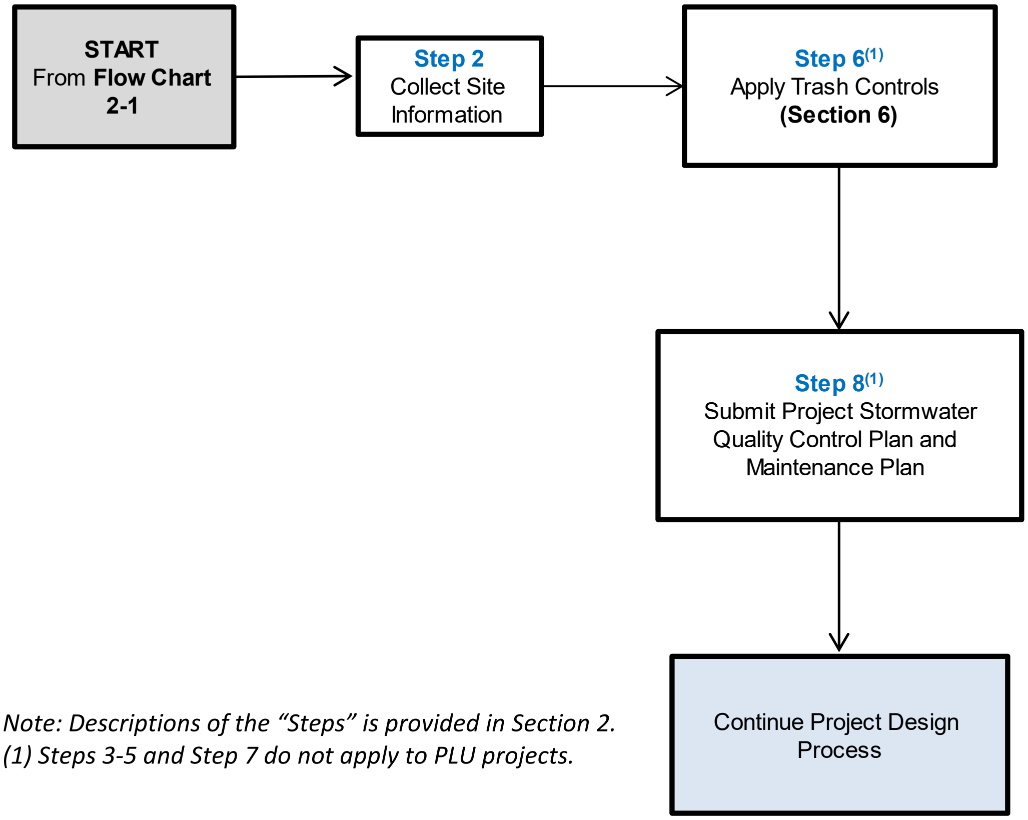
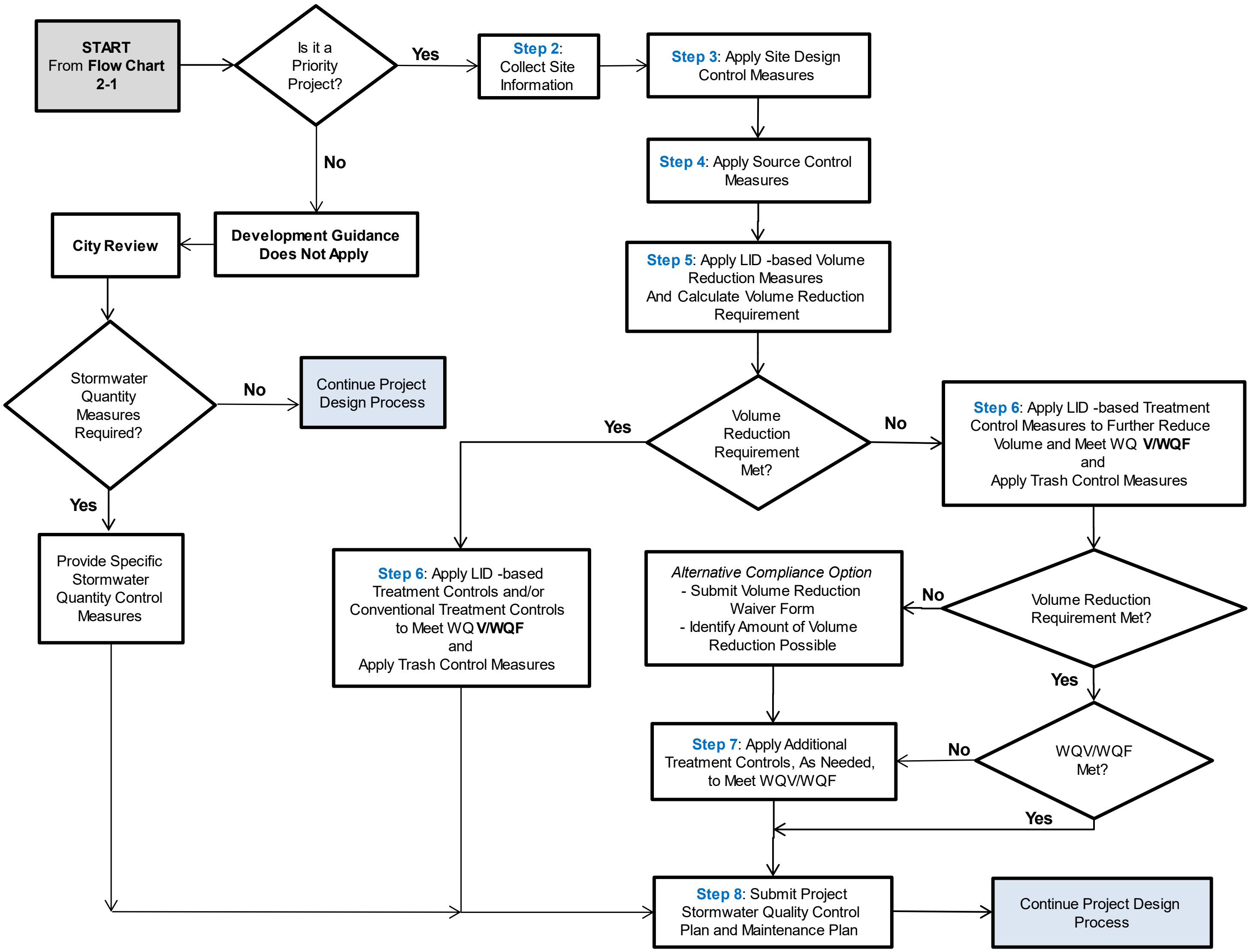


Figure 2-1. Determination of Project Type and Requirements



Note: Descriptions of the "Steps" is provided in Section 2.
(1) Steps 3-5 and Step 7 do not apply to PLU projects.

Figure 2-2. Development Standards for PLU Projects



Note: Descriptions of the "Steps" is provided in Section 2.

Figure 2-3. Development Standards for Priority Projects and PLU/Priority Projects

Table 2-2. Control Measure Selection Matrix for New Development and Significant Redevelopment Project Categories[1]

Project Category	Site Design Control Measures				Source Control Measures							VRMs	Treatment Control Measures
	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 Material Storage Area (S-2)	Trash Storage and Waste Handling Area (S-3)	Outdoor Loading/ Unloading Dock Area (S-4)	Outdoor Repair/ Maintenance Area (S-5)	Outdoor Vehicle/ Equipment Wash Area (S-6)	Fueling and Maintenance Area (S-7)	Rain Garden (V-1) Rain Barrel/Cistern (V-2) Interception Trees (V-3) Grassy Channel (V-4) Vegetated Buffer Strip (V-5)	<u>LID Treatment Controls</u> Bioretention (L-1)[t] Stormwater Planter (L-2) Tree-well Filter (L-3) Water Quality Infiltration Basin (L-4)[t] Water Quality Infiltration Trench (L-5)[t, 2] Porous Pavement Filter (L-6) Vegetated Swale (L-7) Grassy Swale (L-8) Grassy Filter Strip (L-9) Infiltration Well (L-10) Dry Well (L-11) <u>Conventional Treatment Controls</u> Constructed Wetland (C-1) Extended Detention Basin (C-2)[t] Wet Pond (C-3) Proprietary Control Device (C-4) Trash Controls (C-5) Media Filter (C-6)
Residential Subdivisions (≥ 10 units)	R	R	R	R	R	R[1]	-	-	-	-	-	S	S/T
High-Density Residential (> 10 DU/acre)													T
Commercial/Industrial (any size) (including auto repair, RGO, restaurants)	R	R	R	R	R	R[1]	R[1]	R[1]	R[1]	R[1]	R[1]	S	S/T
Parking Lots (≥ 5,000 SF or 25 spaces)	R	R	R	R	R	R[1]	R[1]	-	-	-	-	S	S/T
Mixed Urban / Public Transport Stn	-	-	-	-	-	-	-	-	-	-	-	-	T
Significant Redevelopment (≥5,000 SF)	R	R	R	R	R	R[1]	R[1]	R[1]	R[1]	R[1]	R[1]	S	S/T

R: required; R[1]: required if outdoor activity is included in the project
S: select one or more applicable controls
[t]: can be modified to meet trash control requirements
S/T: select one or more applicable controls; trash control required; T: trash control required
[1]: VRMs and Treatment Controls can be used individually or in combination
[2]: Also known as a French Drain or a Horizontal Drain

Table 2-3. Control Measure Selection Matrix for Meeting Low Impact Development and Treatment Requirements

Control Measure	Assists in Meeting Requirements for:	
	Low Impact Development(1) Volume Retention/ Reduction	Treatment
Rain Garden (V-1)	✓	✓
Rain Barrel/Cistern (V-2)	✓ (2)	
Interception Tree (V-3)	✓ (2)	
Grassy Channel (V-4)	✓ (2)	✓ (3)
Vegetated Buffer Strip (V-5)	✓ (2)	✓ (3)
Bioretention (L-1)	✓	✓
Stormwater Planter (L-2)	✓	✓
Tree-Well Filter (L-3)	✓	✓
Water Quality Infiltration Basin (L-4)	✓	✓
Water Quality Infiltration Trench (L-5)(4)	✓	✓
Porous Pavement Filter (L-6)	✓	✓
Vegetated Swale (L-7)	✓	✓
Grassy Swale (L-8)	✓	✓
Grassy Filter Strip (L-9)	✓	✓
Infiltration Well (L-10)	✓	✓
Dry Well (L-11)	✓	✓
Constructed Wetland (C-1)	✓	✓
Extended Detention Basin (C-2)		✓
Wet Pond (C-3)		✓
Proprietary Control Devices (C-4)(5)	✓	✓
Trash Capture Devices (C-5)		✓
Media Filter (C-6)		✓

(1) This Manual emphasizes LID (which works to replicate pre-project hydrology in a post-project environment) by retaining rainfall on-site through infiltration, evapotranspiration, or harvest and use. These requirements mitigate or eliminate the volume of stormwater runoff from a post-project site that is discharged to the receiving water, thereby mitigating potential hydromodification impacts.
(2) Control measures may provide some LID benefits by mitigating some stormwater runoff volume. However, it must be coupled with other LID control measures to meet LID requirements.
(3) Control measures may provide some pollutant treatment to reduce pollutant load discharged off-site.
(4) Also known as a French Drain or Horizontal Drain
(5) Some types of priorietary control devices may assist in retaining and/or infiltrating stormwater.

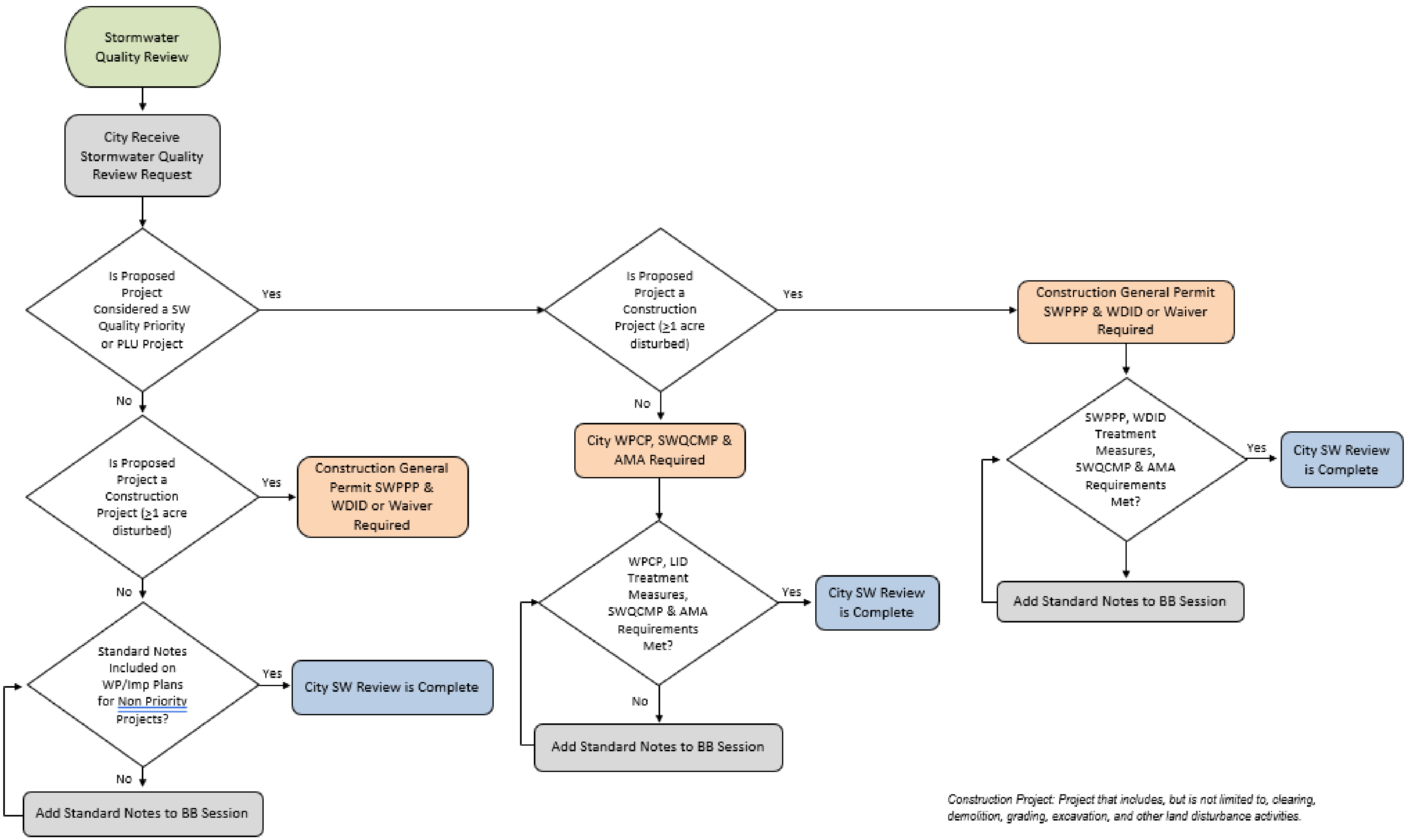


Figure 2-4. City SWQCP Review Process Flowchart

3. SITE ASSESSMENT

During the initial project planning and design, the project site should be evaluated to generate a hydrologically functional site that maximizes volume retention and integrates the necessary stormwater management throughout the site. Some of the principles that should be used during this phase of the project include:

- LID-Based Volume Retention Control Measures should be considered as early as possible in the site planning process. Hydrology should be an organizing principle that is integrated into the initial site assessment planning phases.
- Individual control measures should be distributed throughout the project site, and may influence configuration of roads, buildings, and other infrastructure.
- Consider flood control early in the design stages. Even sites with LID-based Volume Retention Control Measures will still have stormwater runoff that occurs during large storm events. Look for opportunities to simultaneously address flood control requirements.

This section presents the steps for assessing sites during the planning and design phase of a project to determine the existing site conditions and what control measures are feasible. This step is important for identifying site constraints that may limit or reduce the ability of a site to meet volume retention or treatment requirements. Conducting this step early in the planning process reduces the chance of having to re-design the site if proposed control measures are not technically feasible.

3.1 ASSESSING SITE CONDITIONS AND OTHER CONSTRAINTS

Assessing a site's potential for implementation of volume retention and treatment control measures requires the review of existing information as well as the collection of site-specific measurements. Available information regarding site layout and slope, soil type, geotechnical conditions, and local groundwater conditions should be reviewed as discussed below. In addition, soil and infiltration testing must be conducted to determine if stormwater runoff infiltration is feasible, and to determine the appropriate design infiltration rates for infiltration-based treatment control measures. For PLU-only Projects, information is only necessary for **Section 3.1.1.**

3.1.1 Project Location

Once the project location has been identified, it is necessary to conduct initial field investigations of the project site to determine site conditions and other constraints that may limit the ability to apply stormwater quality control measures. As part of this initial assessment, the developer must identify the following:

- Project area size (acres);
- Drainage area (acreage and location via site map);
- Impervious area (acreage and location via site map);
- Location of discharge point(s) (to the storm drain system or local receiving water); and

- Activities expected on-site.

The project area size and drainage area are important factors in determining the sizing and placement of stormwater runoff control measures. Identifying the point(s) of discharge of stormwater runoff off the project site is necessary to determine where stormwater runoff conveyance and/or control measures need to be located. Determining the activities expected to be conducted on-site before, during, and after construction is important in assessing what potential pollutants may be present in stormwater runoff.

3.1.2 Site Conditions

Topography

Assess site topography to evaluate surface drainage, identify topographic high and low points, and locate the presence of steep slopes. Each of these site characteristics can impact the type of volume retention or treatment control measure that will be most beneficial for a given project site. For example, stormwater runoff infiltration is more effective on level or gently sloping sites than steeply-sloped sites. Flows applied to slopes steeper than 15% may runoff as surface flows rather than infiltrate.

Soil Type and Geology

Identify site soil types and geologic conditions to evaluate the infiltration capacity at the site to determine the areas where infiltration is suitable as well as unsuitable for the purpose of locating infiltration-based control measures. Modesto area soil types are:

- Type A Soil – typically sands, loamy sands, or sandy loams. Type A soils have low stormwater runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep and well to excessively drained sands or gravels, and have a high rate of water transmission.
- Type B Soil – typically silt loams or loams. They have moderate infiltration rate when thoroughly wetted and consist chiefly of moderately-deep to deep and moderately-well- to well-drained soils with moderately fine to moderately coarse texture.
- Type C Soil – typically sandy clay loams. They have low infiltration rates when thoroughly wetted, consist chiefly of soils with a layer that impedes downward movement of water, and/or have moderately-fine to fine soil structure.
- Type D Soil – typically clay loams, silty clay loams, sandy clays, silty clays, or clays. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with high swelling potential, permanent high water table, claypan or clay layer at or near the surface, and/or shallow soils over nearly impervious material.

If site-specific data are available, soils with infiltration rates of 0.5 in/hr or greater are considered feasible for infiltration-based control measures. Early identification of soil types throughout the project footprint can reduce the number of test pit investigations and infiltration tests needed by narrowing potential test sites to locations with those that are most likely to be amenable to infiltration.

Available geologic or geotechnical reports on local geology should be reviewed to identify relevant features such as depth to bedrock, rock type, lithology, faults, or hydrostratigraphic or confining units. These geologic investigations, which may also identify shallow water tables and past groundwater issues, provide important information for control measure design.

Groundwater Considerations

Site groundwater conditions must be considered prior to volume retention or treatment control measure siting, selection, sizing, and design. The depth to groundwater beneath the project during the wet season may preclude infiltration because ten (10) feet of separation to the seasonal high groundwater level is required. In areas with known groundwater pollution, infiltration should be avoided because it may potentially contribute to the movement or dispersion of groundwater contamination.

Where soils have very high infiltration rates, groundwater quality may be impacted by infiltration-based control measures. Prior to use of infiltration-based control measures, consult with the City to identify if unconfined aquifers are located beneath the project site to determine the appropriateness of infiltration-based control measures.

Geotechnical Considerations

Water infiltration can cause geotechnical issues, including settlement through collapsible soil, expansive soil movement, and slope instability. Stormwater infiltration temporarily increases the groundwater level near the infiltration control measure, such that the potential geotechnical conditions are likely to be of greatest significance near the infiltration area and diminish with distance. A geotechnical investigation must be performed for the infiltration-based control measure to identify potential geotechnical issues.

Increased water pressure in soil pores reduces soil strength. Decreased soil strength can make foundations more susceptible to settlement and slopes more susceptible to failure. In general, control measures must be set back from building foundations or steep slopes. Recommendations for each site must be determined by a licensed geotechnical engineer based on soils boring data, drainage patterns, and current requirements for stormwater treatment.

Managing Off-Site Drainage

Locations and sources of off-site run-on onto the project site must be identified early in the design process. Off-site drainage must be considered when determining appropriate control measures for the site so that the drainage can be managed. Concentrated flows from off-site drainage may cause extensive erosion if not properly conveyed through or around the project site or otherwise managed. By identifying the locations and sources of off-site drainage, the volume of run-on may be estimated and factored into the siting and sizing of on-site control measures. Vegetated swales or storm drains may be used to intercept, divert, and convey off-site drainage through or around the project site to prevent flooding or erosion that might otherwise occur.

Existing Utilities

Existing utility lines that are on-site will limit the possible locations of certain control measures. For example, infiltration-based control measures should not be located near utility lines where the increased amount of water could damage utilities. Stormwater runoff should be directed away from existing underground utilities and project designs that require relocation of existing utilities should be avoided, if possible.

3.1.3 Pollutants of Concern

The pollutants of concern for a site depend on the type of land use and project category. The pollutants of concern should be identified for the site based on **Table 3-1**.

Table 3-1. Priority Project and PLU Project Categories and Associated Pollutants of Concern

Project Category	Pollutant Category of Concern						
	Sediment	Nutrients	Metals	Trash	Oxygen Demand	Toxic Organics	Bacteria
Residential	X	X	X[1]	X	X		X
Commercial/Industrial (any size) (including auto repair, RGO, restaurants)	X	X	X	X	X	X	X
Parking Lots (≥ 5,000 SF or 25 spaces)	X	X	X	X	X		
Mixed Urban	X	X	X	X	X	X	X
Public Transportation Stations				X			

X = Pollutant assumed to be present in stormwater runoff from project area unless applicant demonstrates otherwise.
1 – Metals are a pollutant category of concern for the street and road infrastructure portion of the residential development.

4. SITE DESIGN CONTROL MEASURES

4.1 INTRODUCTION

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

- Reduction in size of downstream Treatment Control Measures and conveyance systems;
- Reduced pollutant loading to Treatment Control Measures; and
- Reduced hydraulic impact on receiving waters.

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

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

The Site Design Control Measures described in this section are required for all Priority Projects unless the project applicant demonstrates to the satisfaction of the City Engineer that the particular control measures do not apply to the proposed project or the project site conditions; making 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 City Engineer.

4.2 DESCRIPTION

Detailed descriptions and design criteria for each Site Design Control Measures are presented in fact sheets in **Appendix B**.

5. SOURCE CONTROL MEASURES

5.1 INTRODUCTION

Source control measures are BMPs designed to prevent pollutants from contacting stormwater runoff or to prevent the discharge of contaminated stormwater runoff to the storm drain system and ultimately, the receiving waters. This section describes source control measures for activities identified as potentially significant sources of pollutants in stormwater runoff and is primarily focused on structural measures. The City may require additional source control measures not included in this Development Guidance Manual for specific pollutants, activities, or land uses.

Non-structural source controls, such as good housekeeping and employee training, are not included in this Development Guidance Manual. Each measure specified in this section should be implemented with appropriate non-structural source controls to optimize pollution prevention. The California Stormwater Quality Association BMP Development Handbook may be consulted for information on non-structural source controls (CASQA, 2021)[21].

The source control measures apply to both stormwater and non-stormwater discharges. Non-stormwater discharges include any runoff that is occurring on site that is not composed entirely of stormwater. Examples of non-stormwater discharges include cooling water, excess irrigation water, process wastewater, etc.

Some source control measures require a 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 to obtain information regarding sanitary sewer discharges and/or permits.

5.2 DESCRIPTION

Source control measures and associated design features specified for various sites and activities are summarized in **Table 5-1**. Detailed descriptions and design criteria for each Source Control Measure are presented in fact sheets in **Appendix C**. These fact sheets include design criteria established by the City to ensure the effective implementation of the required source control measures.

[21] Available through a subscription at www.casqa.org

Table 5-1. Summary of Source Control Measure Design Features

Source Control Measure[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 (S-2)		X	X	X	X		X
Outdoor Trash Storage and Waste Handling Area (S-3)	X	X	X	X		X	
Outdoor Loading/Unloading Dock Area (S-4)		X	X	X	X		X
Outdoor Repair/Maintenance Area (S-5)		X	X	X	X		X
Outdoor Vehicle/Equipment/ Wash Area (S-6)		X	X	X	X	X	X
Fueling and Maintenance Area (S-7)		X	X	X	X		X

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

6. VOLUME RETENTION MEASURES

6.1 INTRODUCTION

The City's approach to minimize potential water quality impacts from stormwater runoff is implementing a volume retention requirement. By retaining a portion of stormwater runoff onsite, the City expects to reduce and/or eliminate the pollutant loads, which are typically higher during the beginning of storm events, from reaching the receiving waters.

VRMs are required to minimize potential water quality impacts from stormwater. VRMs are BMPs used to direct, retain, reuse and/or infiltrate stormwater runoff (e.g., rain gardens and rain barrels). The type of VRM to be implemented at a site depends on several factors, including the type of potential pollutants in the stormwater runoff, the 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 VRMs vary.

The Design Engineer can utilize the listed and/or any other California Water Board approved VRMs and Treatment Controls individually or in combination to achieve the project requirements.

6.2 VOLUME RETENTION REQUIREMENT

The application of VRMs is driven, in part, by the VRR. The VRR is a requirement developed in response to the recent municipal stormwater permits specifying the use of LID and a combination of site design, source control, and treatment control measures.

The VRR specifies that post-project runoff volumes be reduced to match pre-project levels for the 0.50-inch storm depth, the average 85th percentile/24-hour storm depth estimated for the City's jurisdictional area. This calculated stormwater runoff volume for retention and treatment is different from the flood control retention requirements. The retention and treatment requirements are for water quality purposes, while the flood control retention requirements are for flood control purposes. The procedures for calculating the volume of stormwater runoff that must be retained on-site is presented in Fact Sheet C-1.

New Development Priority Projects may apply a combination of VRMs and LID Treatment Controls (see Step 6) to meet the VRR. Detailed descriptions and design criteria for each VRM are presented in fact sheets in **Appendix D**.

As indicated in **Table 6-1,** some controls are better suited for reducing the volume associated with rooftop runoff (e.g., Rain Barrels). In contrast, others are more suited for reducing the volume associated with pavement runoff (e.g., Interception Trees). Suggested applications of VRMs are illustrated in **Figures 6-1a and b**.

Table 6-1. Summary of Volume Retention and LID Treatment Controls

Control	Function		Disconnection Application	
	Volume Retention	Treatment	Rooftop	Pavement
VRMs (Section 5)				
Rain Garden (V-1)	Primary	Secondary	X	X
Rain Barrel/Cistern (V-2)	Primary	Secondary	X	
Interception Trees (V-3)[1]	Primary	Secondary		X
Grassy Channel (V-4)[1]	Primary	Secondary	X	X
Vegetated Buffer Strip (V-5)[2]	Primary	Secondary	X	X
LID-based Treatment Controls (Section 6)				
Bioretention (L-1) [1]	Primary	Secondary	X	X
Stormwater Planter (L-2)	Secondary	Primary	X	X
Tree-well Filter (L-3)	Secondary	Primary		X
Water Quality Infiltration Basin (L-4) [1]	Primary	Secondary	X	X
Water Quality Infiltration Trench (L-5) [1,3]	Primary	Secondary	X	X
Porous Pavement Filter (L-6)	Primary	Secondary		X
Vegetated Swale (L-7)	Secondary	Primary	X	X
Grassy Swale (L-8)	Secondary	Primary	X	X
Grassy Filter Strip (L-9)	Secondary	Primary	X	X
Infiltration Well (L-10)	Primary	Secondary	X	X
Dry Well (L-11)	Primary	Secondary	X	X

[1] This control may be modified to meet the trash control design criteria.
[2] 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 VRR.
[3] Also known as a French Drain or Horizontal Drain.

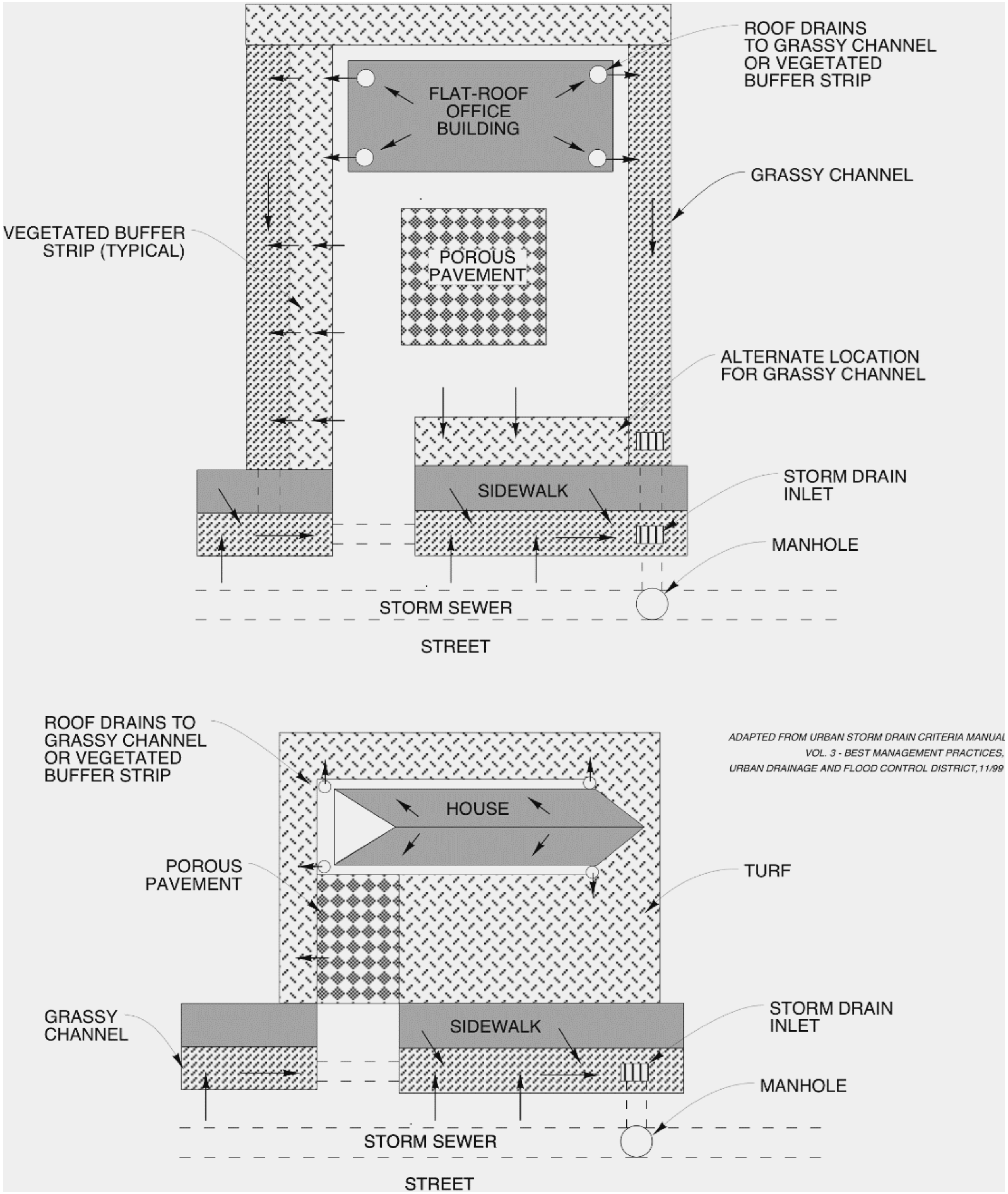


Figure 6-1a. Suggested Applications of Runoff VRMs. *Source: Home. Low Impact Development. (2002, November). Retrieved October 5, 2021, from https://lowimpactdevelopment.org/.*

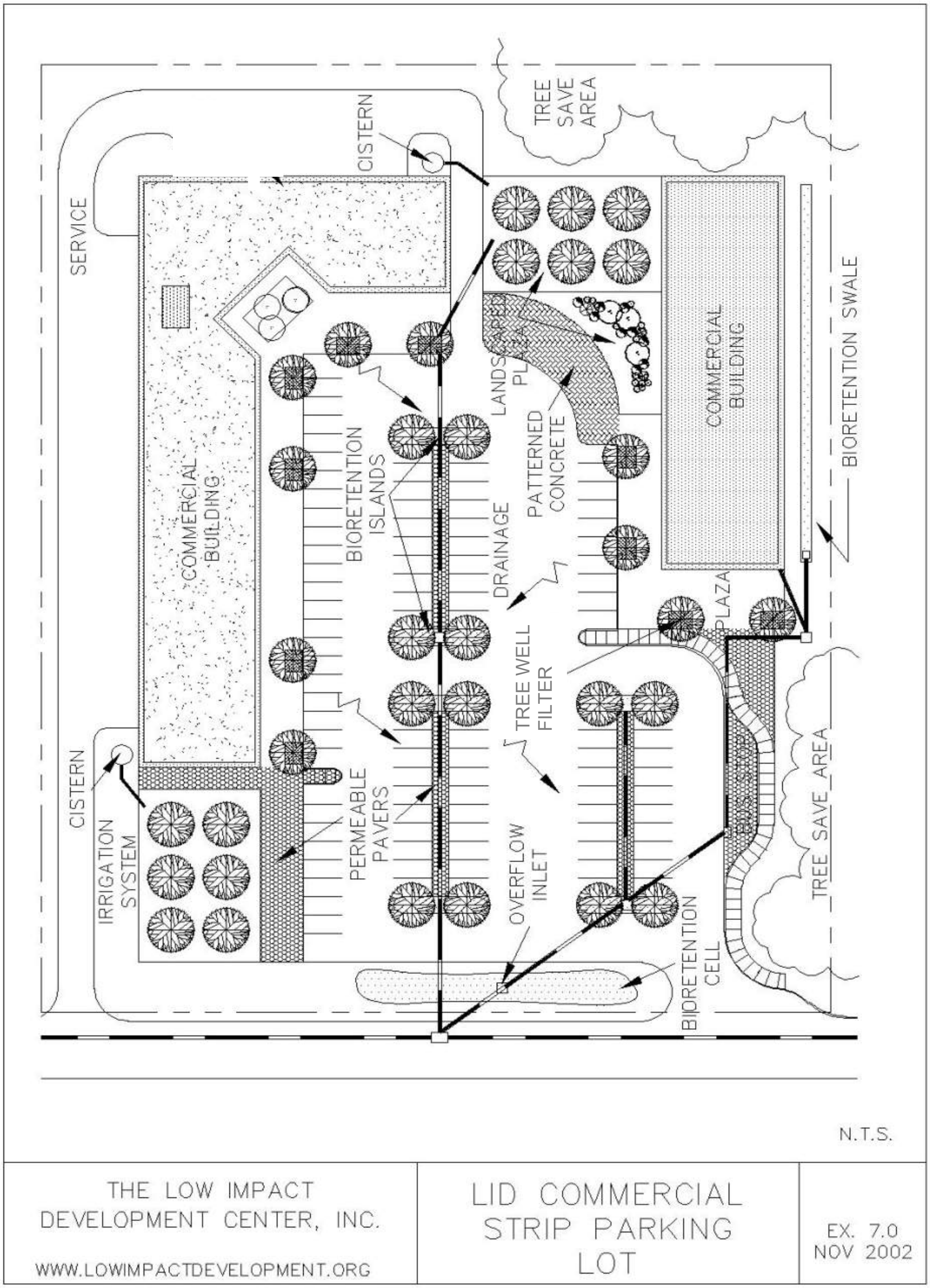


Figure 6-1b. Suggested Applications of Runoff VRMs. *Source: Home. Low Impact Development. (2002) November). Retrieved October 5, 2021, from https://lowimpactdevelopment.org/.*

To assist Priority Projects, **Appendix G** provides additional information on calculating and meeting the VRR. Projects may use the worksheet to help track compliance with the VRR. Compliance with the VRR 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 0.50-inch storm depth. **Appendix G** provides additional information on calculating and meeting the VRR.

Runoff Volume Retention Calculation Procedure:
Runoff Volume (ft^3) = 0.50"/12" x Site weighted runoff coefficient (C_{ra}) x Site area (ft^2)

- Significant Redevelopment Priority Projects must also comply with the VRR; however, an incentive in the form of credits may be applied based on the type of redevelopment. A maximum credit of 0.25 inch from the 0.50-inch VRR may be applied to any of the following types of redevelopment. Credits are issued in 0.05-inch increments based on five criteria:
    a. Significant Redevelopment (as defined in **Section 2.1**)
    b. Brownfield redevelopment
    c. High density ($\geq$22 units per acre);
    d. Vertical Density (2 or more stories); or
    e. Mixed-use and Transit Oriented Development (within ½ mile of public transit, such as a bus stop)

2. Calculate the VRR as the difference between the pre-project runoff volume and the post-project runoff volume (i.e., post–pre).
3. Select applicable VRMs (e.g., Interceptor Trees, Rain Barrels). Each VRM has a certain volume retention "credit" that can be applied toward the VRR. The VRM fact sheets detail the calculation procedure for volume retention.
4. Determine the remaining VRR not met by the VRMs, if any. This remaining VRR must be met by the application of LID Treatment Controls as described in Step 6.
5. Determine tributary impervious area credits associated with the selected VRMs. 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 VRMs 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 VRR is <u>not</u> entirely met using VRMs, the project must apply LID Treatment Controls to reduce further the runoff volume to meet the VRR. LID Treatment Controls must be designed to treat the WQV or WQF as discussed in **Section 6**. The WQV or WQF 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 VRR is met through the use of VRMs, the project may meet the Treatment Control requirement through the use of LID Treatment Controls and/or Conventional Treatment Controls.

7. If the VRR is not entirely met through the combination of VRMs and LID Treatment Controls, the project must demonstrate technical infeasibility and submit a VRR Waiver Form as described below. Priority Projects that cannot fully meet the VRR must select Treatment Control Measures with a ***Medium to High removal efficiency*** for the pollutant of concern (**Table 6-2** in **Section 6**).

Volume Retention Technical Infeasibility and Alternative Compliance

Alternative designs may be allowed if the VRR cannot be fully met due to site constraints. However, even if the project cannot meet the full VRR, the project must still reduce the volume to the MEP. Meeting the VRR is an iterative process. Designers should return to prior steps to explore alternative combinations of VRMs and LID Treatment Controls. The burden of proof is on the project applicant to show that it is technically infeasible to meet the VRR. **Economic hardship is not an acceptable reason for infeasibility.**

In order to demonstrate technical infeasibility, the applicant must show that the project cannot reliably meet the VRR. Technical infeasibility may result from conditions including the following:

- The corrected in-situ infiltration rate is less than 0.3 inch per hour, and it is not technically feasible to amend the in-situ soils to improve it;
- Locations with shallow groundwater, with less than 10 feet separation between the bottom of the infiltration device and the seasonal high groundwater elevation;
- Locations within 100 feet of a groundwater well used for drinking water;
- Brownfield development sites where infiltration poses a risk of pollutant mobilization or other locations where pollutant mobilization is a documented concern (e.g., at or near properties that are contaminated or store hazardous substances underground);
- Locations with potential geotechnical hazards;
- Historic sites, structures, or landscapes that cannot alter their original configuration in order to maintain their historical integrity;
- Locations where infiltration may adversely impact biological resources; or
- Locations where infiltration may cause health and safety concerns.

If meeting the VRR is infeasible, the Applicant must propose an alternative compliance design. Under all such designs, the portion of the design volume that cannot be reliably retained on-site must be stored on-site, treated, and released once the storm event passes.

Projects that are not able to fully meet the VRR must fill out and submit the VRR Waiver Form, **(Appendix H)**. The Waiver must demonstrate technical infeasibility and describe the alternative compliance design.

The VRR Waiver is primarily available for priority redevelopment or infill projects where site constraints, such as available land, may limit the ability to implement VRMs and LID Treatment

Controls to retain and/or treat the WQF or WQV. In general, the City does not expect to grant VRR Waivers for new development projects.

Priority Projects that are not able to fully meet the VRR must fill out and submit the VRR Waiver (**Appendix H**). The City can reject a VRR Waiver request if VRMs and/or LID Treatment Controls are considered feasible at the project site or if adequate alternative compliance design is not proposed.

6.3 SELECTION OF VOLUME RETENTION MEASURES

Various factors must be considered when selecting VRMs. 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 VRMs. Vector breeding considerations must also be addressed because of nuisance and potential human health effects. The site constraints used to select VRMs are provided in **Table 6-2**.

Table 6-2. Site Constraints for VRMs

VRM	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[(2)]	X	X	n/a	Y	L	M
Rain Barrel/Cistern (V-2)	<0.25	n/a	n/a	n/a	n/a	N	H[3]	L
Interception Trees (V-3)	n/a	n/a	X	X	n/a	Y	L	L
Grassy Channel (V-4)	<1	n/a	X	X	≤4%	Y	L	M[4]
Vegetated Buffer Strip (V-5)	<1	n/a	X	X	<5%	Y	L	M[4]

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

7. TREATMENT CONTROL MEASURES

7.1 INTRODUCTION

Treatment Control Measures are required in addition to Site Design Control Measures, Source Control Measures and VRMs to reduce pollutants in stormwater runoff to the MEP. Treatment Control Measures are engineered technologies designed to remove pollutants from stormwater runoff. The type of Treatment Control(s) to be implemented at a site depends on several factors, including:

- Type of pollutant(s) 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
- Other regulatory requirements that apply (e.g, Statewide Trash Amendments, State Industrial General Permit).

The Design Engineer is responsible to demonstrate that the treatment requirements are met by utilizing the listed LID-based and/or conventional treatment control measures or any other approved measures.

Land requirements and costs to design, construct and maintain treatment control measures vary by type of treatment control, location, and site constraints.

Unlike flood control measures that are designed to handle peak flows, stormwater treatment control measures are designed to treat the more frequent, lower-flow storm events or the first-flush portions of stormwater runoff from larger storm events (typically referred to as 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 WQF and WQV, are targets for treatment. In addition, Trash Controls are designed to treat the peak flow rate from a one-year, one-hour storm (0.32 inches[22]).

The Treatment Control Measures presented in this Development Guidance Manual are designed based on flow rates or stormwater runoff volume.

- Treatment Control Measures designed based on flow are designed for the WQF
- Treatment Control Measures designed based on stormwater runoff volume are designed for the WQV.

Definitions and calculation procedures to determine design flows and volumes are presented in this Section. Stormwater runoff in excess of the WDF or WQV must be diverted around the Treatment Control Measure to prevent overloading or may be diverted through the Treatment Control Measure if it will not cause overloading.

[22] This value was determined by using Basin Sizer, which is a software tool developed by Caltrans to determine what the 1-year, 1-hour storm size is for different areas within California. This information is used for the sizing of full trash capture devices. The value may be modified over time due to changing climate or other conditions. https://svctenvims.dot.ca.gov/basinsizer/

Treatment Controls are categorized as either LID Treatment Controls or Conventional Treatment Controls (**Table 7-1**).

- LID-based Treatment Controls can reduce stormwater runoff volumes and may be used in combination with the VRMs described in **Section 5** to meet the VRR.
- Conventional Treatment Controls typically do not reduce stormwater runoff volumes.

Table 7-1. LID-based and Conventional Treatment Control Measures

LID-based Treatment Control Measures	Conventional Treatment Control Measures
Bioretention (L-1)[1] Stormwater Planter (L-2) Tree-well Filter (L-3) Water Quality Infiltration Basin (L-4)[1] Water Quality Infiltration Trench (L-5)[1,2] Porous Pavement Filter (L-6) Vegetated Swale (L-7) Grassy Swale (L-8) Grassy Filter Strip (L-9) Infiltration Well (L-10) Dry Well (L-11)	Constructed Wetland (C-1) Extended Detention Basin (C-2)[1] Wet Pond (C-3) Proprietary Control Device (C-4) Trash Capture Device (C-5) Media Filter (C-6)

[1] These treatment controls may be designed to also meet the trash control requirements.
[2] Also known as a French Drain or Horizontal Drain.

The relative effectiveness of the Treatment Control Measures in reducing pollutants of concern is shown in **Table 7-2**.

The selection of the Treatment Control Measures should be based on their ability to reduce runoff volumes and/or remove pollutants of concern. Priority Projects that cannot fully meet the VRR must select Treatment Control Measures with a ***Medium to High removal efficiency*** for the pollutants of concern (**Table 2-1 and Table 7-2**). All PLU and Priority Projects must include trash Treatment Controls.

Table 7-2. Efficiency of Treatment Control Measures for Reduction of Pollutants of Concern

Treatment Control Measures	Pollutant of Concern[1]				
	Bacteria	Pesticides	Oxygen Demanding Substances	Sediments	Trash
LID-based Treatment Controls					
Bioretention (L-1)	M	M	M	H	H[T]
Stormwater Planter (L-2)	M	M	M	H	--
Tree-well Filter (L-3)	M	M	M	H	--
Water Quality Infiltration Basin (L-4)	H	M	M	H	H[T]
Water Quality Infiltration Trench (L-5)[4]	H	M	M	H	H[T]
Porous Pavement Filter (L-6)	M	M	M	H	--
Vegetated Swale (L-7)	L[2]	L[2]	M	M	--
Grassy Swale (L-8)	L[2]	L[2]	M	M	--
Grassy FIlter Strip (L-9)	M	M	M	H	--
Infiltration Well (L-10)	H	M	M	H	--
Dry Well (L-11)	H	M	M	H	--
Conventional Treatment Controls					
Constructed Wetland (C-1)	M	M	M	M	--
Extended Detention Basin (C-2)	M	M	M	M	H[T]
Wet Pond (C-3)	M	M	M	H	--
Proprietary Devices(C-4)[3]	–	–	–	–	-
Trash Full Capture Systems (C-5)	L	L	M	M	H
Media Filter	M	M	H	H	H[T]

[1] H = >75% expected pollutant removal efficiency for typical urban stormwater runoff; M = 25% to 75% expected removal efficiency for typical urban stormwater runoff; L = <25% expected removal efficiency for typical urban stormwater runoff.
T = Treatment Control can be modified to meet trash control requirements.
[2] If the pollutants of concern (**Table 2-1**) are 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.
[4] Also known as a French Drain or Horizontal Drain.

7.2 SELECTION OF TREATMENT CONTROL MEASURES

Various factors must be considered when selecting Treatment Control Measures. 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, site slope, hydraulic head, size of the Treatment Control Measure, and need for vegetation irrigation are important factors in selecting the appropriate Treatment Control Measure. Vector breeding considerations must also be addressed due to the potential nuisance and human health effects. The applicability of specific controls outlined within this Section should be confirmed with the City. Site constraint considerations are presented in **Table 7-3**.

Volume Retention Requirement

All Priority Projects must meet the VRR through a combination of VRMs and LID Treatment Controls.

- Project applicant does not fully meet the VRR through VRMs - LID Treatment Controls must be used to further reduce stormwater runoff volumes and treat the WQF or WQV.
- Project applicant does meet the VRR through VRMs - a treatment control may be chosen from the LID-based Treatment Control or Conventional Treatment Control list.

Calculation procedures for determining the volume retention for LID-based Treatment Control Measures are provided within each fact sheet.

If the VRR cannot be fully met due to site constraints, see "Technical Infeasibility and Alternative Compliance" in **Section 5**. Projects that do not fully meet the VRR must select Treatment Controls with a ***Medium to High removal efficiency*** for the pollutant of concern (**Table 2-1 and Table 7-2**).

7.3 DESCRIPTION OF TREATMENT CONTROL MEASURES

Detailed descriptions and design criteria for each Treatment Control Measure are presented in fact sheets in **Appendices E [LID-Based Treatment Controls] and F [Conventional Treatment Controls]**. The fact sheets for the Treatment Control Measures include siting considerations, design criteria, calculation fact sheets and worksheets to aid in the design of water quality treatment controls, and maintenance requirements to ensure optimal performance of the measures.

Bioretention LID-based Treatment Controls (L-1) that maximize infiltration to the underlying soils are highly encouraged even if it is infeasible to infiltrate the full amount of runoff (if there are no other conditions that would make infiltration unsafe).

If infiltration is precluded due to site constraints (see "Technical Infeasibility and Alternative Compliance" in **Section 5),** flow-through treatment controls must be utilized.

It should be noted that proprietary device (C-4) vault systems should be avoided since they are typically equipped with high-flow rate media filters and are thus, less effective at pollutant removal and more challenging to maintain compared to the landscape-based LID type treatment controls. Therefore, proprietary device (C-4) vault systems should be considered only as a last resort, after all other viable alternatives have been thoroughly evaluated.

Table 7-3. Site Constraints for Treatment Control Measures

Treatment Control Measure	Drainage Area		Depth to Groundwater		Soil Type[2]		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-based Treatment Controls												
Bioretention (L-1)[1]	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
Water Quality Infiltration Basin (L-4)[1]	X			X	X			X	H	Y*	L	M
Water Quality Infiltration Trench (L-5)[1,5]	X			X	X			X	H	N	L	L
Porous Pavement Filter (L-6)	X		X	X		X		X	M	N	L	L
Vegetated 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
Infiltration Well (L-10)	X			X	X			X	H	N	L	M
Dry Well (L-11)	X			X	X			X	H	N	L	M
Conventional Treatment Controls												
Constructed Wetland (C-1)		X	X	X		X	X		L	Y	H	H
Extended Detention Basin (C-2)[1]		X	X	X		X	X		L	Y*	M	M
Wet Pond (C-3)		X	X	X		X	X		L	Y*	H	M
Proprietary Devices[3](C-4)												
Trash Full Capture Systems[4] (C-5)												
Media Filter (C-6)	X	X	X	X		X	X		H	N	L	M

Adopted by the City Council on Aug 26, 2025 by Resolution No. 2025-308

X: Treatment Control Measure is suitable for listed site condition. H= high; M = medium; L = low; Y= yes; Y* = yes if vegetated; N= no

1. Treatment Control can be modified to meet trash control requirements

2. 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.

3. Suitability of proprietary devices varies depending on the manufacturer and type of device.

4. Trash Full Capture Devices are proprietary devices and their suitability depends on the manufacturer and type of device.

5. Also known as a French Drain or Horizontal Drain.

7.4 CALCULATION OF WATER QUALITY DESIGN FLOW AND WATER QUALITY DESIGN VOLUME

Purpose

With the exception of Trash Full Capture Systems (FCS) (C-5), the primary control strategy for all of the treatment control measures is to treat the water quality flow (WQF) or water quality volume (WQV). This section presents calculation procedures and design criteria necessary to determine the WQF and WQV, which are distinct and separate parameters from the VRR discussed in **Section 5**. The WQF and WQV are required design parameters used to size treatment control measures.

The treatment control measures are listed in **Table 7-4,** along with the basis of design (WQF or WQV) and the design drawdown periods for those treatment control measures that use the WQV as the basis for design (**Figure 7-1**).

Table 7-4. Sizing Criteria for Treatment Control Measures

Treatment Control Measure	Design Basis	Design Drawdown[2]
Bioretention (L-1)[1]	WQV	12 hours
Stormwater Planter (L-2)[1]	WQV	12 hours
Tree-well Filter (L-3)[1]	WQV	12 hours
Water Quality Infiltration Basin (L-4)	WQV	48 hours
Water Quality Infiltration Trench (L-5)[1,3]	WQV	48 hours
Porous Pavement Filter (L-6)	WQV	12 hours
Vegetative Swale (L-7)	WQV	12 hours
Grassy Swale (L-8)	WQF	N/A
Grassy Filter Strip (L-9)	WQF	N/A
Infiltration Well (L-10)	WQV	48 hours
Dry Well (L-11)	WQV	48 hours
Constructed Wetland (C-1)	WQV	24 hours
Extended Detention Basin (C-2)	WQV	48 hours
Wet Pond (C-3)	WQV	12 hours
Proprietary Control Measures (C-4)	WQV or WQF	48 hours
Trash Full Capture Devices (C-5)	Flow rate for 1-hr, 1-yr storm	N/A
Media Filter (C-6)	WQV or WQF	48 hours

[1] Can be modified to meet trash control requirements.
[2] Design drawdown period used to determine Unit Basin Storage Volume (**Figure 7-1**).
[3] Also known as a French Drain or Horizontal Drain.

Determining Design Imperviousness, Runoff Coefficient and Effective Area

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

- Weighted stormwater runoff coefficient (C_r) (without application of impervious area credits)
- The effective tributary area following the application of area credits (A_{eff})

Weighted Imperviousness and Stormwater Runoff Coefficient Calculations

Projects typically comprise a variety of site elements that have variable values of imperviousness and associated stormwater 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 to be used for calculating WQV and WQF are listed in **Table 7-5** 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 7-5**.
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 7-5. Stormwater Runoff Coefficients for Typical Site Elements[1,2]

Site Element	Runoff Coefficient (C_r)	
	Type A and B Soils	Type 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.
[3] Variable with product type. Consult manufacturer for appropriate design values.

Example calculations for weighted stormwater runoff coefficients for a site with Type D soils are shown in **Table 7-6.**

Table 7-6. Example Calculation Table for Weighted Stormwater 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
Forest/undisturbed open space	5,000	0.05	0.03	0.01
Total Site (A_{site})	100,000			0.90

[1] Actual area without adjustment for tributary impervious area credits from VRMs

Effective Tributary Area Calculations

The effective tributary area is defined as the effective area to be used in calculations for WQV and WQF for a specific treatment control measure and is determined by subtracting the tributary impervious area credits earned for VRMs 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 VRM must be applied to a treatment control that serves the same tributary drainage area as the VRM for which the credit is earned. The credits cannot be greater than the tributary drainage areas of the treatment controls to which they are applied. Example calculations for the effective area are shown in **Table 7-7**.

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

Site Element	Element Area, ft^2	Area Credit[1] (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[2]	5,000	0	5,000
Managed Turf	20,000	0	20,000
Forest/undisturbed open space	5,000	0	5,000

[1] Area Credit from VRMs (e.g. rain gardens, rain barrels, interception trees, grassy channel, or vegetated buffer strip)
[2] Credit for permeable pavement has already been provided in the form of a reduced runoff coefficient (**Tables 7-5 and 7-6**).

Water Quality Flow (WQF) Calculation

Hydrologic calculations for design of flow-based treatment control measures in Modesto shall be in accordance with the most current City of Modesto Standard Specifications.

The WQF is defined to be equal to the maximum flow rate of stormwater 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 Modesto area is estimated to be approximately 0.10 inches/hour, based on California State University, Sacramento Office of Water Programs' *Basin Sizer, Version 1.45 (2007)* (not to be confused with the 85th percentile, 24-hour storm depth associated with the VRR).

Calculation Procedure

1. Determine the 85th percentile hourly rainfall intensity for the Modesto area. Use 0.10 in/hr.
2. Multiply the 85th percentile hourly rainfall intensity by a factor of two to obtain design rainfall intensity. Use i = 0.10 x 2 = 0.20 in/hr.
3. Determine the weighted runoff coefficient for the project area using the procedure illustrated in **Table 7-6**.
4. Determine the effective area (A_{eff}) of the drainage area using the procedure illustrated in **Table 7-7**.
5. Calculate the WQF using the following equation.

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

Where

WQF = Stormwater Quality Design flow, cfs

i = Design storm intensity = 0.20 in/hr
C_{ra} = Weighted stormwater 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

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

Water Quality Volume (WQV) Calculation

Hydrologic calculations for the design of volume-based treatment control measures in Modesto shall be in accordance with the most current City of Modesto Standard Specifications.

The WQV is defined as the volume necessary to capture and treat 80 percent or more of the average annual stormwater runoff volume from the site at the design drawdown period specified for each treatment control measure. The WQV volume should not be confused with the VRR, which is a separate requirement as defined in **Section 5**.

Calculation Procedure

1. Review the drainage area of the proposed treatment control measure. Determine the weighted stormwater runoff coefficient (Cra) using the procedure illustrated in **Table 7-6**.

2. A direct reading of Unit Basin Storage Volumes (**Figure 7-1**) is required for 80% annual capture of stormwater runoff for values of "C_{ra}" determined in Step 1. A direct reading from **Figure 7-1** is conducted as follows:

- Enter the horizontal axis with the "C_{ra}" value from Step 1.
- Move vertically up the figure until the appropriate drawdown period line is intercepted.
- Move horizontally across the figure from this point until the vertical axis is intercepted.
- Read the Unit Basin Storage Volume along the vertical axis.

3. Determine the effective area of the drainage area using the procedure illustrated in **Table 7-7**.

4. The WQV for the proposed treatment control measure is calculated by multiplying the Unit Basin Storage Volume by the effective 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.

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

Where:

Vu = Unit basin storage volume (ft); and

Aeff = Effective drainage area (acres).

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 x Drawdown period = 12 hrs

2. Determine the Unit Basin Storage Volume for 80% Annual Capture, V_u using **Figure 7-1**.

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

3. Calculate the WQV for the basin.

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

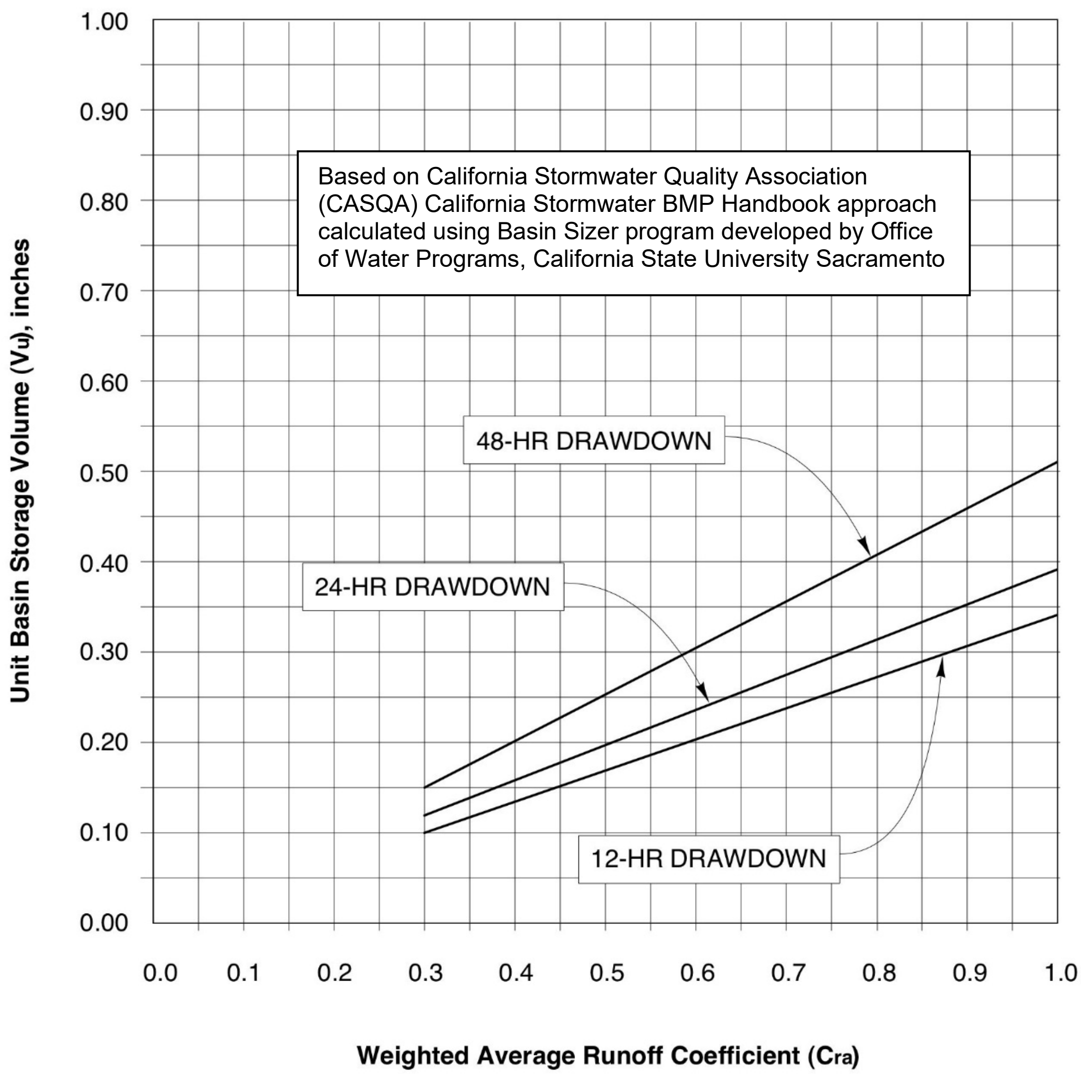


Figure 7-1. Unit Basin Storage Volume vs. Weighted Runoff Coefficient *Computing Stormwater Runoff Rates and Volumes. NJDEP New Jersey Department of Environmental Protection. (2004). Retrieved October 7, 2021, from https://www.njstormwater.org/bmp_manual2.htm.*

8. CONTROL MEASURE MAINTENANCE

The continued effectiveness of the control measures specified in this Development Guidance Manual depends on diligent ongoing inspection and maintenance. To ensure that such maintenance is provided, the City requires the submittal of a Maintenance Plan and execution of a Maintenance Agreement with the owner/operator of stormwater control measures prior to the issuance of the Building Permit for a private development project, which may include one or more of the control measures detailed in **Sections 3,4, 5**, and **6**.

Unless otherwise agreed to by the City, 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 and for complying with the Maintenance Agreement. The maintenance agreement and plan will provide the City designee with complete access to the Device and its immediate vicinity at any time. Requirements for the Maintenance Plan and Maintenance Agreement are presented in this section. A template agreement is provided in **Appendix I**, however it is recommended that the project proponent use the most recent template agreement available on the City website[23].

8.1 MAINTENANCE PLAN

A post-construction Maintenance Plan shall be prepared and submitted to the City as part of the Project Stormwater Quality Control Measures Plan (SWQCP) submittal. The Maintenance Plan should include:

- Operation plan and schedule;
- Site map;
- Operations, maintenance and cleaning activities, including;
  a. A schedule;
  b. Equipment and resources required; and
  c. Responsible party(ies).

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 the 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

[23] https://www.modestogov.com/1263/Forms

having contaminated soil or where toxins are stored or have been stored/disposed of in the past.

4. Within the 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 the 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. 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 (not required for PLU Only Projects)

1. Provide emergency notification procedures (phone and agency/persons to contact).
2. As appropriate for the site, provide emergency containment and cleaning procedures.
3. Note downstream receiving water bodies which may be affected by spills or chronic untreated discharges.
4. 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

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 ensure documentation of training.
2. Training to include:
   a. Good housekeeping procedures defined in the Maintenance Plan
   b. 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 an on-site 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, ensure 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. Perform maintenance and replacement as scheduled and as needed in a timely manner to ensure stormwater controls are performing as designed and approved.
6. Assure *unauthorized* low-flow discharges from the property do not bypass stormwater controls.

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 control measures or procedures is required, the owner shall obtain approval from the City prior to commencing any work. Corrective measures or modifications shall not cause discharges to bypass or otherwise impede existing stormwater control measures.

H. Monitoring & Reporting Program

1. The City may require a Monitoring & Reporting Program to ensure the stormwater control measures approved for the site are performing according to design.
2. If required by the City, the Maintenance Plan shall include performance testing and reporting protocols specified by the City.

8.2 MAINTENANCE AGREEMENT

Verification of maintenance provisions is required for all structural controls specified in this Development Guidance Manual, whether Site Design Controls (**Section 3**), Source Controls (**Section 4**), VRMs (**Section 5**), or Treatment Controls (**Section 6**). Verification, at a minimum, shall include:

1. The owner/developer's signed statement accepts responsibility for inspection and maintenance until the responsibility is legally transferred. A sample Owners Certification statement is provided in **Appendix I**, 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 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 Homeowners 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 must be executed by the owner/operator before occupancy of the project is approved. A template agreement is provided in **Appendix I**, however it is recommended that the project proponent use the most recent template agreement available on the City website[24].

Owners, developers, and/or successors-in-interest (ODS) must establish a maintenance entity acceptable to the City 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.

[24] https://www.modestogov.com/1263/Forms

Private Maintenance Entity

The ODS of treatment controls constructed and located in private facilities must execute a Maintenance Agreement with the City before obtaining a building permit for a development project. The ODS will remain responsible for funding and performing the long-term operation, maintenance, replacement, and administration of the treatment controls.

Public Maintenance Entity

The ODS of any subdivision project that includes treatment controls pursuant to the SWQCCP and that will be annexed to the City is required to form a Storm Drainage Maintenance Assessment District to provide funding for the long-term operation, maintenance, replacement, and administration of the treatment controls and all assets of the distribution system (e.g., pump stations, inlets, outlets) constructed for the project. The Assessment District must be formed prior to the recording of a Final Map and 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.

Appendices

A: Glossary of Terms and List of Acronyms

B: Site Design Control Measure Fact Sheets (G1-G4)

C: Source Control Measure Fact Sheets (S1-S7)

D: Volume Retention Measure Fact Sheets (V1-V5)

E: LID-based Treatment Control Measure Fact Sheets (L1-L12)

F: Conventional Treatment Control Measure Fact Sheets (C1-C6)

G: Volume Retention Requirement Worksheet

H: Volume Retention Requirement Waiver Application

I: Maintenance Agreements and Forms

I-1: Stormwater Treatment Device Access and Maintenance Agreement Template

I-2: SWQCP Owner's Certification Statement

J: SWQCP Submittal Guidance

J-1: Stormwater Quality Control Plan Guidance

J-2: Stormwater Quality Control Plan Template

J-6: Stormwater Maintenance Plan Guidance

J-7: Stormwater Maintenance Plan Template

K: Hydrologic Soil Groups

L: Plants Suitable for Vegetative Control Measures

M: Standard Calculations for Diversion Structure Design

N: Approved Proprietary Control Measures

O: Example Calculation

P: References

APPENDIX A

GLOSSARY OF TERMS AND LIST OF ACRONYMS

APPENDIX A. GLOSSARY OF TERMS AND LIST OF ACRONYMS

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.

Berm: An earthen, asphalt, or concrete mound used to direct the flow of stormwater 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 stormwater. BMPs include structural and nonstructural control measures, 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 stormwater runoff from streets and pavements.

Clean Water Act (CWA): (33 U.S.C. 1251 et seq.) requirements of the National Pollutant Discharge Elimination System program are defined under Sections 301, 307, 402, 318 and 405 of the CWA.

Commercial Development (for a Priority Project): This category is defined as any development on private land that is not for residential uses, where the land area for development is greater than or equal to 10,000 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, office commercial, retail commercial, educational institutions), recreational facilities, commercial retail nurseries, car wash facilities, mini-malls, and other business complexes, shopping malls, hotels, office buildings, public warehouses, and other industrial facilities.

Conduit: Any channel or pipe for directing the flow of water.

Construction Activity: Includes clearing, grubbing, grading, excavation, demolition, and contractor activities that result in soil disturbance.

Construction General Permit[5]: A National Pollutant Discharge Elimination System permit issued by the State Water Resources Control Board for the discharge of stormwater associated with construction activity from soil disturbance of one (1) acre or more.

Conventional Treatment Control Measures: A subset of Treatment Control Measures that can be designed to treat the WQV/WQF. These control measures do not reduce stormwater runoff

[5] https://www.waterboards.ca.gov/water_issues/programs/stormwater/construction.html

volumes and cannot be used to help meet the Volume Retention Requirement. For the purpose of this Guidance Manual, these are treatment control measures identified as C-1 through C-6.

Conveyance System: Any channel or pipe for collecting and directing stormwater runoff.

Culvert: A covered channel or a large diameter pipe that crosses under a road, sidewalk, etc.

Detention: The temporary storage of stormwater runoff to allow treatment by sedimentation and metered discharge of stormwater 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.

Discharge of a Pollutant: 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 through a man-made structure;
- 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, grubbing, grading, demolition, and/or excavation.

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, commercial, 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).

Full Capture System (FCS): A treatment control, or series of treatment controls, including but not limited to, a Multi-Benefit projects or a low impact development control that traps all particles that are 5 mm or greater, and has a design treatment capacity that is either: a) of not less than the peak flow rate, Q, resulting from a one-year, one-hour storm in the subdrainage area (0.31 inches/hour)[6], or b) appropriately sized to, and designed to carry at least the same flows as, the corresponding storm drain.

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-stormwater discharges except discharges pursuant to a National Pollutant Discharge Elimination System permit, discharges that are identified in Discharge Prohibitions of this Order, and discharges authorized by the Regional Board.

Impermeable Liner: Filter fabric of relatively small mesh or pore size that is used to prevent both water and sediment from passing through.

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

[6] Determined using the tool Basin Sizer (ca.gov)

are not limited to, rooftops, walkways, patios, driveways, parking lots, roads or concrete and asphalt paving.

Industrial General Permit[7]: A National Pollutant Discharge Elimination System Permit issued by the State Water Resources Control Board for the discharge of stormwater associated with industrial activity.

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.

Low Impact Development-based Treatment Control Measures: A subset of Treatment Control Measures that can be designed to treat the WQV/WQF and reduce runoff volumes. The runoff reduction achieved by these controls can be used to help meet the Volume Retention Requirement.

Material Storage Areas: On site locations where raw materials, products, final products, by-products, or waste materials are stored.

Multi-Benefit Project: A treatment control project designed to achieve any of the benefits set forth in section 10562, subdivision (d) of the Water Code. Examples include projects designed to: infiltrate, recharge or store stormwater for beneficial reuse; develop or enhance habitat and open space through stormwater and non-stormwater management; and/or reduce stormwater and non-stormwater runoff volume.

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 stormwater runoff, 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.

[7] https://www.waterboards.ca.gov/water_issues/programs/stormwater/industrial.html

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 system that is not composed entirely of stormwater (e.g., discharges containing process wastewater, non-contact cooling water, or sanitary wastewater).

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.

Outfall: The point where stormwater runoff discharges from a pipe, channel, ditch, or other conveyance to a waterway/receiving water.

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: 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.

Priority Land Uses (PLU): Those developed sites, facilities, or land uses (i.e., not simply zoned land uses) within the municipal jurisdiction from which discharges of trash are regulated

1. High-density residential: all land uses with at least ten (10) developed dwelling units/acre.
2. Industrial: land uses where the primary activities on the developed parcels involve product manufacture, storage, or distribution (e.g., manufacturing businesses, warehouses, equipment storage lots, junkyards, wholesale businesses, distribution centers, or building material sales yards).
3. Commercial: land uses where the primary activities on the developed parcels involve the sale or transfer of goods or services to consumers (e.g., business or professional buildings, shops, restaurants, theaters, vehicle repair shops, etc.)

4. Mixed urban: land uses where high-density residential, industrial, and/or commercial land uses predominate collectively (i.e., are intermixed).
5. Public transportation stations: facilities or sites where public transit agencies' vehicles load or unload passengers or goods (e.g., bus stations and stops).

Priority Project: Any project that meets the following project types or thresholds (where applicable):

1. Residential subdivision of 10 housing units or more.
2. Commercial and industrial developments greater than or equal to 10,000 square feet of impervious area.
3. Automotive repair shops.
4. Retail gasoline outlets.
5. Restaurants.
6. Parking lots 5,000 square feet or more or with 25 or more parking spaces and potentially exposed to urban runoff.
7. Significant redevelopment.

Receiving Water: A "water of the United States" into which pollutants are or may be discharged.

Redevelopment (Significant): Land disturbing activity that results in the *creation, addition, or replacement of at least 5,000 square feet of impervious surface area* 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. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or 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.

Residential (Priority Project): (subdivision of 10 housing units or more) Includes single-family homes, multi-family homes, condominiums, and apartments, as well as the related street and road paved surfaces that are used for the transportation of automobiles, trucks, motorcycles, and other vehicles (not including parking lots, see separate parking lot requirement below). A housing unit is also defined as a dwelling unit.

Restaurant (Priority Project): This category is defined as a facility that sells prepared foods and drinks for consumption, including stationary lunch counters and refreshment stands selling 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. For restaurants less than 5,000 square feet, the development must meet all development standards except for treatment control measures and numeric sizing criteria.

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.

Runoff: Water originating from rainfall, melted snow, and other sources 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 areas other than that where it originated.

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 transported by runoff.

Sediments: Soil, sand, and minerals washed from land into water, usually after rain, that accumulate in reservoirs, rivers, and harbors.

Significant Redevelopment (Priority Project): Land disturbing activity that results in the creation, addition, or replacement of at least 5,000 square feet of impervious surface area 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 . It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or emergency construction activities required to immediately protect public health and safety.

In the case of an addition, if the addition constitutes less than 50 percent of the original development, post-construction stormwater requirements only apply to the addition.

Source Control Measures: 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.

Storm Drains: Above- and below-ground structures for transporting stormwater runoff to streams or outfalls for flood control purposes.

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 Pollution Prevention Plan (SWPPP): A written plan 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.

Trash: All improperly discarded solid material from any production, manufacturing, or processing operation including, but not limited to, products, product packaging, or containers constructed of plastic, steel, aluminum, glass, paper, or other synthetic or natural materials.

Trash Amendments: *Amendment to the Water Quality Control Plan for Ocean Waters of California to Control Trash* and *Part 1 Trash Provision of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries* they are collectively referred to as "the Trash Amendments". The State Water Quality Control Board adopted these on April 7, 2015.

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.

Treatment Control Measures: 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 Control Measures (Trash Amendments): Structural best management practices to either

a) remove pollutants and/or solids from STORMWATER runoff, wastewater, or effluent, or

b) capture, infiltrate or reuse stormwater runoff, wastewater, or effluent.

Treatment controls include full capture systems and low impact development controls.

Volume Retention Measures: BMPs that can be used to direct, retain, reuse and/or infiltrate stormwater runoff (e.g., rain gardens and rain barrels**).**

Volume Retention Requirement: Priority Projects must reduce post-project runoff volume to pre-project runoff volumes for the 0.50" rainfall event (85th percentile, 24-hour storm depth) using a combination of Volume Retention Measures and LID Treatment Controls.

LIST OF ACRONYMS

ASTM	American Society for Testing Materials
BMPs	Best Management Practices
CASQA	California Stormwater Quality Association
CWA	Clean Water Act
FCS	Trash Full Capture System
IPM	Integrated Pest Management
LID	Low Impact Development
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
O&M	Operations and Maintenance
PCC	Portland Cement Concrete
PLU	Priority Land Use
PPF	Porous Pavement Filter
SIC	Standard Industrial Classification
WQF	Water Quality Flow
WQV	Water Quality Volume
SWPPP	Stormwater Pollution Prevention Plan
SWQCP	Stormwater Quality Control Plan
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
VRM	Volume Retention Measures
VRR	Volume Retention Requirement
WPCP	Water Pollution Control Plan

APPENDIX B

Site Design Control Measures Fact Sheets (G1 – G4)

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 an undisturbed natural 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 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 in the most recent City Standard Specifications. 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 stormwater 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.

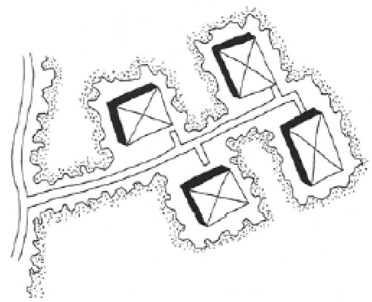
Channel Protection

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

1. Utilize natural drainage systems where feasible but minimize stormwater 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 structures (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 them 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

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



Dynamic modelling of a single-stage high-rate anaerobic reactor—I. Model derivation. *Water Research. Source: Costello, D.J., Greenfield, P.F., & Lee, P.L. (1991).*

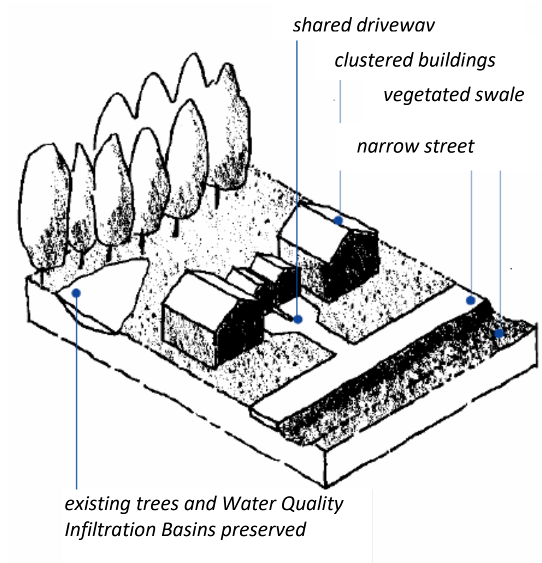
Design Criteria

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. The project should consider soil amendments to restore permeability and organic content in these cases.

G-4: Minimize Impervious Area

Purpose

The potential for the discharge of pollutants in stormwater runoff from a project site increases as the percentage of the impervious area within the project site increases since the resulting volume and rate of runoff flow also increase. Pollutants deposited on impervious areas tend to be easily mobilized and transported by runoff flow. Minimizing impervious areas 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 a reduction in the size of downstream conveyance and treatment systems, yielding savings in development costs.



Source: Low Impact Development Handbook Stormwater Management Strategies. (2014, July). https://www.sandiegocounty.gov/content/dam/sdc/dpw/WATERSHED_PROTECTION_PROGRAM/watershedpdf/S-BMP/Filtration_O&M_Form.pdf.

Minimizing impervious area will also reduce the stormwater runoff coefficient, which is directly proportional to the volume retention requirement (VRR). Therefore, lowering the stormwater runoff coefficient will lower the amount of stormwater runoff that must be retained on-site and treated.

Design Strategies

Some aspects of site design are directed by City building and fire codes and ordinances. These design strategies are intended to enhance and be consistent with the local codes and ordinances. Strategies for minimizing impervious surfaces through site design include:

1. Use minimum allowable roadway and sidewalk cross sections, driveway lengths and parking stall widths (refer to City Standard Specifications).
2. Minimize or eliminate the use of curb and gutter, so that roadway runoff drains to swales and other volume retention measures (VRMs) or Low Impact Development (LID) Treatment Controls are 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 footprints of buildings 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.
10. Use grass-lined channels or surface swales to convey runoff instead of paved gutters.

APPENDIX C

Source Control Measures Fact Sheets (S1 – S7)

Purpose

Waste material dumped into storm drain inlets can adversely impact surface and ground water. 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 wastes into storm drain inlets is prohibited and/or the drain that discharges to local receiving waters.

Design Criteria

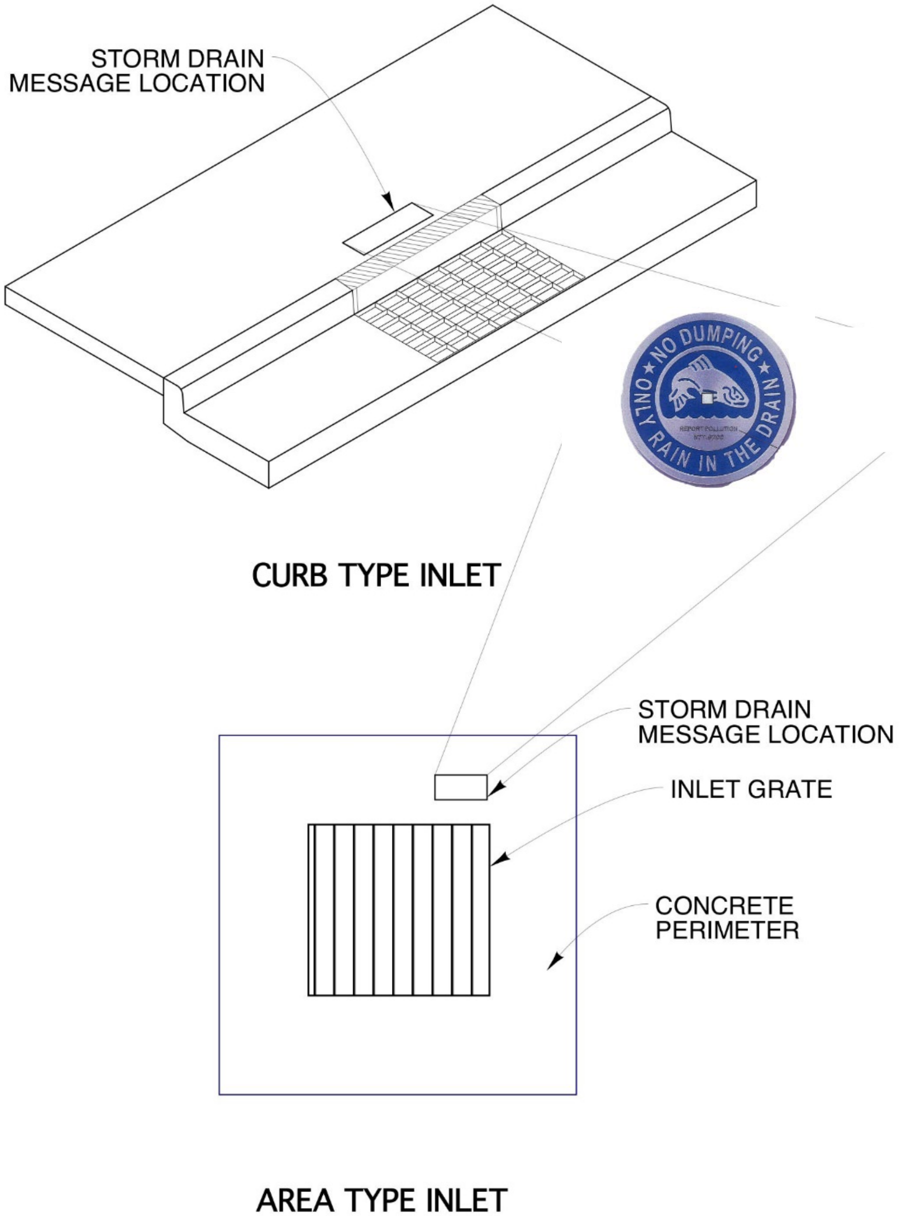
Signs with language and/or graphical icons, which prohibit illegal dumping, shall be posted at designated public access points along channels and streams within a project area. Consult with City staff to determine specific signage requirements.

Storm drain message markers, placards, or concrete stamps are required at all storm drain inlets within the boundary of the development project. Markers should be placed in clear sight adjacent to inlets (**Figure S-1.1**). All storm drain inlet locations must be identified on the development site map.

All storm drain catch basins and drain inlets must be labeled with the City's approved stormwater quality message, prior to acceptance by the City.

Maintenance Requirements

Legibility of markers and signs shall be maintained.



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 S-1.1. Storm Drain Message Location

Purpose

Materials (i.e., raw, finished, or waste products) stored outdoors can become sources of pollutants in stormwater runoff if not handled or stored properly. The type of pollutants associated with the materials will vary depending on the type of activities conducted onsite.

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

Applicability

Materials are classified into three categories based on the potential risk for pollutant release associated with stormwater contact – high risk, low risk, and non-risk. The general types of materials under each category are listed in **Table S-2.1**. The City will make final determinations regarding category listings, if necessary.

Table S-2.1. Classification of Materials for Potential Pollutant Risk

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

Metal buildings, roofing, and fencing materials may be significant sources of metals in stormwater runoff. Minimizing the use of copper and galvanized (zinc coated) metals on buildings and fencing can help reduce leaching of these constituents into stormwater runoff. Materials that are conventionally made of galvanized metals include metal roofs, chain-link fencing, metal downspouts, and metal vents of roofs.

To reduce the risk of metals pollutant release, alternatives to copper and galvanized materials can be used such as coated metal products which are available for both roofing and gutter application. Vinyl-coated fencing is an alternative to traditional galvanized chain-link fences. These products eliminate contact of bare metal with precipitation. There are also roofing materials made of recycled rubber and plastic.

Design Criteria

Design requirements for material storage areas are governed by current City Building and Fire Codes, ordinances, and zoning requirements. Source control measures described in this fact sheet are intended to enhance and be consistent with these code and ordinance requirements. The design features presented in **Table S-2.2** should be incorporated into the design of outdoor material storage areas when stored materials could potentially contribute significant pollutants if the materials came into contact with stormwater runoff.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater may accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of per applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permission and/or permit. Contact the City regarding permits for the discharge of contaminated accumulated water.

Table S-2.2. Design Criteria for Outdoor Material Storage Areas

Design Feature	Design Criteria
Surfacing	• High-Risk Materials: ○ 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: ○ No requirement for surfacing
Covers	• High-Risk Materials: ○ 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. ○ Covers 10 feet high or less shall have a minimum overhang of 3 feet measured from the perimeter of the hydraulically isolated storage area. ○ 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: ○ At a minimum, completely cover erodible material with temporary plastic sheeting during rainfall events.
Hydraulic Isolation and Drainage	• High-Risk Materials: ○ Hydraulically isolate the storage area by means of grading, berms, or drains to prevent run-on of stormwater from surrounding areas or roof drains.

Design Feature	Design Criteria
	○ 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. ○ 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 sanitary sewer or approved collection point. • Low-Risk Materials: ○ Drainage from storage area may be to an approved treatment control measure or possibly to an approved standard stormwater drain(s). ○ 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 the surrounding area and to prevent migration of material due to wind erosion.

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 as required by the City's Municipal Code. Failure to properly maintain building and property may subject the property owner to enforcement. Maintenance agreements between the City and the owner/operator may be required **(Appendix I)**.

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 receiving waters. Waste handling operations that may be sources of pollutants include dumpsters and waste piles.

Design Criteria

Design requirements for waste handling areas are governed by Building and Fire Codes as well as current City 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 under legal requirements established in Title 22 of the 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 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 the City.

The trash storage area design features presented in **Table S-3.1** were developed to enhance the City codes and ordinances and should be implemented depending on the type of waste and the type of containment.

Table S-3.1. Design Criteria for Outdoor Trash Storage and Waste Handling Areas

Source Control Design Feature	Design Criteria
Surfacing	• Construct storage area base with a material impervious to leaks and spills.
Screens/Covers	• Install a screen or wall around the trash storage area to prevent off-site transport of loose trash. • Use lined bins or dumpsters to reduce the leaking of liquid wastes. • Use water-proof lids on bins/dumpsters or provide a roof to cover the enclosure (City discretion) to prevent rain 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.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater may accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of per applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permission and/or permit. Contact the City regarding permits for the 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 as required by the City's Municipal Code. Failure to properly maintain the building and property may subject the property owner to enforcement. Maintenance agreements between the City and the owner/operator may be required **(Appendix I).**

Purpose

Materials spilled, leaked, or lost during loading or unloading may collect on impervious surfaces or in the soil and be carried away by stormwater 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 runoff to the storm drain system is prohibited.

Design Criteria

Design requirements for outdoor loading/unloading materials are governed by Building and Fire Codes and current City ordinances and zoning requirements. Source control measures described in the fact sheet are meant to enhance and be consistent with these code and ordinance requirements. The design criteria presented in **Table S-4.1** should be followed when developing construction plans for outdoor material loading/unloading areas and are not intended to be in conflict with requirements that may be established by individual companies. Conflicts or issues should be discussed with City staff.

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

Table S-4.1. Design Criteria for Outdoor Loading/Unloading Dock Area

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.

Design Feature	Design Criteria
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 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 may accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of per applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permission and/or permit. Contact the City regarding permits for the 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 as required by the City's Municipal Code. Failure to properly maintain the building and property may subject the property owner to enforcement. Maintenance agreements between the City and the owner/operator may be required **(Appendix I).**

Purpose

Activities that can contaminate stormwater at outdoor vehicle and equipment repair/maintenance areas 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 contaminate stormwater runoff.

Design Criteria

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

The design criteria required for vehicle and equipment maintenance and repair are presented in **Table S-5.1**. All hazardous and toxic waste must be prevented from entering the storm drainage system. Conflicts or issues should be discussed with City staff.

Table S-5.1. Design Criteria for Outdoor Vehicle/Equipment Repair/Maintenance Areas

Design Feature	Design Criteria
Surfacing	• Construct the vehicle/equipment maintenance/repair floor area with Portland cement concrete (PCC).
Covers	• Cover areas where parts and fluids are stored. • Cover or enclose all 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 the 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 may accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of per applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permission and/or permit. Contact the City regarding permits for the 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 as required by the City's Municipal Code. Failure to properly maintain the building and property may subject the property owner to enforcement. Maintenance agreements between the City and the owner/operator may be required **(Appendix I).**

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 that can be transported to the storm drain system or receiving water.

Design Criteria

Design requirements for vehicle and equipment washing areas are governed by Building and Fire codes and current City ordinances and zoning requirements. The design criteria described in **Table S-6.1** are intended to enhance and be consistent with these code requirements. Hazardous and toxic wastes cannot enter the storm drain system. Conflicts or issues should be discussed with City staff.

Table S-6.1. Design Criteria for Outdoor Vehicle/Equipment Wash Areas

Design Feature	Design Criteria
Surfacing	• Construct the vehicle/equipment wash area floors with Portland Cement Concrete (PCC).
Covers	• Provide a cover that extends at least 3 feet beyond the hydraulically isolated area for cover heights less than or equal to 10 feet. • Provide a cover that extends 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 before discharging to the sanitary sewer. • Direct stormwater 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 may accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of per applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permission and/or permit. Contact the City regarding permits for the 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 as required by the City's Municipal Code. Failure to properly maintain the building and property may subject the property owner to enforcement. Maintenance agreements between the City and the owner/operator may be required **(Appendix I)**.

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 control measures. When stormwater mixes with fuel spilled or leaks onto the ground, it becomes contaminated with petroleum-based materials that can harm humans, fish and wildlife.

Design Criteria

Design requirements for fueling and maintenance areas are governed by Building and Fire Codes and by current City ordinances and zoning requirements. The design criteria described in **Table S-7.1** are intended to enhance and be consistent with these code requirements. Hazardous and toxic wastes cannot enter the storm drain system. Conflicts or issues should be discussed with City staff.

Table S-7.1. Design Criteria for Fuel and Maintenance Areas

Design Feature	Design Criteria
Surfacing	• Pave fuel dispensing and maintenance area with Portland cement concrete. 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 area. Direct stormwater runoff from the cover away from the area to a stormwater disposal point that meets all applicable code requirements and applicable requirements of this manual. ○ 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. ○ 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.
Hydraulic Isolation and Drainage	• Design the area pad with zero slope (flat) to keep minor spills and leaks on the pad and encourage use of proper cleanup methods, which consist of dry cleanup, 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 American Disabilities Act requirements for disabled access:

Design Feature	Design Criteria
	• Berms: Design the berm height four (4) inches above the surface of the area pad such that the pad 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 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 structure's maximum oil/fuel storage capacity 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 the contents disposed of by applicable laws. • Elevated fueling pad: Elevate the grade of the fueling pad such that it is high enough to prevent run-on from surrounding areas. The fueling pad should be flat in order to contain small spills and prevent stormwater runoff. • 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.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater may accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of per applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permission and/or permit. Contact the City regarding permits for the 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 as required by the City's Municipal Code. Failure to properly maintain the building and property may subject the property owner to enforcement. Maintenance agreements between the City and the owner/operator may be required **(Appendix I)**.

APPENDIX D

Volume Retention Measures Fact Sheets (V1 – V5)

Source: Rain Gardens & Rebate program. Flows to Bay. (n.d.). Retrieved October 5, 2021, from https://www.flowstobay.org/preventing-stormwater-pollution/at-home/rain-gardens/.

Description

A rain garden is a planted depression designed to receive, retain, and infiltrate stormwater runoff from impervious areas, such as rooftops and pavement. Stormwater 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 facilitate infiltration. Treatment of the runoff occurs through various natural mechanisms as the runoff filters through the root zone of the vegetation. Part of the water held in the root zone of the garden is returned to the atmosphere through transpiration by plants. Rain gardens 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. Root systems of the plants enhance infiltration, moisture redistribution, and diverse microbial populations involved in biofiltration. Rain gardens may also include an underdrain pipe, but they may reduce the retention capabilities of the Rain Garden.

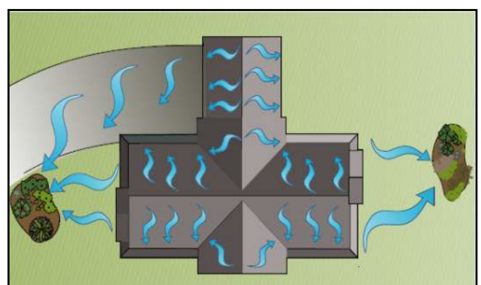
RAIN GARDEN

A rain garden is similar 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.



Source: Hinman, C. (2007). (rep.). Rain Garden Handbook for Western Washington Homeowners (p. 9).

Limitations

- Volume retention may be limited by available space.
- 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 an impermeable liner prevents infiltration.

Planning and Siting Considerations

- Locate Rain Gardens at least 10 feet from the building foundations.
- Maintain a slope of at least one (1) percent from the 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.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the Rain Garden, and cars are allowed to overhang the Rain Garden.
- Irrigation is typically required to maintain viability of the Rain Garden vegetation. Coordinate design of general landscape irrigation system with that of the Rain Garden, as applicable.

Design Criteria

Design criteria for Rain Gardens are listed in **Table V-1.1**. A schematic showing the basic elements of a typical Rain Garden is presented in **Figure V-1.1**.

Table V-1.1. Rain Garden Design Criteria

Design Parameter	Criteria	Notes
Surface area of ponding zone	20-30%	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% coarse 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 drainpipe (optional)	4 inches	Perforated PVC or HDPE. Use with Type C and D soils
Excavation side slope of (H:V)	3:1	Maximum steepness

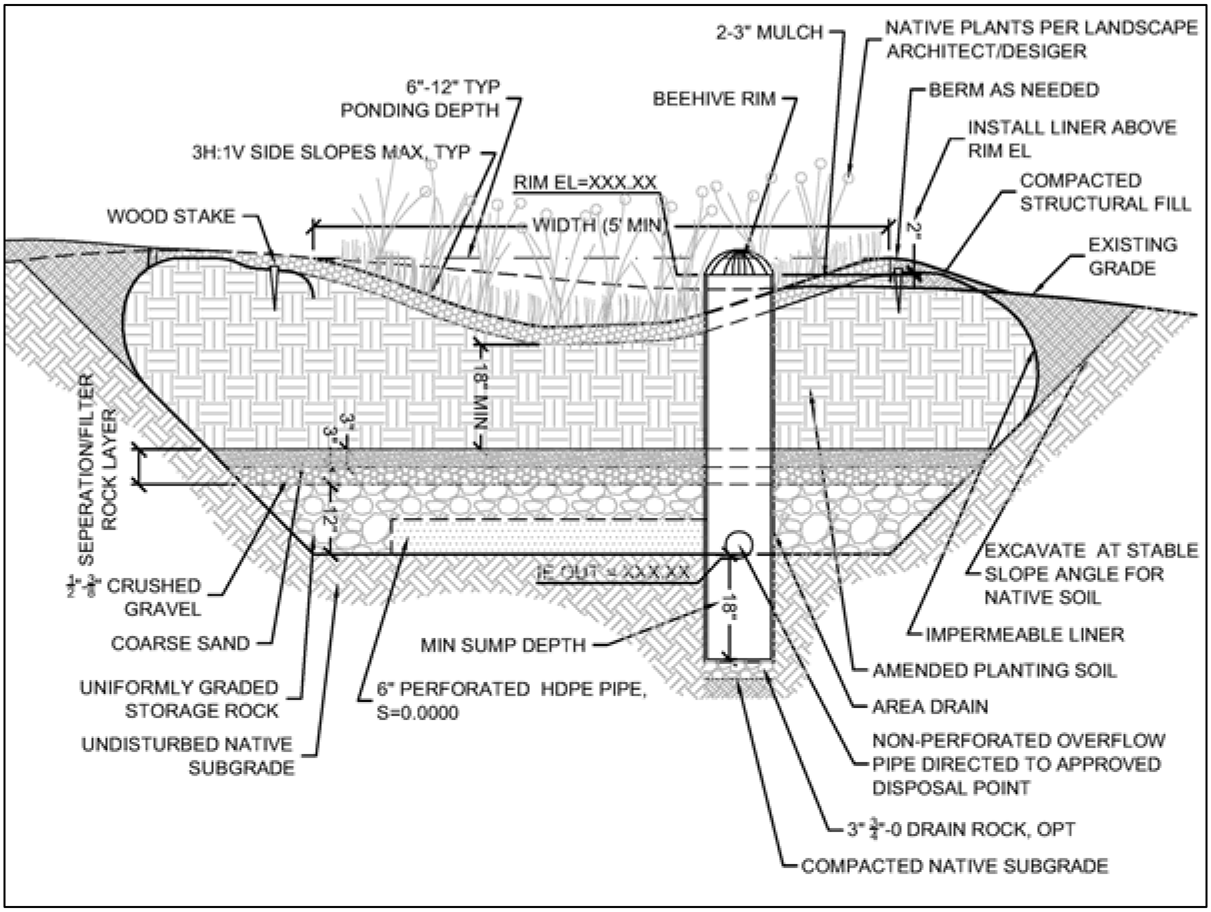


Figure V-1.1. Example Rain Garden. *Source: Oregon State University. (n.d.). Choose the right Rain Garden. Retrieved October 6, 2021, from https://extension.oregonstate.edu/node/119221/printable/print.*

Volume Retention and Tributary Impervious Area Credit Calculation

Rain Gardens provide volume retention by capturing water in the pore spaces of the planting soil layer (detention/filtration zone) and infiltrating it into the underlying soil. Rain Gardens may be used to help meet the volume retention requirement (VRR) and can also be used to reduce the size of required treatment control measures (**Section 6**). The volume retention credit calculation for Rain Gardens is presented in **Table V-1.2. Appendix G** provides additional information on calculating and meeting the VRR.

Rain Gardens can also be used to reduce the size of required treatment control measures through the application of the tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the water quality volume (WQV) or water quality flow (WQF), which are used to size the treatment control measures.

Implementing Rain Gardens reduces effective impervious area and, thereby, the volume of water that needs to be treated. The credit is based on the ratio of the volume retention to the WQV for the Rain Garden drainage area. Note that these credits must be applied to treatment control measures that are in the same tributary drainage area as the Rain Garden for which the credits are determined and that the credits cannot be greater than the tributary drainage area of the Rain Garden. **Table V-1.2** details how the tributary impervious area credit is calculated for Rain Gardens.

Construction Considerations

- Divert stormwater runoff during the period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials, such as silt fences.
- Install sediment controls, such as silt fences, around the Rain Garden 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.

Table V-1.2. Rain Garden Volume Retention and Tributary Impervious Area Credit Calculation

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

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, including volume retention measures (VRMs) such as Rain Gardens. Such agreements typically include requirements like those outlined in **Table V-1.3**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the VRM and its immediate vicinity at any time. Maintenance is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix I**.

Table V-1.3. Inspection and Maintenance Requirements for Rain Gardens

Activity	Schedule
Remulch void areas	As needed
Treat diseased trees and shrubs	As needed
Use Integrated Pest Management practices	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

Source: Communications, I. F. A. S. (n.d.). Rain barrels. Rain Barrels - UF/IFAS Extension. Retrieved October 6, 2021, from http://sfyl.ifas.ufl.edu/sarasota/gardening-and-landscaping/horticulture-residential/florida-yards-and-neighborhoods/rain-barrels/.

Description

Rain Barrels and Cisterns collect and store rainwater runoff 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 V-2.1**). 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.

Source: Chesapeake Bay Foundation

Limitations

- Storage volume may be limited.
- Stored water is not suitable for human or pet consumption.
- Contact of stored water with fruits and vegetables should be avoided due to unknown risks.
- May not be compatible with site aesthetics.
- Potential for mosquito 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 Barrels above-ground with a sturdy platform to provide spigot clearance.

- Provide screens or deflectors on rain gutters to minimize the discharge of debris to Rain Barrels.
- Direct Cistern overflow discharge to drain away from building foundations and to vegetated areas.

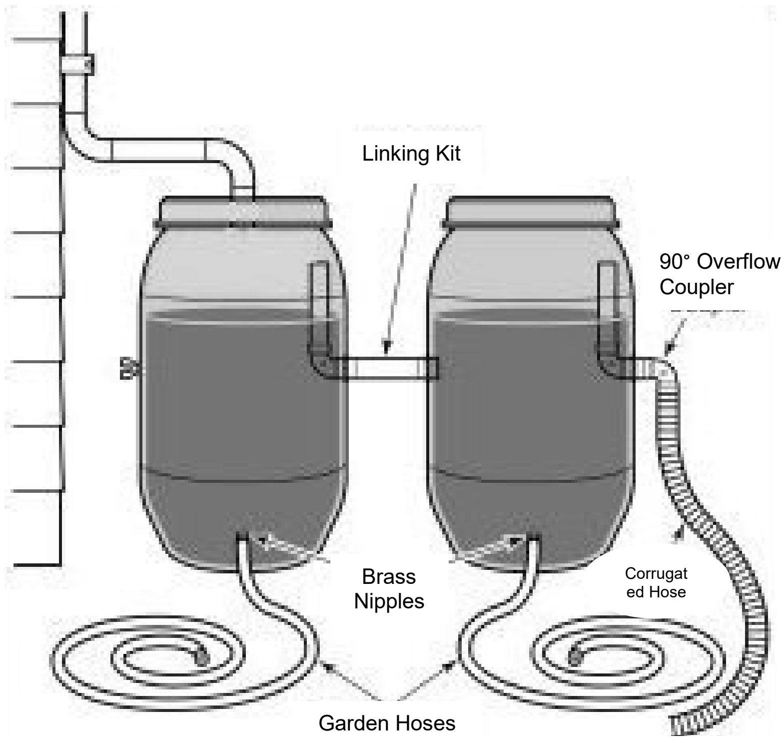


Figure V-2.1 Rain Barrel Schematic. *Source: Home. Low Impact Development. (2002, November). Retrieved October 5, 2021, from https://lowimpactdevelopment.org/.*

Volume Retention and Tributary Impervious Area Credit Calculation

Rain Barrels and Cisterns reduce volume by storing water in a container. Rain Barrels and Cisterns may be used to help meet the VRR and reduce the size of required treatment control measures (**Section 6**). The volume retention credit calculation for Rain Barrels and Cisterns is presented in **Table V-2.1.**

Rain Barrels and Cisterns can also be used to reduce the required treatment control measure size by applying for tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the WQV or WQF, which are used to size Treatment Control Measures (**Section 6**).

Implementation of Rain Barrels and Cisterns reduces effective impervious area and thereby the volume of water to be treated. The credit is based on ratio of the volume retention to the WQV for the Rain Barrel or Cistern drainage area. Note that these credits must be applied to treatment control measures that are in the same tributary drainage area as the Rain Barrel or Cistern for which the credits are determined, and the credits cannot be greater than the tributary drainage areas of the Rain Barrel or Cistern. **Table V-2.1** details how the tributary impervious area credit is calculated.

Table V-2.1. Rain Barrel/Cistern Volume and Tributary Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Volume retention ($Vol_{retention}$) a. Total storage volume of Rain Barrel/Cistern (V_s) b. Effectiveness factor (Eff) = 75% c. $Vol_{retention} = V_s$ x Eff	V_s = ________ ft^3 Eff = 0.75 $Vol_{retention}$ = ___ ft^3	The effectiveness factor considers that storage container may not be emptied between each storm
2. Total roof area (A_{roof})	A_{roof} = __________ ft^2	
3. WQV for roof area based on 12-h drawdown WQV = 0.32 in x A_{roof} / 12 in/ft	WQV = _________ ft^3	Unit basin storage volume for 12-h drawdown at 100 % imperviousness (C_r= 0.95) = 0.32 in
4. Tributary Impervious Area Credit ($Area_{credit}$) $Area_{credit} = A_{roof}$ x $Vol_{retention}$ / WQV	$Area_{credit}$ = ________ ft^2	Maximum allowable $Area_{credit}$ = A_{roof}

Construction Considerations

Stormwater runoff should not be diverted to the Rain Barrel or Cistern until the overflow discharge area has been stabilized.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, including VRMs such as Rain Barrels and Cisterns. Such agreements typically include requirements like those outlined in **Table V-2.2**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the VRM and its immediate vicinity at any time. Maintenance is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix I**.

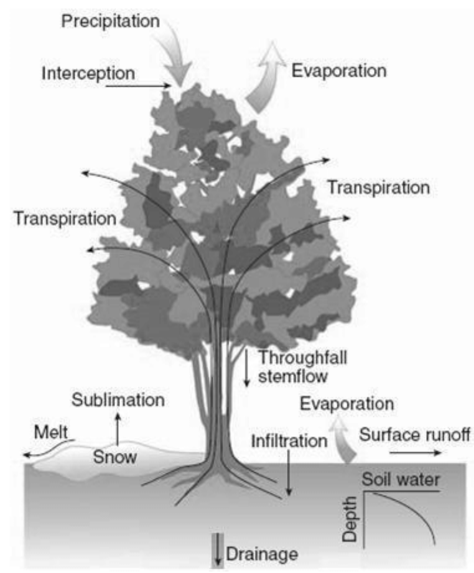
Table V-2.2. Inspection and Maintenance Requirements for Rain Barrels and Cisterns

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: Stringham, T.K., Snyder, K.A., Snyder, D.K., Lossing, S.S., Carr, C.A., and Stringham, B.J. (2018). Rainfall interception by singleleaf piñon and Utah juniper: implications for stand-level effective precipitation. Rangeland Ecology & Management 71(3):327-335.

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 retention benefit. The rainfall interception and evaporation benefits are received through a tree's hydrologic cycle.



Source: Ekhuemelo, David. (2016). Importance Of Forest and Trees in Sustaining Water Supply And Rainfall. Nigeria Journal of Education, Health And Technology Research (Njehetr).

Advantages

- Reduces stormwater runoff volume and pollutant discharge.
- Enhances site aesthetics.
- Increases property values.
- Provides shading and cooling.
- Improves air quality.
- Can also be used to meet 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.
- Locate trees at appropriate distances from buildings and infrastructure to avoid damage by roots and interference by branches.
- Locate trees such that canopies project over impervious areas, if possible.
- Irrigation is typically required to maintain viability of Interception Trees. Coordinate design of general landscape irrigation system with that of Interception Trees, as applicable.

Volume Retention and Tributary Impervious Area Credit Calculation

Interception Trees provide volume retention through the storage of water in the leaves, branches, and stem of the tree. Interception Trees may be used to help meet the VRR and reduce the size of required treatment control measures (**Section 6**). The calculation procedure for volume retention and tributary impervious area credit for Interception Trees is presented in **Table V-3.1.**

Interception Trees can also be used to reduce the required treatment control measure size through the application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the WQV or WQF, which are the primary design criteria used to size Treatment Control Measures (**Section 6**).

Implementing Interception Trees reduces effective impervious area and, thereby the volume of water that needs to be treated. The credit is based on the area of canopy projection over impervious areas and the percentage of rainfall interception allowed for the type of tree selected. **Table V-3.1** details how the tributary impervious area credit is calculated for Interception Trees.

Table V-3.1. 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 = 0.50 inch
5. Volume retention for interception ($Vol_{retention}$) $Vol_{retention}$ = d x $Area_p$ x Int x No. of trees /12 in/ft	$Vol_{retention}$ = _________ ft^3	Provide separate calculation for each type of tree with different canopy and Int value
6. Tributary Impervious Area Credit for tree interception $Area_{credit}$ = $Area_p$ x 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 Forestry, 1999)
- Limit the 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 requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, including VRMs such as Interception Trees. Such agreements typically include requirements like those outlined in **Table V-3.2**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the VRM and its immediate vicinity at any time. Maintenance is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix I**.

Table V-3.2. Inspection and Maintenance Requirements for Interception Trees

Activity	Schedule
Remove and replace any diseased or dying trees	Annually
Maintain trees (watering, pruning)	As needed
Use Integrated Pest Management Practices	As needed

Grassy channel. *Source: Fairfax County Virginia. (n.d.). Control Heavy Runoff - Solving Drainage and Erosion Problems. Retrieved October 6, 2021, from https://www.fairfaxcounty.gov/soil-water-conservation/drainage-problem-control-runoff.*

Description

Grassy Channels are densely vegetated drainage ways with gentle side slopes and gradual longitudinal slopes in the direction of flow that receives stormwater runoff from impervious areas and slowly conveys the runoff to downstream points of treatment or discharge. Grassy Channels allow 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.

Grassy Channels are appropriate for use in residential, commercial, industrial, and institutional settings for drainage areas typically less than five (5) acres. They can be used in conjunction with Grassy Filter Strips and are located adjacent to impervious areas to be mitigated. Several Grassy Channels may be used on a single site, each designed to receive stormwater runoff from different impervious areas. Grassy Channels can also provide pretreatment for other stormwater treatment control measures, such as bioretention areas. Irrigation and regular mowing are required to maintain the grass cover. Options for the types of vegetation that can be used are provided in **Appendix L**.

> 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.
- A preferred alternative to curb and gutter, where feasible.

Limitations

- Not suitable for areas that receive substantial to full shade.
- Not suitable for industrial sites or sites where spills may occur unless infiltration is prevented by an impermeable liner.
- Requires individual owners/tenants to perform maintenance.

Planning and Site Considerations

- Select location where site topography allows for design of a Grassy Channel with sufficiently mild slopes and enough surface area to maintain non-erosive velocities in the channel.
- Integrate Grassy Channels into open space buffers and other landscape areas when possible.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the Grassy Channel, and cars are allowed to overhang the channel.
- Irrigation is typically required to maintain viability of Grassy Channel vegetation.
- Coordinate design of general landscape irrigation system with that of the Grassy Channel, as applicable.
- The potential for mosquitoes due to standing water will be greatly reduced or eliminated if the Grassy Channel is properly designed, constructed, and operated.

Design Criteria

Design elements, construction considerations and maintenance requirements of Grassy Channels are similar in most respects to those of full treatment Grassy Swales. 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 V-4.1,** along with reference values for use in the calculation of credits for reducing the effective impervious area. The design and reference value ratios are used in the calculation of credits for reducing effective impervious area.

Table V-4.1. 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.

Design Parameter	Criteria	Notes
Vegetation	–	Turf grass (irrigated, not artificial)
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	**Design Criteria**	**Notes**
Reference Design Flow (WQF_{ref})	WQF	WQF = 0.20 in/hr x C x A (**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 Retention and Tributary Impervious Area Credit Calculation

Grassy Channels provide volume retention through water infiltration during conveyance and retaining water in the vegetative layer. Grassy Channels may also be used to help meet the VRR and reduce the size of required treatment control measures (**Section 6**). Volume retention achieved with Type C and D soils is less than that achieved with Type A and B soils because less infiltration will occur with Type C and D soils. The volume retention credit calculation for Grassy Channels is presented in **Table V-4.2.**

Grassy Channels can also be used to reduce the size of the required treatment control measures by applying tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the WQV or WQF, which are the primary design criteria used to size Treatment Controls (**Section 6**).

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 retention to the WQF for the Grassy Channel drainage area. Note that these credits must be applied to treatment control measures 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 V-4.2** details how the tributary impervious area credit is calculated for Grassy Channels.

Table V-4.2. Grassy Channel Volume Retention and Tributary Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Determine reference WQF a. Impervious tributary area b. Impervious area runoff coefficient (C_{imp}) **c.** WQF_{Fref}= 0.2 x A_{imp} x C_{imp} / 43,560	A_{imp} =___________ ft^2 C_{imp} =___________ WQF_{ref} = ___________cfs	C_{imp}= 0.95
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 Grassy Channel (L_{GC})	L_{GC} =________________ ft	
5. Flow geometry @ WQF from Manning equation a. Design flow depth (D_{GC}) b. Design flow area (A_{GC}) c. Design flow velocity (v_{GC})	D_{GC} =____________ ft A_{GC} =____________ ft^2 v_{GC} =____________ ft/sec	
6. Contact time @ WQF (t_{GC}) t_{GC} = L_{GC} / v_{GC} / 60 sec	t_{GC} =_____________ min	
7. Impervious Area credit for Grassy Channel (A_{credit}) i) 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 retention for Grassy Channel ($Vol_{retention}$) a. V_{soils} for A and B soils = 0.50 b. V_{soils} for C and D soils = 0.25 c. $Vol_{retention}$ = (A_{credit}) x V_{soils} x (0.50/12)	V_{soils} =__________ft^3 $Vol_{retention}$ = _______ft^3	V_{soils} is volume retention factor allowed for infiltration, which varies with soil permeability

Credit Calculation Examples

An example of volume retention and tributary impervious area credit calculations are presented below.

Step 1 – Calculate WQF for impervious area tributary to Grassy Channel

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

$WQF_{ref} = i \times C_{imp} \times A_{imp}$

where

WQF_{ref} = Stormwater Quality Design Flow, cfs

i = Design storm intensity = 0.20 in/hr

C_{imp} = Stormwater 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

WQF_{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 the ease of mowing and maintenance should be considered.

Example:

W_{GC} = 0.5 ft

Step 3 – Determine longitudinal design 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 WQF using Manning's Equation

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

where

$Q = WQF_{ref}$

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 WQF and the design channel geometry.

Example:

D_{GC} = 1.5 in

A_{GC} = 0.0625 ft^2

$v_{GC} = Q_{WQF} / A_{GC}$ = 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:

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

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

$A_{credit} = 680.3\ ft^2$

Step 8 – Calculate volume retention credit for 0.50-inch storm depth

$Vol_{reduction} = (A_{credit}) \times V_{soils} \times (0.50/12)$

Example:

V_{soils} = 0.25 for C and D soils

$Vol_{reduction}$= 680.3 x 0.25 x (0.50/12) = 7.2 ft^3

Construction Considerations

- Divert stormwater runoff during period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with temporary erosion control materials.
- Install sediment controls around the Grassy Channel to prevent high sediment loads from entering the Grassy Channel 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 requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, including VRMs such as Grassy Channels. Such agreements typically include requirements like those outlined in **Table V-4.3**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the VRM and its immediate vicinity at any time. Maintenance is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix I**.

Table V-4.3. Inspection and Maintenance Requirements for Grassy Channels

Activity	Schedule
Mow grass to maintain height of 4-6 inches or above flow depth at WQF.	As required
Remove grass clippings.	As required
Use Integrated Pest Management practices.	As required
Remove trash and debris from Grassy Channel.	As required
Inspect Grassy Channel for signs of erosion, vegetation damage/coverage, channelization problems, debris build-up, and excess sedimentation in bottom of channel. Correct problems or remove debris and sediment as soon as possible.	At least twice annually. One inspection at the end of wet season so that summer maintenance can be scheduled. Additional inspections after periods of heavy stormwater runoff are desirable.
Remove sediment in inlet areas, the channel, culverts, and outlets whenever flow into the channel is slowed or blocked.	As required
Repair ruts or holes by removing vegetation, adding and tamping soil, and reseeding. Replace damaged vegetation.	As required
Inspect Grassy Channel for obstructions and pools of standing water that can provide mosquito-breeding habitat.	At least twice during wet season after significant storm events. Additional inspections after periods of heavy stormwater runoff are desirable.

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 retention is achieved through the retention of a portion of the flow in the surface soil and thatch layer of the strip and infiltration. Some pollutant removal is also achieved as the stormwater runoff flows through the vegetation and over the soil surface at a shallow depth by a variety of physical, chemical, and biological mechanisms.

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.

For rooftop drainage disconnection, direct stormwater runoff away from the building foundation and disperse flow to the strip. Buried extensions with pop-up outlets can be used for the same purpose. To increase the effectiveness of a Vegetated Buffer 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 the slope of the strip exceeds 4 percent.

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 an impermeable liner prevents infiltration.

Planning and Siting Considerations

- Select a location where site topography allows for the design of buffer strips with proper slopes in the 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 the viability of the buffer strip vegetation. Coordinate the design of the general landscape irrigation system with 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 Filter Strips presented in Fact Sheet L-9. Vegetated Buffer Strips typically differ in terms of the values used for the two principal design parameters that govern treatment performance:

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

Key design criteria and reference values for Vegetated Buffer Strips are listed in **Table V-5.1,** along with reference values for use in the calculation of credits for reducing the effective impervious area. The ratio of design and reference values are used in calculating credits for volume retention and effective impervious area reduction.

Table V-5.1. 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% 0.5%	Maximum 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 (WQF_{ref})	WQF	WQF = 0.20 in/hr x C x A (**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 0.25	A and B soils C and D soils

Volume Retention and Tributary Impervious Area Credit Calculation

Vegetated Buffer Strips provide volume retention through water infiltration during conveyance and retaining water in the vegetative layer. Vegetated Buffer Strips may be used to help meet the VRR and can also be used to reduce the size of required treatment controls (**Section 6**). The calculation procedure for volume retention and tributary impervious area credit for Vegetated Buffer Strips is presented in **Table V-5.2.**

Vegetated Buffer Strips can also be used to reduce the required treatment control size by applying for tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the WQV or WQF, which are the primary design criteria used to size Treatment Controls (**Section 6**).

Implementing 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 retention for the Vegetated Buffer Strip to the volume retention 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 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 V-5.2** details how the tributary impervious area credit is calculated for Vegetated Buffer Strips.

Table V-5.2. Vegetated Buffer Strip Volume and Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Determine reference WQF a. Impervious tributary area b. Impervious area runoff coefficient (C_{imp}) c. $WQF_{ref} = 0.2 \times A_{imp} \times C_{imp} / 43{,}560$	A_{imp} =________ ft2 C_{imp} =________ WQF_{ref} = ________cfs	C_{imp}= 0.95
2. Design width of Vegetated Buffer Strip (W_{vbs})	WVBS = _________ ft	Minimum default width = 3.0 ft
3. Design linear application rate (q_a) $q_a = WQF_{ref} / W_{VBS}$	qa =__________ cfs/ft	Reference qa = 0.005 cfs/ft
4. Design length of Vegetated Buffer Strip (L_{VBS})	LVBS =________ ft	Reference LVBS = 20 ft, which is max length allowed for credit
5. Tributary Impervious Area credit for Vegetated Buffer Strip (A_{credit}) $A_{credit} = (q_{aref}/q_a)^2 \times (L_{VBS}/L_{ref}) \times A_{imp}$	Acredit =_______ ft2	If calculated values of (qaref/qa) or (LVBS/Lref) are > 1.0, the value is set to 1.0. Maximum allowable credit = Aimp
6. Volume retention for Vegetated Buffer Strip ($Vol_{retention}$) $Vol_{retention} = (A_{credit}) \times (C_{imp} - C_{VBS}) \times (0.51/12)$	$Vol_{retention}$ = ___ ft3	CVBS = 0.18 for A and B soils CVBS = 0.25 for C and D soils

Credit Calculation Examples

Examples of volume and area credit calculations are presented below.

Step 1 – Calculate WQF for impervious area tributary to Vegetated Buffer Strip

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

$WQF_{ref} = i \times C_{imp} \times A_{imp}$

where

WQF_{ref} = Stormwater Quality Design Flow, cfs

i = Design storm intensity = 0.20 in/hr

C_{imp} = 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

WQF_{ref} = 0.20 x 0.95 x 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 = WQF_{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} = $(q_{aref}/q_a)^2$ x (L_{VBS}/L_{ref}) ⍰ 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} = $(0.005/0.005)^2$ x (12/20) x 3,600 ft^2

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

A_{credit} = 0.6 x 3,600 ft^2 = 2,160 ft^2

Step 6 – Calculate Volume retention for 0.50-inch storm depth

$Vol_{retention}$ = (A_{credit}) x C_{imp} – C_{VBS}) x (0.50/12)

Example:

C_{VBS} = 0.25 for C and D soils

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

Construction Considerations

- Divert stormwater runoff during period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials, such as silt fences.
- Install sediment controls, such as silt fences, around the Vegetated Buffer Strip to prevent high sediment loads from entering the Vegetated Buffer Strip during ongoing upstream construction activities.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, including VRMs such as Vegetated Buffer Strips. Such agreements typically include requirements like those outlined in **Table V-5.3**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the VRM and its immediate vicinity at any time. Maintenance is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix I**.

Table V-5.3. Inspection and Maintenance Requirements for Vegetated Buffer Strips

Activity	Schedule
Mow grass to maintain height of 2-4 inches.	As required
Remove grass clippings.	As required
Use Integrated Pest Management practices.	As required
Remove trash and debris from Grassy Channel.	As required
Inspect for signs of erosion, vegetation damage/coverage, channelization problems, debris build-up, and excess sedimentation in bottom of channel. Correct problems or remove debris and sediment as soon as possible.	At least twice annually. One inspection at the end of wet season so that summer maintenance can be scheduled. Additional inspections after periods of heavy stormwater runoff are desirable.
Remove sediment in inlet areas, the channel, culverts, and outlets whenever flow into the channel is slowed or blocked.	As required
Repair ruts or holes by removing vegetation, adding and tamping soil, and reseeding. Replace damaged vegetation.	As required
Inspect Grassy Channel for obstructions and pools of standing water that can provide mosquito-breeding habitat.	At least twice during wet season after significant storm events. Additional inspections after periods of heavy stormwater runoff are desirable.

APPENDIX E

LID-based Treatment Control Measure Fact Sheets (L1 – L11)

Description

Roadway Bioretention Areas in Raleigh, NC. *Source: Raleighnc.gov. (n.d.). Retrieved October 6, 2021, from https://raleighnc.gov/SupportPages/roadway-Bioretention-areas.*

A Bioretention area is a vegetated shallow depression that is designed to receive, retain, and infiltrate stormwater 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 the 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 various natural mechanisms as the runoff filters through the vegetation root zone and is detained in the pore spaces 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.

- No Underdrain - If the underlying soil is permeable (typically Type A or B soil with a permeability greater than the engineered soil layers), the Bioretention area can be constructed without an underdrain pipe, in which case all of the captured runoff will infiltrate into the underlying soil profile. An impermeable liner cannot be used for a Bioretention area without an underdrain system in order to receive a volume retention credit.
- Use of Underdrain - If the underlying soil is less permeable (typically Type C or D soils) or the site slopes are steep, an underdrain is required to prevent excessive ponding. If an underdrain is present, only a portion of the captured stormwater runoff will be retained on-site through vegetation uptake In this case, all captured stormwater runoff will infiltrate into the underlying soil profile.[1]

[1] Bioretention facilities are sometimes referred to as biofiltration (Bioretention facility with an underdrain or elevated underdrain) or bioinfiltration (Bioretention facility with no underdrain) facilities. These types of facilities are designed for partial or full infiltration and treatment of stormwater. The terminology continues to be further refined. https://stormwater.pca.state.mn.us/index.php/Bioretention_terminology

Bioretention Systems Source: Bioretention System. *New Jersey Future Green Infrastructure Developers Guide. (2020, May 7). Retrieved October 6, 2021, https://developersguide.njfuture.org/bmp/bioretention-system/.*

Advantages

- Low installation cost.
- Enhances site aesthetics.
- Reduces or retains stormwater volume and pollutant discharge.
- Potential water conservation.
- Easy maintenance.
- Can be designed to meet trash control requirements.

Limitations

- Not appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.
- Requires underdrains for low permeability soils or steep slopes.
- Will require individual owners/tenants to perform maintenance.
- Not appropriate for areas with steep slopes or high groundwater.

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 the impervious surface to the Bioretention areas inlet.
- Provide for overflow discharge that drains away from building foundations to a storm drain system or more suitable infiltration area.
- Provide impermeable liners in areas subject to spills or pollutant hot spots.
- Provide underdrain pipe in areas with C and D soils.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the Bioretention area, and cars are allowed to overhang the Bioretention area.
- Irrigation is typically required to maintain viability of Bioretention area vegetation. Coordinate design of general landscape irrigation system with that of the Bioretention area, as applicable.

Design Criteria

Design criteria for Bioretention are listed in **Table L-1.1**. A typical cross-section illustrating design features is shown in **Figure L-1.1a and b**.

Table L-1.1. Bioretention Design Criteria

Design Parameter	Design 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
Depth to groundwater	>10 feet	The depth to seasonal high groundwater level should be at least 10 feet from the bottom of the structure.
Excavation side slope of (H:V)	2:1	Maximum steepness
For Bioretention with Underdrains		
Aggregate filter blanket	9 - 12 inches	For use with subsurface drainpipe
Subsurface drainpipe	4 - 8 inch	Slotted PVC per American Society for Testing Materials (ASTM) D1785 SCH 40. (Use with C and D soils)

Design Procedure (for Trash Control see below)

Step 1 – Calculate Water Quality Volume (WQV)

Using the procedures presented in **Section 7.4**, determine the WQV 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 WQV depth between six (6) and twelve (12) inches. The 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 WQV and D_{PZ} as follows:

$$A_S = WQV / D_{PZ}$$

Where

WQV = water quality volume (ft^3)

D_{PZ} = average ponding depth (ft)

Step 4 – Design Planting Media Layer

Planting media layer – Provide a mix of 60-65% loamy sand + 35-40% compost or 30% loamy sand + 30% coarse 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.

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

Step 5 – Select Subbase Liner (For Bioretention with Underdrains)

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 (For Bioretention with Underdrains)

If C or D soils are present or infiltration is not desired, provide a subsurface drainpipe with a diameter sized for the required hydraulic capacity (4-in minimum). Use a heavy-walled, slotted PVC pipe (ASTM D1785 SCD 40) to allow pressure water cleaning and root cutting, if necessary. Connect the subsurface drainpipe to the 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 identified on the list of approved plants – **Appendix L**;
- Is suited to well-drained soil;
- Will be dense and strong enough to stay upright, even in flowing water;
- Has a minimum need for fertilizers;
- Is not prone to pests and is consistent with Integrated Pest Management 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 Irrigation System

Provide irrigation system to maintain viability of vegetation, if applicable. The irrigation system must include a City-approved automatic timer.

Step 9 – 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 WQV surcharge water level. A drop inlet or an overflow standpipe with an inverted opening is an appropriate overflow device).

Design Criteria – Trash Control[1]

The Bioretention treatment area consists of a ponding layer, a vegetated and mulched layer, an engineered soil layer, and a supporting bed layer of sand or gravel. The vegetated and mulched layer must have a surface area large enough to trap trash and reduce the risk of trash and other debris (e.g.; vegetation) interfering with the hydraulic capacity of the Bioretention system. The subsurface may include perforated pipes, chambers, open bottom concrete galleries, or other high voids structures designed to temporarily store water prior to infiltration.

The Bioretention system must be designed, constructed, and maintained in accordance with the following six (6) requirements: :

1. Trap trash particles that are 5 millimeters or greater at any time during a storm event for the following:
   a. The peak flow rate generated by the region specific one-year, one-hour storm event from the applicable sub-drainage area (0.31 inches/hour); or
   b. The peak flow rate of the corresponding storm drain (if the Bioretention system is designed to treat flows from the corresponding storm drain that is designed for less than the peak flow rate generated from a one-year, one-hour storm event).
2. Bioretention systems may include either or both of the following to trap particles for either flow described above in section 1.a or 1.b:
   a. A screen at the system's inlet, overflow, or bypass outlet; or
   b. An up-gradient structure designed to bypass flows exceeding the flows as described in section 1.a or 1.b[2].
3. The peak flow rates references in section 1.a shall be calculated using one of the following methods:
   a. For small drainage areas (generally less than 50 acres) - the Rational Equation Method, which is expressed as Q = CiA, where:
      Q = design flow rate (cubic feet per second),

      C = runoff coefficient (dimensionless),

[1] Based on the State Water Resources Control Board Categorically Certified Multi-Benefit Trash Treatment Systems – Bioretention information sheet June 2023 and any subsequent revisions.

[2] Upon approval by the appropriate Regional Water Quality Control Board Executive Officer, a 5 millimeter screen and/or upgradient structure may not be required if the Bioretention System is designed for flood control from flows generated by very large storm events

i = design rainfall intensity (0.31 inches/hour), and

A = subdrainage area (acres).

b. For large drainage areas (generally 50 acres or more) – Other accepted hydrologic mathematical methods that more accurately calculate peak flow rates from large drainage areas, provided a registered California-licensed professional engineer documents the calculations within the design plans.

4. Permittees that have developed a Stormwater Resource Plan (SWRP) pursuant to California Water Code Section 10562 shall only install or approve Bioretention System designs with groundwater recharge functionality at locations suitable for groundwater recharge.
5. For Bioretention Systems that incorporate groundwater recharge capacity into the sizing of the Bioretention System for the purpose of requirements related to the peak flow rates in item 1, above, the percolation rate below the Bioretention System must either be measured directly or estimated employing conservative hydrogeologic assumptions.
6. A registered California licensed Professional Engineer shall stamp and sign Bioretention System design plans as required by California Business & Professions Code section 6700, et seq.

Vector breeding considerations must also be addressed due to the potential nuisance and human health effects.

Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets located within the parcel's boundaries and operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public RoW if the City has agreed to enter into a maintenance agreement with the property owner (**Appendix I**).

Volume Retention Calculation

Bioretention may be used to achieve the VRRs in addition to treatment control requirements. A Bioretention area without an underdrain provides volume retention for the entire WQV calculated in Step 1 of the Design Procedure. The volume retention for a Bioretention area is less if a subsurface drainpipe is provided because less infiltration will occur. The calculation procedure for volume retention for Bioretention is presented in **Table L-1.2.**

Table L-1.2. Bioretention Volume Retention Calculation

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

Construction Considerations

- Divert runoff (other than necessary irrigation) during vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials.
- Install sediment controls around the Bioretention area to prevent high sediment loads from entering the area during ongoing construction activities.
- Avoid compaction of native soils below the planting media layer or gravel zone.

- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, including treatment controls such as Bioretention. Such agreements will typically include requirements such as those outlined in **Table L-1.3**. 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 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.

Table L-1.3. Inspection and Maintenance Requirements for Bioretention Areas

Activity	Schedule
Remulch void areas	As needed
Treat diseased trees and shrubs	As needed
Use Integrated Pest Management practices	As needed
Water plants daily for two weeks	At project completion
Inspect soil and repair eroded areas	Monthly
Remove trash	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

<u>Trash Considerations</u>

Because regular maintenance of the Bioretention System is required to maintain adequate trash capture capacity and to ensure that captured trash does not migrate offsite, the Permittee shall establish a maintenance schedule based on:

a. The maintenance frequency as required in the applicable State/Regional Water Board stormwater permit; and b.

b. Site-specific factors including the design trash capture capacity of the Bioretention System, local storm frequency, and characterization of trash and vegetation accumulation in the corresponding sub-drainage area.

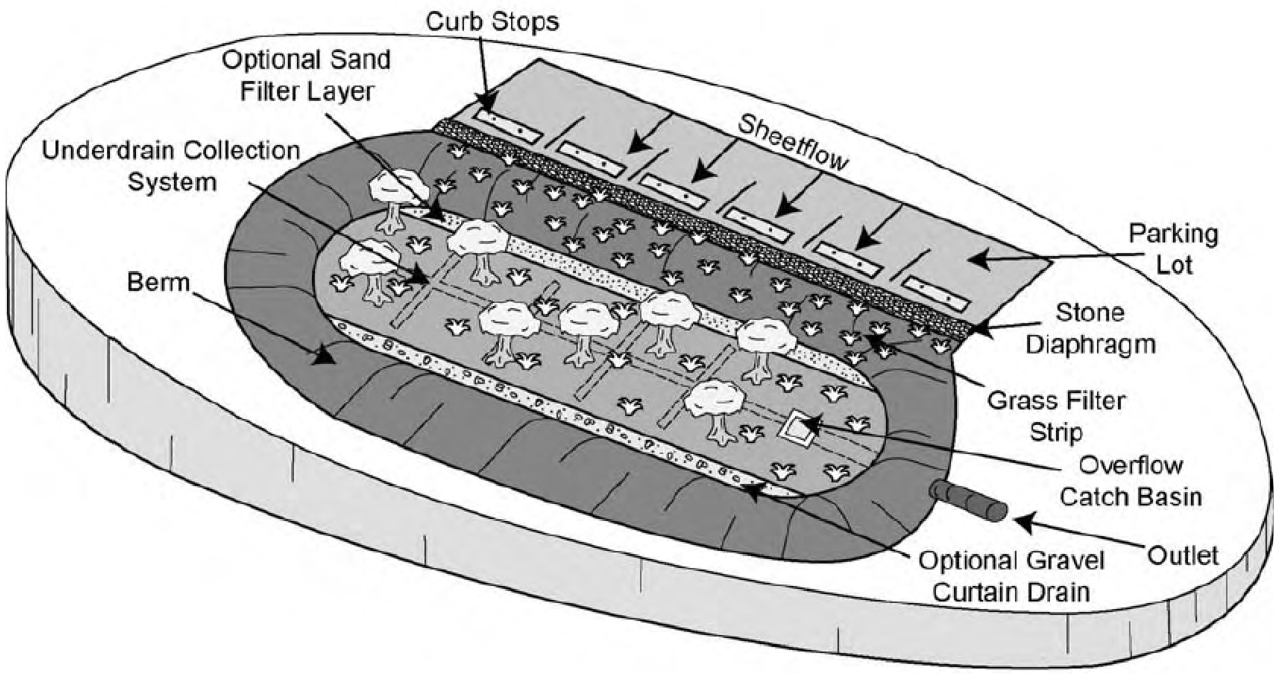


Figure L-1.1a. Bioretention Schematic.

Source: Tom Schueler. (n.d.). (tech.). Urban Stormwater Retrofit Practices (3rd ed., Vol. 1, p. 184).

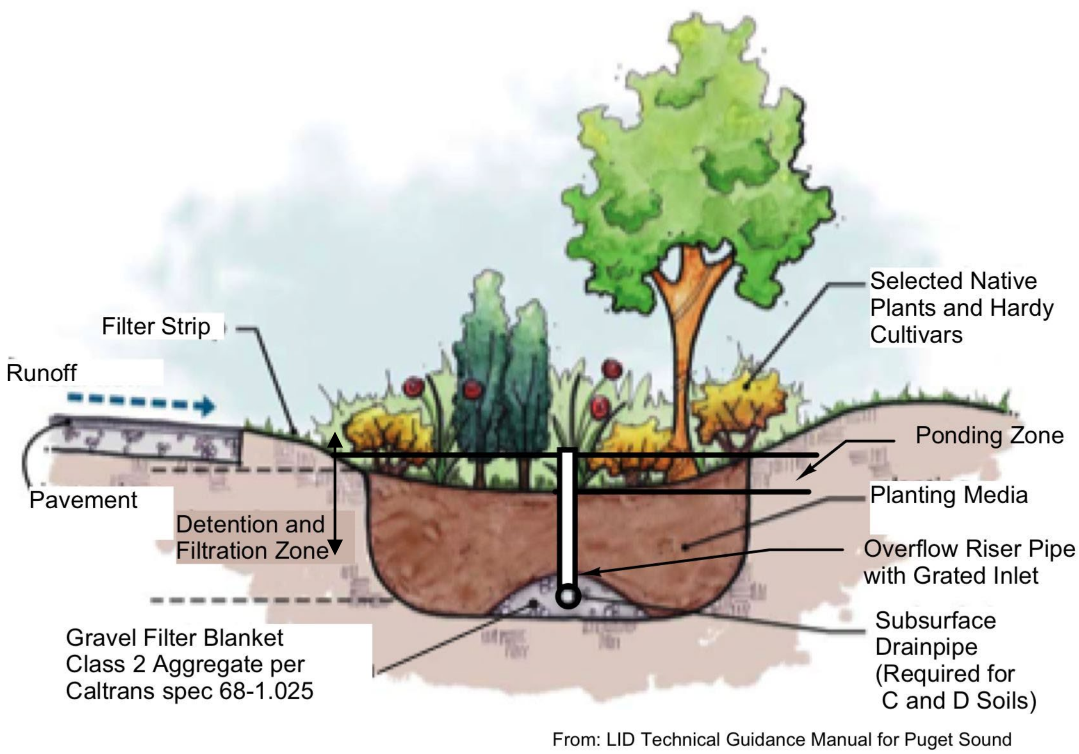


Figure L-1.1b. Bioretention Schematic. *Source: Curtis Hinman. (2012). (rep.). Low Impact Development: Technical Guidance Manual for Puget Sound. Puyallup, WA.*

Image 1. Sidewalk Stormwater Planter
Source: California, S. of. (n.d.). Erosion control toolbox: Sidewalk Stormwater Planter. Erosion Control Toolbox: Sidewalk Stormwater Planter | Caltrans. Retrieved October 6, 2021, from https://dot.ca.gov/programs/design/lap-erosion-control-design/tool-1-lap-erosion-control-toolbox/tool-1kk-37-sidewalk-stormwater-planter.

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 stormwater runoff from downspouts or piped inlets or sheet flow from adjoining impervious areas. A shallow ponding zone is provided above the vegetated surface to temporarily store the captured runoff. During rainfall events, runoff accumulates in the ponding 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 stormwater runoff occurs through a variety of natural mechanisms as the runoff infiltrates through the root zone of the vegetation and during the 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 Stormwater Planters are used, the volume of runoff can be retained through infiltration into underlying soils. For planters underlain with expansive soils or located next to buildings where infiltration of runoff is undesirable, a 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 stormwater runoff. The underdrain gradually dewaters the sand/peat bed over the drawdown period and discharges the runoff to downstream conveyance. However, a Stormwater Planter with an underdrain pipe reduces the amount of water retained and may not allow the site to meet the volume retention requirement.

- 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 WQV 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 L-2.1** and **L-2.2** for typical Stormwater Planter configurations.

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 areas for stormwater detention.
- Reduces peak flows during small storm events.
- Enhances site aesthetics.
- Easy maintenance.

Limitations

- Irrigation is typically required to maintain vegetation.
- Not appropriate for industrial sites or locations where spills may occur unless infiltration is prevented. An impermeable liner may be used, but the benefit of volume retention will be eliminated.
- Not suitable for steeply sloping areas.
- Potential increased cost associated with waterproofing of exterior building walls, if needed.

Planning and Siting Considerations

- Select a location where site topography is relatively flat and allows stormwater 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.
- Irrigation is typically required to maintain viability of Stormwater Planter vegetation. Coordinate design of general landscape irrigation system with that of a Stormwater Planter, as applicable.
- In expansive soils, locate Stormwater Planters far enough from structure foundations to avoid damage to structures (as determined by a structural or geotechnical engineer).

Design Criteria

Design criteria for Stormwater Planters are listed in **Table L-2.1**.

Table L-2.1. Stormwater Planter Design Criteria

Design Parameter	Design 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	WQV	See **Section 7.4**
Design drawdown time	12 hrs	Period of time over which WQV 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 (WQV)

Using the procedures presented in **Section 7.4**, determine the contributing area and WQV based on a 12-hour drawdown period.

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

Select the average WQV depth between six (6) and twelve (12) inches. The 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 WQV and D_{PZ} as follows:

$$A_S = WQV/D_{PZ}$$

Where

WQV = water quality volume (ft^3); and

D_{PZ} = average ponding depth (ft).

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 L-2.1** and **L-2.2**. 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 alternative to the topsoil and sand/peat mix.

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

Step 6 – Design subsurface drainpipe (if required)

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

Step 7 – Select vegetation

Select vegetation that:

- Is identified on the list of approved plants – **Appendix L**;
- Is suited to well-drained soil;
- Will be dense and strong enough to stay upright, even in flowing water;
- Has a minimum need for fertilizers;
- Is not prone to pests and is consistent with Integrated Pest Management 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 Irrigation System

Provide irrigation system to maintain viability of vegetation, if applicable. The irrigation system must include a City-approved automatic timer.

Step 9 – Design overflow device

Provide an overflow device with an inlet to storm drainage system. Set the overflow inlet elevation above the WQV surcharge water level. A drop inlet or an overflow standpipe with an inverted or grated opening is appropriate overflow devices.

Volume Retention Calculation

Stormwater Planters may be used to achieve the VRRs in addition to treatment control requirements. The volume retention for a Stormwater Planter is less if a subsurface drainpipe is provided because less infiltration will occur. The calculation procedure for volume retention for Stormwater Planters is presented in **Table L-2.2**.

Table L-2.2. Stormwater Planter Volume Retention Calculation

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

Construction Considerations

- Divert stormwater 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 the planting media layer or gravel zone for infiltration planter.
- Repair, seed, or re-plant damaged areas immediately.
- For planters next to buildings, provide waterproofing of exterior building walls as directed by an architect or structural engineer.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner before final acceptance of a private development project, including treatment controls such as Stormwater Planters. Such agreements will typically include requirements such as those outlined in **Table L-2.3**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City 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.

Table L-2.3. 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 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

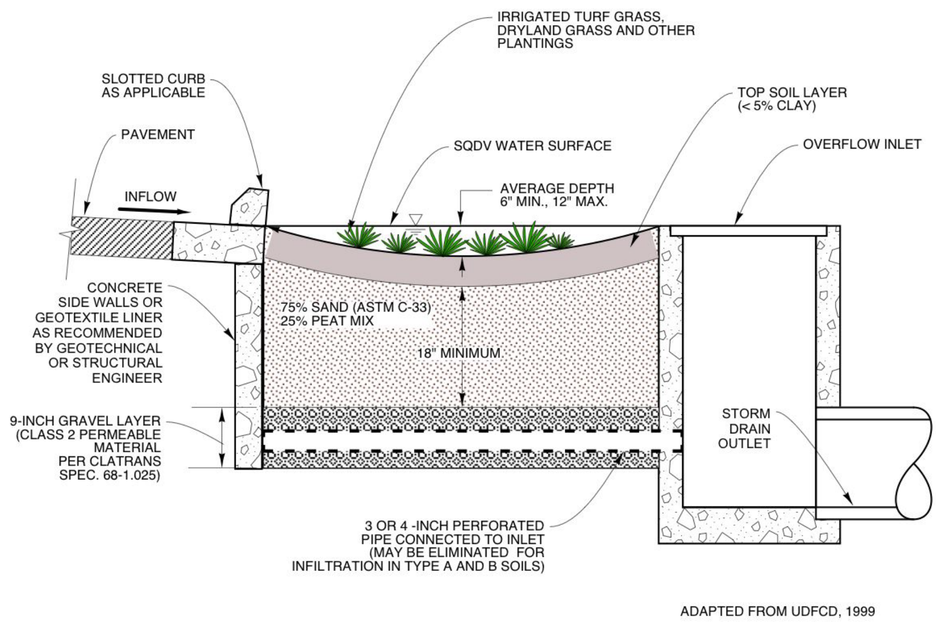


Figure L-2.1. Stormwater Planter Configuration. *Source: Urban Drainage and Flood Control District (UDFCD). (1999, rev. 2008). Drainage Criteria Manual (Vol 3). Denver, CO.*

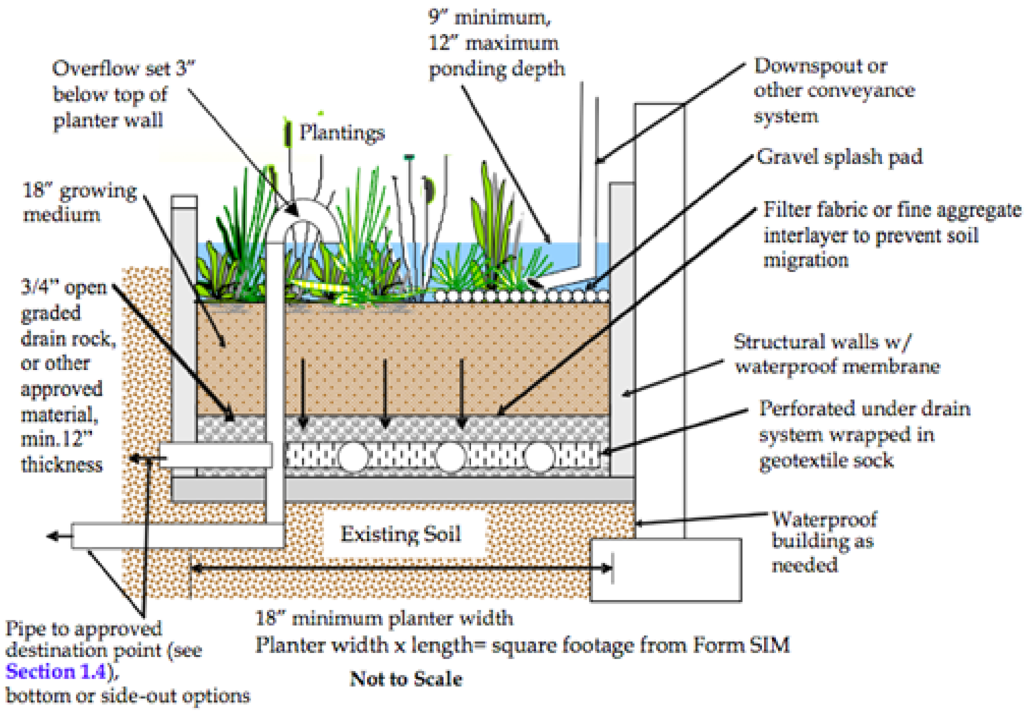


Figure L-2.2. Flow-through Stormwater Planter Configuration. "Stormwater Planters." *Source: Stormwater Management Manual. [Eugene, Or.]: City of Eugene. (2008). 2-58--62. Print. http://ceppcontent.eugene1.net;7087/publishedcontent/publish/pw/stormwater/docs/ch2e.pdf*

(Top) **A tree box installed with a speed bump to assist the flow of water towards the inlet.** *Source Photo: Pat Rector Rutgers, The State University of New Jersey, U.S. Department of Agriculture, and County Boards of Chosen Freeholders. Rutgers Cooperative Extension, a unit of the Rutgers New Jersey Agricultural Experiment Station, is an equal opportunity program provider and employer*

(Bottom) **Tree Box.** *Source: MSD. (n.d.). Retrieved October 7, 2021, from https://louisvillemsd.org/comply-consent-decree.*

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 trees might normally be installed, and is designed to receive, retain, and infiltrate stormwater runoff from adjoining paved areas. During rain 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 stormwater runoff occurs through a variety of natural mechanisms as the runoff filters through the root zone of the vegetation and during the 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 have a 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.

Limitations

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

Planning and Siting Considerations

- Select a 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.
- Irrigation is typically required to maintain viability of Tree-well Filters. Coordinate design of general landscape irrigation system with that of tree well-filters, as applicable.
- Connect underdrain into storm drain system.

Design Criteria

Design criteria for Tree-well Filters are listed in **Table L-3.1.** A Design Data Summary Sheet is provided at the end of this fact sheet.

Table L-3.1. Tree-well Filter Design Criteria

Design Parameter	Design 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	WQV	**Section 7.4**
Design drawdown time	12 hrs	Period of time over which WQV 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 (WQV)

Using the procedures presented in **Section 7.4**, determine the contributing area and WQV based on a 12-hour drawdown period.

Step 2 – Design average surcharge depth (d_s)

Select the average WQV depth between six (6) and twelve (12) inches. The 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 WQV and d_s as follows:

$$A_S = WQV/d_s$$

Where:

WQV = water quality volume (ft^3); and

ds = average ponding depth (ft).

Step 4 – Design base courses

Sand/Peat layer – Provide a 24-inch (minimum) sand and peat layer over a 9-inch gravel layer, as shown in **Figure L-3.1**. 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 alternative to the topsoil and sand/peat mix.

Gravel envelope (for subsurface drainpipe) – Place drainpipe on a 3- ft wide, 3-inch-deep bed of gravel (Class 2 Permeable Material per Caltrans Spec 68-1.025). Cover the top and sides of the pipe with gravel to a minimum depth of 6 inches. Place a strip of non-woven filter fabric on top of the gravel layer that extends 18 inches on either side of the drainpipe. Do not wrap the 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 Type C or D soils are present or an impermeable liner is used, provide a subsurface drainpipe with a diameter sized for the required hydraulic capacity (4-in minimum). Use a heavy-walled, slotted PVC pipe (ASTM D1785 SCD 40) to allow pressure water cleaning and root cutting, if necessary. Connect the subsurface drainpipe to the downstream open conveyance (e.g., swale) or the storm drain system.

Step 7 – Select tree

Select a tree that:

- Is identified on the list of approved plants – **Appendix L**;
- 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 Integrated Pest Management 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 Irrigation System

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

Step 9 – Design overflow device

Provide an overflow device with an inlet to storm drainage system. Set the overflow inlet elevation above the WQV surcharge water level. A drop inlet or an overflow standpipe with an inverted or grated opening is appropriate overflow devices.

Volume Retention Calculation

Tree-well Filters may be used to achieve the VRRs in addition to treatment control requirements. The volume retention for a Tree-well Filter is less if an impermeable bottom is used because less infiltration will occur. The calculation procedure for volume retention for Tree-well Filter is presented in **Table L-3.2.**

Table L-3.2. Tree-well Filter Volume Retention Calculation

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

$Vol_{Retention} = (D_{PZ} \times A_{PZ}) + (D_{PM} \times A_{PM} \times 0.10)$		

Construction Considerations

- Divert runoff (other than necessary irrigation) during 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 the planting media layer or gravel zone.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner before final acceptance of a private development project, including treatment controls such as Tree-well Filters. Such agreements will typically include requirements such as those outlined in **Table L-3.3**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City 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.

Table L-3.3. 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 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

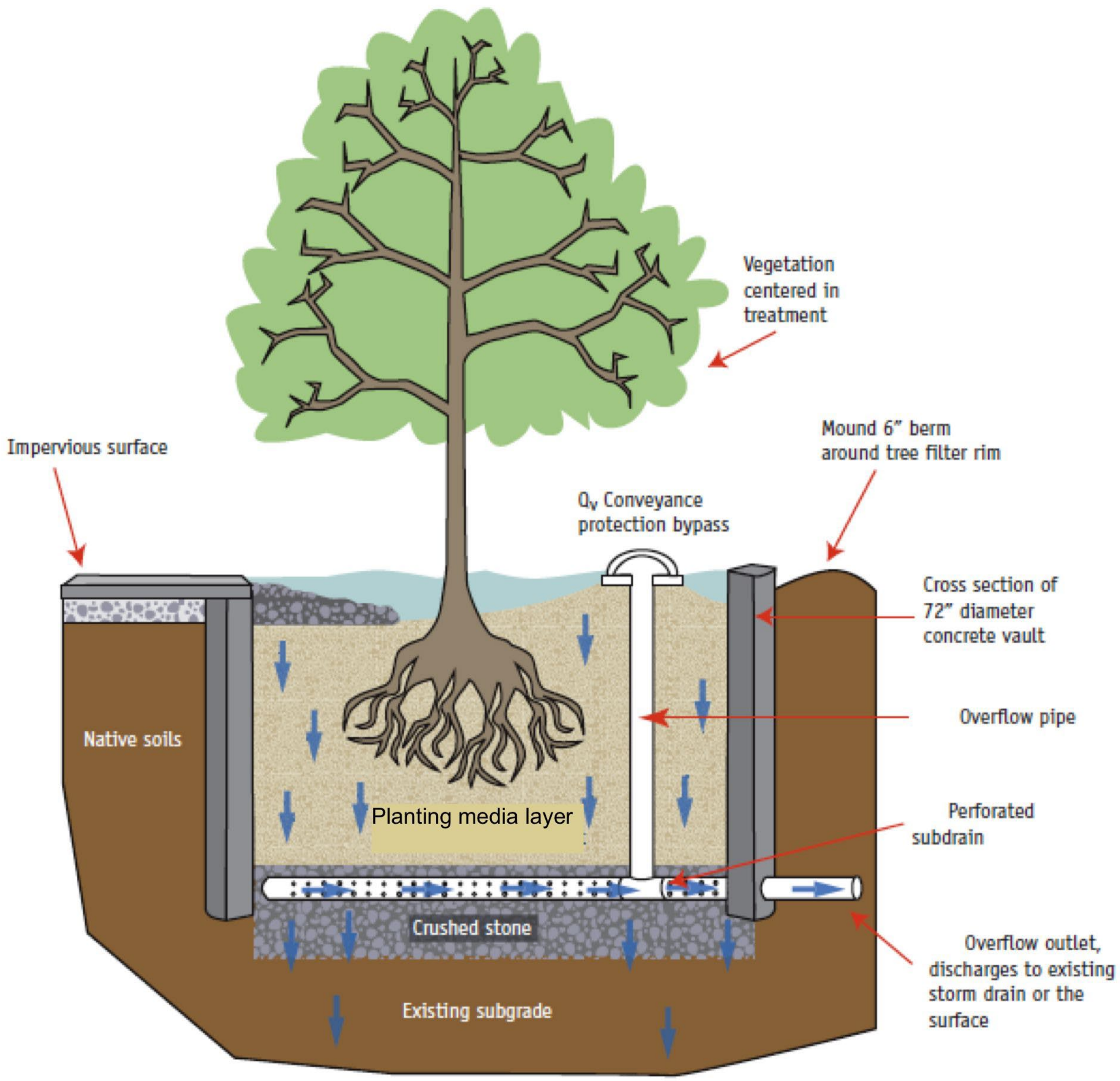


Figure L-3.1. Tree-well Filter Schematic. *Source: University of New Hampshire, Stormwater Center. (2009) 2009 Biannual Report. p.22.*

Description


Source: Ball Field Water Quality Infiltration Basin. Stormwater Discovery Tours. (2019, March 28). Retrieved October 7, 2021, from https://stormwater.cob.org/tour-squalicum-creek-park/site-ball-field-infiltration-basin/.

A Water Quality Infiltration Basin is a shallow earthen basin constructed in naturally pervious soils (type A or B) designed for infiltrating stormwater runoff. This type of basin retains the WQV and. allows the retained runoff to percolate into the underlying native soils and into the groundwater table over a specified drawdown period. Infiltration Basins are similar to the City's Water Quality Infiltration Basins but differ in that they are designed for the purpose of stormwater runoff treatment and retention as opposed to drainage.

The bottom of the basin is typically vegetated with dryland 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 basin bottom and the seasonal maximum groundwater surface level should be a minimum of ten (10) feet. A typical layout of a Water Quality Infiltration Basin is shown in **Figure L-4.1.**

***Other Names**: Percolation Basin*

Advantages

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

Limitations

- Not appropriate for areas with low permeability soils or high groundwater.
- Not appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.
- Must be protected from high sediment loads. Once clogged with sediment, restoration of basin infiltration capacity may be difficult.
- Potential for mosquito breeding due to standing water. This can be greatly reduced and/or eliminated if the basin is properly designed, constructed, and operated to maintain its infiltration capacity.

- Not appropriate on fill or sites with steep slopes.

Planning and Siting Considerations

- A qualified geotechnical engineer or geologist should determine soil permeability, and depth to groundwater and design safety factors to ensure that conditions conform to the criteria listed in **Table L-4.1.**
- Integrate Water Quality Infiltration Basins into open space buffers, undisturbed natural areas, and other landscape areas when possible.
- Pretreatment using Grassy Channels, Vegetated Buffer Strips, Vegetated Swales, Grassy Swales, and/or Vegetated Filter Strip is required to protect Water Quality Infiltration Basins from high sediment loads.
- Irrigation may be required to maintain the viability of vegetation on the slopes and bottom of the basin if vegetation is included in the design. Coordinate the design of the general landscape irrigation system with that of the basin, as applicable.
- Plan for setback requirements.

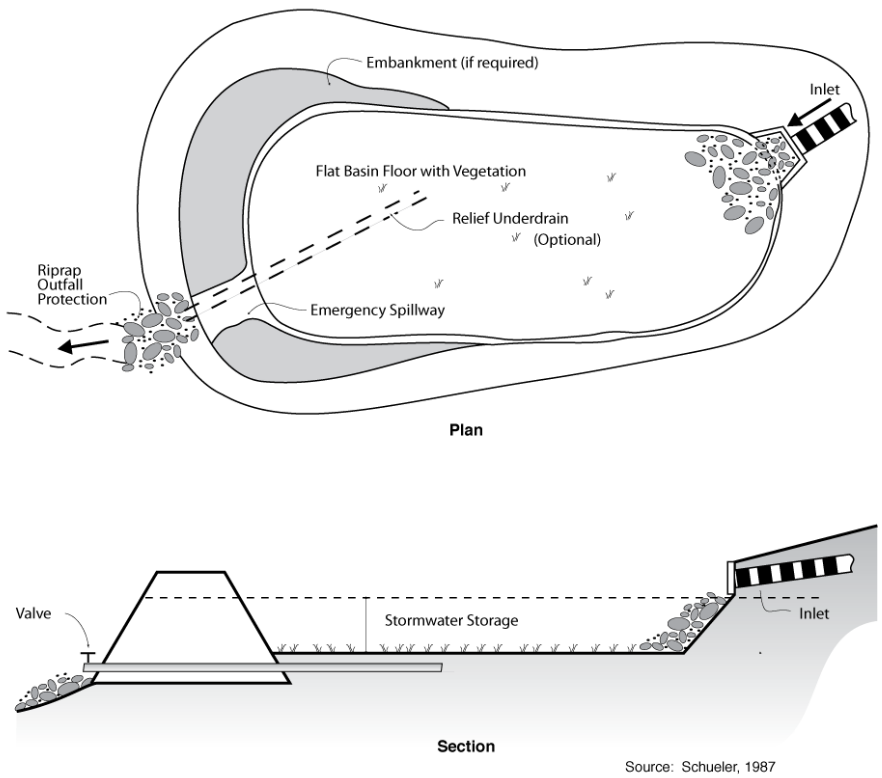


Figure. L-4.1. Example Water Quality Infiltration Basin. *Source: Henao Casas, Jose & Walther, Marc & Kalwa, Fritz & Rausch, Randolf. (2019). Numerical and Analytical Assessment of Stormwater Infiltration via Vadose Zone Wells and Infiltration Trenches. 10.13140/RG.2.2.14098.07368.*

Design Criteria and Procedure

Principal design criteria for Water Quality Infiltration Basins are listed in **Table L-4.1.**

Table L-4.1. Water Quality Infiltration Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for WQV	hrs	48
WQV	ac-ft	80% annual capture; 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 ft	100 ft from wells, tanks, fields, springs 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)	–	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 Criteria (for Trash Control see below)

Step 1- Calculate Water Quality Volume (WQV)

Using the procedures presented in **Section 7.4**, determine the tributary drainage area and WQV for 48-hour drawdown.

Step 2– Calculate Design Maximum Depth of Water Surcharge in the Water Quality 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 above, the safety factor accounts for possible inaccuracies in the infiltration rate measurement. A larger safety factor should be used when the infiltration rate is less certain. 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 a permeability greater than two (2) inches per hour may be used if full pretreatment is provided using one of the approved treatment controls.

Step 3- Calculate Minimum Surface Area of the Water Quality Infiltration Basin Bottom (A_{min})

$$A_{min} = WQV/D_{max}$$

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 the removal of course sediment by sedimentation. The volume of the forebay should be five (5) to ten (10) percent of the WQV. 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 all-weather access for maintenance vehicles to the bottom and outlet works. The maximum grades of access ramps should be ten (10) percent and the minimum width should be ten (10) feet. Ramps should be paved with concrete colored to blend with the surroundings.

Step 7 – Design Security Fencing

Provide aesthetic security fencing around the basin to protect habitat except when specifically waived by the City. Fencing design shall adhere to the City of Modesto Standard Specifications and be approved by the City.

Step 8 – Design Bypass

Provide for bypass or overflow of runoff volumes in excess of the WQV. Provide spillway or overflow structures, as applicable.

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

Select vegetation from the list of approved plants – **Appendix L**. 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 the viability of vegetation, if applicable.

Design Procedure – Trash Control[8]

Water Quality Infiltration Basins may be backfilled with porous media such as gravel, sand, soil, or various locally earthed rocks (assuming such media does not generate pollutants of concern). These Basins store water for infiltration to underlying soils. The subsurface of the Basin may include perforated pipes, chambers, open bottom concrete galleries, or other high voids structures designed to temporarily store water prior to infiltration. The surface of the Basin must have a surface area large enough to trap trash and reduce the risk of trash and other debris (e.g., vegetation) interfering with the hydraulic capacity.

The Water Quality Infiltration Basin must be designed, constructed, and maintained in accordance with the following five (5) requirements:

1. Trap trash particles that are 5 millimeters or greater at any time during a storm event for the following:
    a. The peak flow rate generated by the region specific one-year, one-hour storm event from the applicable sub-drainage area (0.31 inches/hour); or
    b. The peak flow rate of the corresponding storm drain (if the Basin is designed to treat flows from the corresponding storm drain that is designed for less than the peak flow rate generated from a one-year, one-hour storm event).
2. Water Quality Infiltration Basins may include either or both of the following to trap particles for either flow described above in section 1.a or 1.b:
    a. A screen at the system’s inlet, overflow, or bypass outlet; or
    b. An up-gradient structure designed to bypass flows exceeding the flows as described in section 1.a or 1.b[9]
3. The peak flow rates references in section 1.a shall be calculated using one of the following methods:
    a. For small drainage areas (generally less than 50 acres) - the Rational Equation Method, which is expressed as Q = CiA, where:
    Q = design flow rate (cubic feet per second),

        C = runoff coefficient (dimensionless),

        i = design rainfall intensity (0.31 inches/hour), and

        A = subdrainage area (acres).
    b. For large drainage areas (generally 50 acres or more) – Other accepted hydrologic mathematical methods that more accurately calculate peak flow rates from large

[8] Based on the State Water Resources Control Board Categorically Certified Multi-Benefit Trash Treatment Systems – Infiltration Basin information sheet June 2023 and any subsequent revisions.

[9] Upon approval by the appropriate Regional Water Quality Control Board Executive Officer, a 5 millimeter screen and/or upgradient structure may not be required if the Basin is designed for flood control from flows generated by very large storm events.

drainage areas, provided a registered California-licensed professional engineer documents the calculations within the design plans.

4. For the purpose of requirements related to the peak flow rates in item 1, above, the percolation rate below the Water Quality Infiltration Basin must either be measured directly or estimated employing conservative hydrogeologic assumptions.
5. A registered California licensed Professional Engineer shall stamp and sign Bioretention System design plans as required by California Business & Professions Code section 6700, et seq.

Vector breeding considerations must also be addressed due to the potential nuisance and human health effects.

Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets located within the parcel's boundaries and operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public RoW if the City has agreed to enter into a maintenance agreement with the property owner (**Appendix I**).

Volume Retention Calculation

Water Quality Infiltration Basins may be used to achieve VRRs in addition to treatment control requirements. The volume retention allowed is equal to the WQV calculated in Step 1 of the design procedure.

Construction Considerations

- If possible, stabilize the entire tributary area to the Water Quality 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 the entire tributary area to the basin before allowing runoff to enter the 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 the 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 requires the execution of a maintenance agreement with the property owner before final acceptance of a private development project, including treatment control measures. Such agreements will typically include requirements such as those outlined in **Table L-4.2**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City designee with complete access to the treatment control measure and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner.

Trash Considerations

Because regular maintenance is required to maintain adequate trash capture capacity and to ensure that captured trash does not migrate offsite, the Permittee shall establish a maintenance schedule based on:

a. The maintenance frequency as required in the applicable State or Regional Water Board stormwater permit; and

b. Site-specific factors including the design trash capture capacity of the Water Quality Infiltration Basin, local storm frequency, and characterization of trash and vegetation accumulation in the corresponding sub-drainage area.

Table L-4.2. Inspection and Maintenance Requirements for Water Quality 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 the 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
Maintain pretreatment control measures in accordance to its respective “Long-Term Maintenance” section.	As required

Infiltration Trench. *Source: AWWA. (2019, February 1). Infiltration trench: Do-it-yourself conservation practices. Acton Wakefield Watersheds Alliance. Retrieved October 7, 2021, from https://awwatersheds.org/infiltration-trench-do-it-yourself-conservation-practices/.*

Description

A Water Quality Infiltration Trench (also known as a French Drain or Horizontal Drain) 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. Stormwater 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 trench becomes clogged. Water Quality Infiltration Trenches are similar to the City's infiltration trenches but differ in that they are designed for the purpose stormwater runoff treatment and retention as opposed to drainage.

Infiltration Vaults and Infiltration Leach Fields are subsurface variations of the Water Quality Infiltration Trench concept in which stormwater runoff is distributed to the upper zone of the subsurface gravel bed utilizing perforated pipes.

A Water Quality Infiltration Trench is designed to retain the WQV 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 stormwater runoff occurs through various 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 Water Quality Infiltration Trench configuration is shown in **Figure L-5.1**.

Other Names: Percolation Trench, Dispersal Trench, French Drain

Advantages

- Provides effective treatment 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.
- Reduces peak flows during small storm events.
- Can be designed to meet trash control requirements.

Limitations

- Potential for clogging of media. Upstream treatment control measures 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 with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.

Planning and Siting Considerations

- Integrate Water Quality Infiltration Trenches into open space buffers, undisturbed natural areas, and other landscape areas when possible.
- Plan for setback requirements as listed in **Table L-5.1**.
- Do not locate trenches under tree drip lines.
- Pretreatment using Grassy Channels, Vegetated Buffer Strips, Vegetated Swales, Grassy Swales, and/or Vegetated Filter Strip is required to protect Water Quality Infiltration Trenches from high sediment loads.

Design Criteria

Design criteria for Water Quality Infiltration Trenches are listed in **Table L-5.1.**

Table L-5.1. Water Quality Infiltration Trench Design Criteria

Design Parameter	Criteria	Notes
Tributary Drainage Area	≤ 5 acres	
Design volume	WQV	**Section 7.4**
Maximum drawdown time for WQV	48 hrs	Based on WQV
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 20 ft 100 ft –	From wells, tanks, fields, springs Downslope from foundations 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 (**Table L-5.2**) prevents clogging
Observation well size	4-6 in.	Perforated PVC pipe with removable cap
Pretreatment vegetated buffer strip length/slope	10 ft/5%	Minimum length/maximum slope in flow direction

Table L-5.2. Geotextile Fabric Specifications

Property	Test Method	Unit	Specification
Material			Nonwoven geotextile fabric
Unit Weight		oz/yd3	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 (for Trash Control see below)

Step 1 – Calculate Water Quality Volume (WQV)

Using the procedures presented in **Section 7.4** determine the effective tributary drainage area and WQV for 48-hour drawdown.

Step 2 – Calculate Minimum Surface Area of Trench Bottom (A_{min})

$$Area_{min} = \frac{WQVxsx12}{t_{max}x1}$$

Where

WQV = water quality volume (ft^3)

t_{max} = Maximum drawdown time = 48 hrs

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

s = Safety factor

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 a permeability greater than two (2) inches per hour may be used if full pretreatment is provided using one of the approved treatment controls.

Step 3 – Calculate Design Depth of Water Surcharge in Trench (D_{max})

$$D_{max} = \frac{WQV}{PxArea_{min}}$$

Where

WQV = water quality volume (ft^3)

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

$Area_{min}$ = 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 trench on a footplate and with a locking, removable cap. The observation well is needed to monitor the infiltration rate and is useful for marking the location of the Water Quality Infiltration Trench.

Step 5 – Design Bypass

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

Design Procedure – Trash Control[6]

Water Quality Infiltration Trenches may be backfilled with porous media such as gravel, sand, soil, or various locally earthed rocks (assuming such media does not generate pollutants of concern). These Trenches store water for infiltration to underlying soils. The subsurface of the Trench may include perforated pipes, chambers, open bottom concrete galleries or other high voids structures designed to temporarily store water prior to infiltration. The surface of the Trench must have a surface area large enough to trap trash and reduce the risk of trash and other debris (e.g., vegetation) interfering with the hydraulic capacity.

The Water Quality Infiltration Trench must be designed, constructed, and maintained in accordance with the following five (5) requirements:

1. Trap trash particles that are 5 millimeters or greater at any time during a storm event for the following:
    a. The peak flow rate generated by the region specific one-year, one-hour storm event from the applicable sub-drainage area (0.31 inches/hour); or
    b. The peak flow rate of the corresponding storm drain (if the Trench is designed to treat flows from the corresponding storm drain that is designed for less than the peak flow rate generated from a one-year, one-hour storm event).
2. Water Quality Infiltration Trenches may include either or both of the following to trap particles for either flow described above in section 1.a or 1.b:

[6] Based on the State Water Resources Control Board Categorically Certified Multi-Benefit Trash Treatment Systems – Infiltration Trench information sheet.

a. A screen at the system's inlet, overflow, or bypass outlet; or
b. An up-gradient structure designed to bypass flows exceeding the flows as described in section 1.a or 1.b[7].

3. The peak flow rates references in section 1.a shall be calculated using one of the following methods:
   a. For small drainage areas (generally less than 50 acres) - the Rational Equation Method, which is expressed as Q = CiA, where:
      Q = design flow rate (cubic feet per second),

      C = runoff coefficient (dimensionless),

      i = design rainfall intensity (0.31 inches/hour), and

      A = subdrainage area (acres).
   b. For large drainage areas (generally 50 acres or more) – Other accepted hydrologic mathematical methods that more accurately calculate peak flow rates from large drainage areas, provided a registered California-licensed professional engineer documents the calculations within the design plans.
4. For the purpose of requirements related to the peak flow rates in item 1, above, the percolation rate below the Water Quality Infiltration Trench must either be measured directly or estimated employing conservative hydrogeologic assumptions.
5. A registered California licensed Professional Engineer shall stamp and sign Bioretention System design plans as required by California Business & Professions Code section 6700, et seq.

Vector breeding considerations must also be addressed due to the potential nuisance and human health effects.

Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets that are located within the boundaries of the parcel and that are operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public RoW if the City has agreed to enter into a maintenance agreement with the property owner (**Appendix I)**.

Volume Retention

Water Quality Infiltration Trenches may be used to achieve the VRR in addition to treatment control requirements. The volume retention allowed is equal to the WQV calculated in Step 1 of the design procedure.

[7] Upon approval by the appropriate Regional Water Quality Control Board Executive Officer, a 5 millimeter screen and/or upgradient structure may not be required if the Basin is designed for flood control from flows generated by very large storm events.

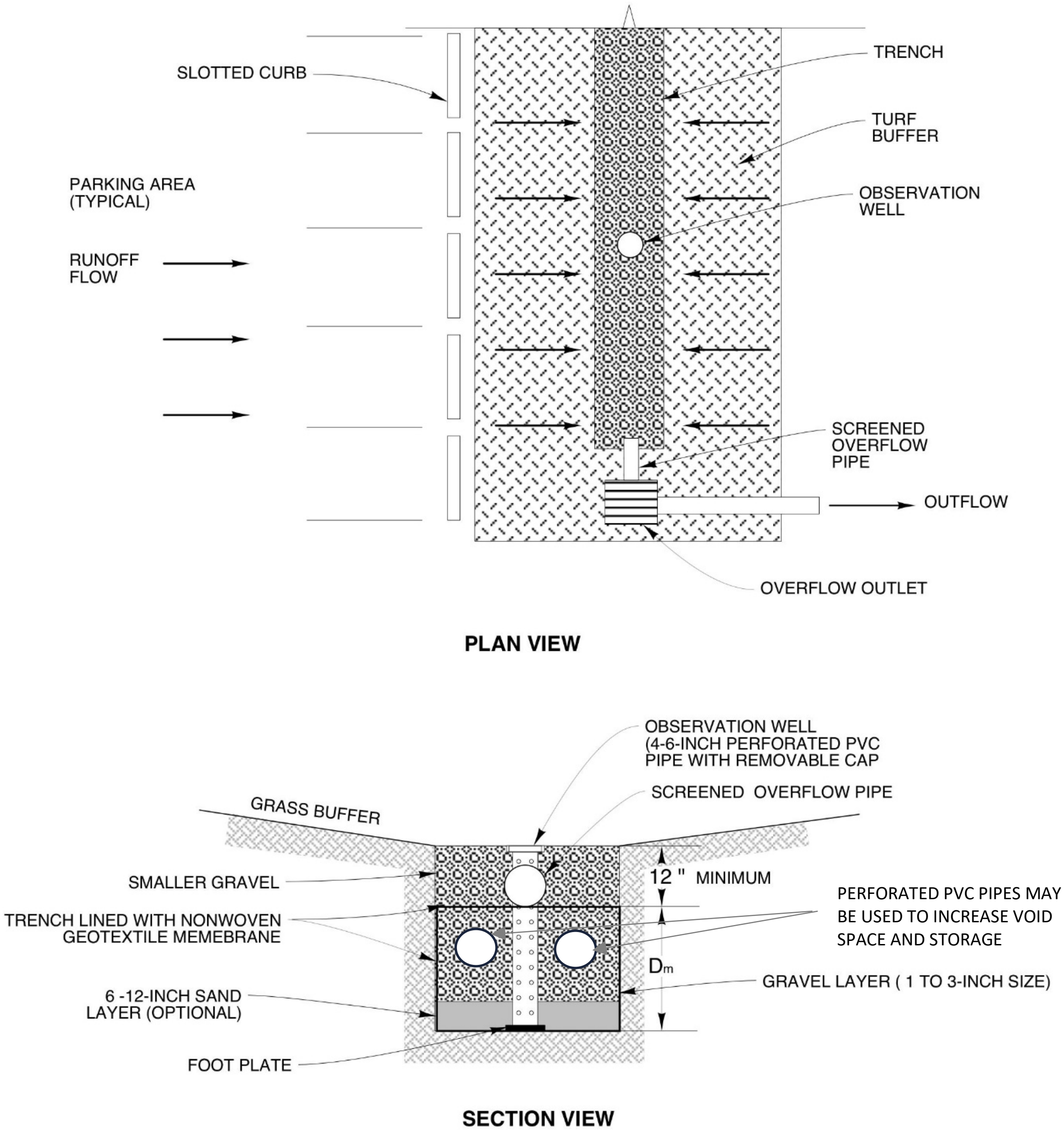


Figure L-5.1 Infiltration Trench. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November)*

Construction Considerations

- If possible, stabilize the entire tributary area to the 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 geotextile fabric on the sides, bottom, and one foot below the surface of the trench. 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 a plate compactor. The use of unwashed gravel can result in clogging.

Long-term Maintenance

The City requires the execution of a maintenance agreement with the property owner prior to the final acceptance of a private development project, which includes treatment controls such as Water Quality Infiltration Trenches. Such agreements will typically include requirements such as those outlined in **Table L-5.3**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan must provide the City 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.

<u>Trash Considerations</u>

Because regular maintenance is required to maintain adequate trash capture capacity and to ensure that captured trash does not migrate offsite, the Permittee shall establish a maintenance schedule based on:

a. The maintenance frequency as required in the applicable State or Regional Water Board stormwater permit; and

b. Site-specific factors including the design trash capture capacity of the Water Quality Infiltration Trench, local storm frequency, and characterization of trash and vegetation accumulation in the corresponding sub-drainage area.

Table L-5.3. Inspection and Maintenance Requirements for Water Quality 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

Pervious Pavers. *Source: Bay, A. for the C. (n.d.). Reduce your stormwater. Pervious Pavers. Retrieved October 7, 2021, from https://www.stormwater.allianceforthebay.org/take-action/installations/pervious-pavers.*

Porous Asphalt. *Source: Cornell University Urban Horticulture Institute. (2007). Using Porous Asphalt and CU-Structural Soil®. Retrieved October 7, 2021, from http://www.hort.cornell.edu/uhi/outreach/pdfs/cu_porous_asphalt.pdf.*

Description

Porous Pavement Filter (PPF) 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 stormwater 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 PPF system is shown in **Figure L-6.1**.

Advantages

- Reduces stormwater runoff volume and peak flow during small storm events.
- Can serve functional and aesthetic purposes.
- Creates dual use for limited spaces.

Limitations

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

Note: the pavement design needs to meet the project-specific loads, which must be reviewed and accepted by the City.

Planning and Siting Considerations

- Should only be installed on relatively flat surfaces.
- May be used in low vehicle-movement zones. Potential applications may 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;
  - Residential driveways;
  - Sidewalks, walkways, patios;
  - Maintenance roads and trails; and
  - 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 block voids, but it may require irrigation and lawn care.
- Should be located far enough from foundations in expansive soils so as to limit damage to potential structures.
- When a commercial or 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

The design Criteria for the PPF are summarized in **Table L-6.1**.

Table L-6.1. PPF Design Criteria

Design Parameter	Design Criteria	Notes
Drawdown time for WQV	12 h	Minimum
WQV	80% annual capture	12-hr drawdown
Surcharge storage volume above pavement	WQV	
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 (WQV)

Using the procedures presented in **Section 7.4**, determine the tributary drainage area and WQV for a 12-hour drawdown period.

Step 2 – Determine Filter Ponding Zone Storage Volume (V_{PZ})

The ponding zone storage volume above the pavement is equal to:

$$V_{PZ} = C \times WQV$$

Where

WQV = water quality volume (ft^3)

C = Use 1.0 for soil types A and B; use 0.25 for soil types C and D (see **Table L-6.2**)

Step 3 – Determine Filter Surface Area (A_S)

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

$$\text{Surface Area } (A_S) = WQV\ (ft^3)/0.17\ (ft)$$

Where

WQV = water quality volume (ft^3).

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 dimensions 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**.**

Step 7 – Provide Perimeter Wall

Provide a concrete perimeter wall to confine the edges of the PPF 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 8 – Install Subbase

If expansive soils or rocks 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 9 – 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 Retention Calculation

PPF may be used to achieve the VRR in addition to treatment control requirements. The volume retention for a PPF is less if a subsurface drainpipe is provided because less infiltration will occur. If the PPF is constructed with an impermeable liner, no volume retention credit is given. The calculation procedure for volume retention for PPF is presented in **Table L-6.2**.

Table L-6.2. PPF Volume Retention Calculation

Design Parameter	Design Criteria	Notes
PPF with Subsurface Drainpipe		Required for C and D soils
1. Volume retention for PPF ($Vol_{reduction}$) $Vol_{reduction}$ = (WQV x 0.25)	$Vol_{reduction}$ =___ ft^3	Infiltration allowance for water in ponding zone = 0.25 No volume retention credit is given for PPFs with impermeable liners
PPF without Subsurface Drainpipe		Use with A and B soils only
1. Volume retention for PPF ($Vol_{reduction}$) $Vol_{reduction}$ = (WQV x 1.0)	$Vol_{reduction}$ = ___ ft^3	Infiltration allowance for water in ponding zone water = 1.0

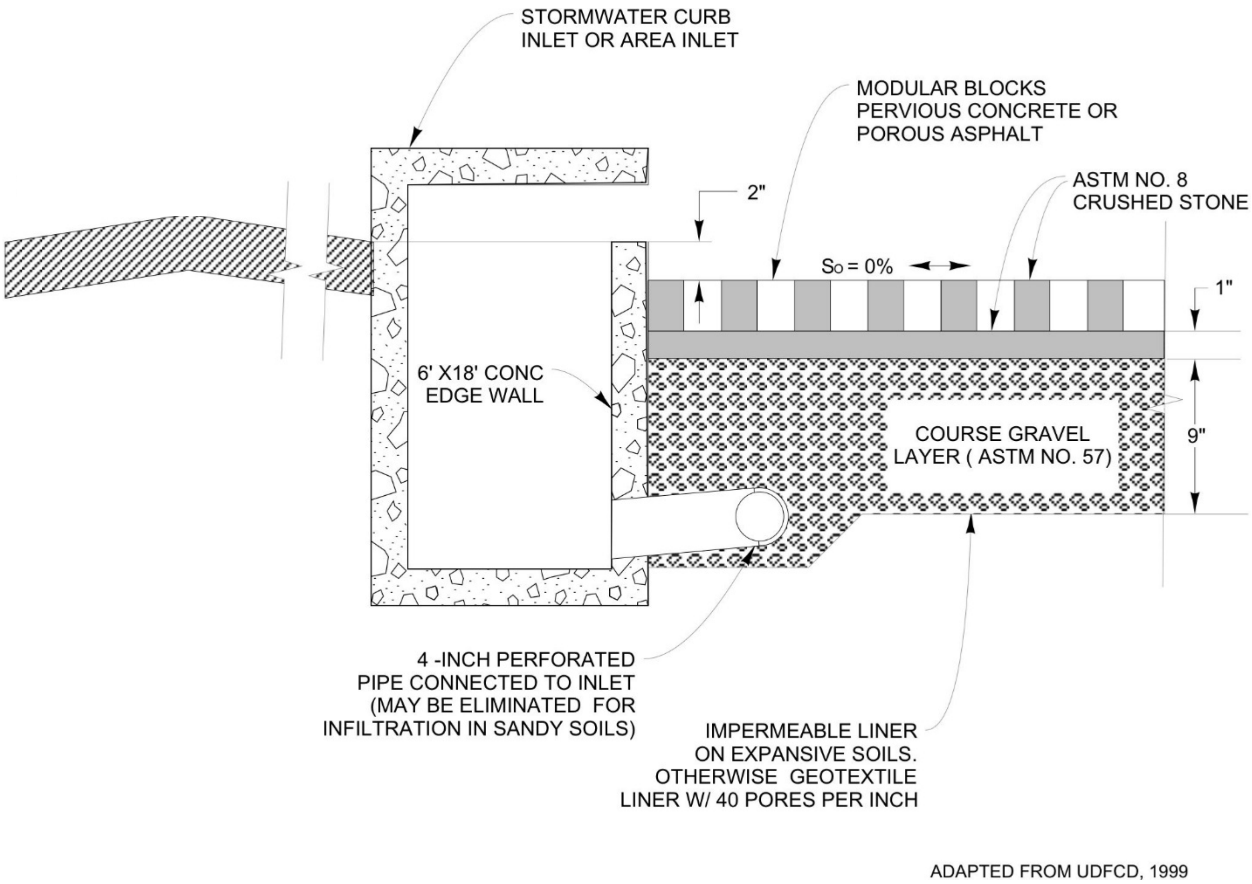


Figure L-6.1. Porous Pavement Filter. *Source: Infiltration Stormwater Planter Configuration. Urban Drainage and Flood Control District (UDFCD). (1999, rev. 2008). Drainage Criteria Manual (Vol 3). Denver, CO***.**

Construction Considerations

- Before the entire site is graded, the area planned for the PPF should be cordoned off to prevent heavy equipment from compacting the underlying soils.
- Install geotextile fabric under the base course. Provide generous overlap at all seams.
- Both prior to and during construction, diversions should be installed around the perimeter of the PPF as needed to prevent runoff and sediment from entering the site until the PPF is in place.

Maintenance Requirements

The City requires the execution of a maintenance agreement with the property owner prior to the final acceptance of a private development project, which includes treatment controls such as PPFs. Such agreements will typically include requirements such as those outlined in **Table L-6.3**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City 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.

Table L-6.3. Inspection and Maintenance Requirements for PPF

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 storm events. 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.

Image 6-10. ***Vegetated Swale, Maria Cahill.*** *Water-quality swales: Low-impact development fact sheet. (2018, June 1). OSU Extension Catalog,Oregon State University. Retrieved October 7, 2021, from https://catalog.extension.oregonstate.edu/em9209/html.*

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 L-7.1** and **L-7.2** for typical Vegetated Swale configurations.

Advantages

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

Limitations

- Irrigation is typically required to maintain vegetation.
- 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 measure must be provided at the end of the swale and possibly at points along the swale to allow the discharge of 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.

- Irrigation is typically required to maintain viability of the Vegetated Swale vegetation. Coordinate design of general landscape irrigation system with that of Vegetated Swale, as applicable.
- 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 L-7.1**. Note that the sizing of the Vegetated Swale is volume-based.

Table L-7.1. Vegetated Swale and Vegetated Street Swale Design Criteria

Design Parameter	Design Criteria	Notes
Design volume	WQV	Based on 12-hour drawdown. See **Section 7.4** for calculation of WQV.
Side slopes	3:1	H:V, Maximum
Flat bottom width	2 ft 4 ft	Minimum Minimum (Street Swale)
Top width	5 ft 7 ft	Minimum Minimum (Street Swale)
Longitudinal slope	6%	Maximum
Setbacks	5 ft 10 ft	From centerline of swale to property lines From building foundations (unless lined with impermeable fabric or approved by City
Check Dams Length Width Height Spacing interval	12 in. Width of swale 3 to 6 in. 12 to 20 ft	Use 12 ft for Street Swale
Water storage depth above bottom	6 in. 12 in.	Minimum 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

Design Parameter	Design Criteria	Notes
Perforated PVC pipe diameter	6 in.	
Vegetation	No./100 ft2	Trees, shrubs, grasses, and groundcover. Quantity based on surface area of swale facility. See Design Procedure for minimum quantities.

Design Procedure

Step 1 – Calculate Water Quality Volume (WQV)

Using the procedures presented in **Section 7.4**, determine the WQV 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 L-7.1** and site conditions, determine appropriate 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

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

Where

D_{pz} = ponding zone storage depth (ft);

W_{bottom} = bottom width of Vegetated Swale (ft); and

W_{top} = top width of Vegetated Swale (ft).

Step 4 – Determine Swale Length

$$L_{swale} \frac{WQV}{A_{storage}}$$

Where

WQV = water quality volume (ft3); and

$A_{storage}$ = cross-sectional area of Vegetated Swale 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.

Step 6 – Select Vegetation

Select vegetation from the list of approved plants – **Appendix L**. 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 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 the 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 the viability of Vegetated Swale landscaping.

Volume Retention

Vegetated Swales may be used to achieve the VRR in addition to treatment control requirements. The volume retention for Vegetated Swale is less if a subsurface drainpipe is provided because less infiltration will occur. The calculation procedure for volume retention for a Vegetated Swale is presented in **Table L-7.2.**

Table L-7.2. Vegetated Swale Volume Retention Calculation

Design Parameter	Design Criteria	Notes
Vegetated Swale with Subsurface Drainpipe		Required for Type C and D soils and Street Swales
1. Ponding Zone a. Depth of ponding zone (D_{PZ}) b. Surface Area of ponding zone (A_{PZ})	D_{PZ} = ________ ft A_{PZ} = ________ ft^2	Infiltration allowance for water in ponding zone water = 0.25
2. Planting Media Layer a. Depth of planting media layer (D_{PM}) b. Area of planting media layer (A_{PM})	D_{PM} = ________ ft A_{PM} = ________ ft^2	Available Water Holding Capacity of planting media layer = 0.1 x volume
3. Gravel Zone below drainpipe a. Depth of gravel below pipe (D_{GZ}) b. Area of gravel below pipe (A_{GZ})	D_{GZ} = ________ ft A_{GZ} = ________ ft^2	Porosity of gravel zone = 0.30 Minimum depth below pipe = 6 in Minimum width of gravel = 3 ft
1. Volume retention for Swale ($Vol_{Retention}$) $Vol_{Retention}$ = (D_{PZ} x A_{PZ} x 0.25) + (D_{PM} x A_{PM} x 0.1) + (D_{GZ} x A_{GX} x 0.3)	$Vol_{Retention}$ = ________ ft^3	
Vegetated Swale without Subsurface Drainpipe		Recommended for Type A and B soils
1. Ponding Zone a. Depth of ponding zone (D_{PZ}) b. Area of ponding zone (A_{PZ})	D_{PZ} = ________ ft A_{PZ} = ________ ft^2	Infiltration allowance for water in ponding zone water = 1.0
2. Planting Media Layer a. Depth of planting media layer (D_{PM}) b. Area of planting media layer (A_{PM})	D_{PM} = ________ ft A_{PM} = ________ ft^2	Minimum depth = 18 inches
3. Volume retention ($Vol_{Retention}$) $Vol_{Retention}$ = (D_{PZ} x A_{PZ}) + (D_{PM} x A_{PM} x 0.10)	$Vol_{Retention}$= ________ 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 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 requires the execution of a maintenance agreement with the property owner prior to the 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 L-7.3**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City 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.

Table L-7.3. 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 the landscape area	As required
Use Integrated Pest Management 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

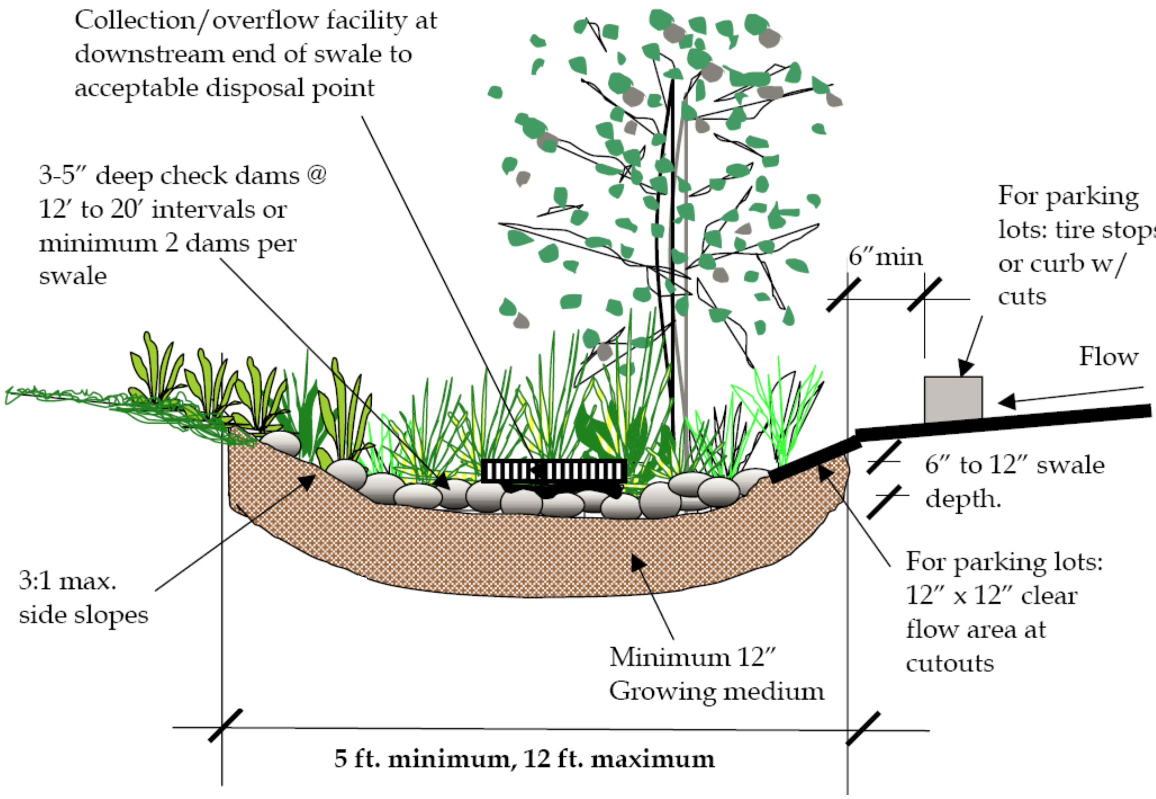


Figure L-7.1. Vegetated Swale. *Source: Vegetated Swale Specifications. City of Sandy, Oregon. (2021, October 23). Retrieved October 7, 2021, from https://www.ci.sandy.or.us/publicworks/page/vegetated-swale-specifications.*

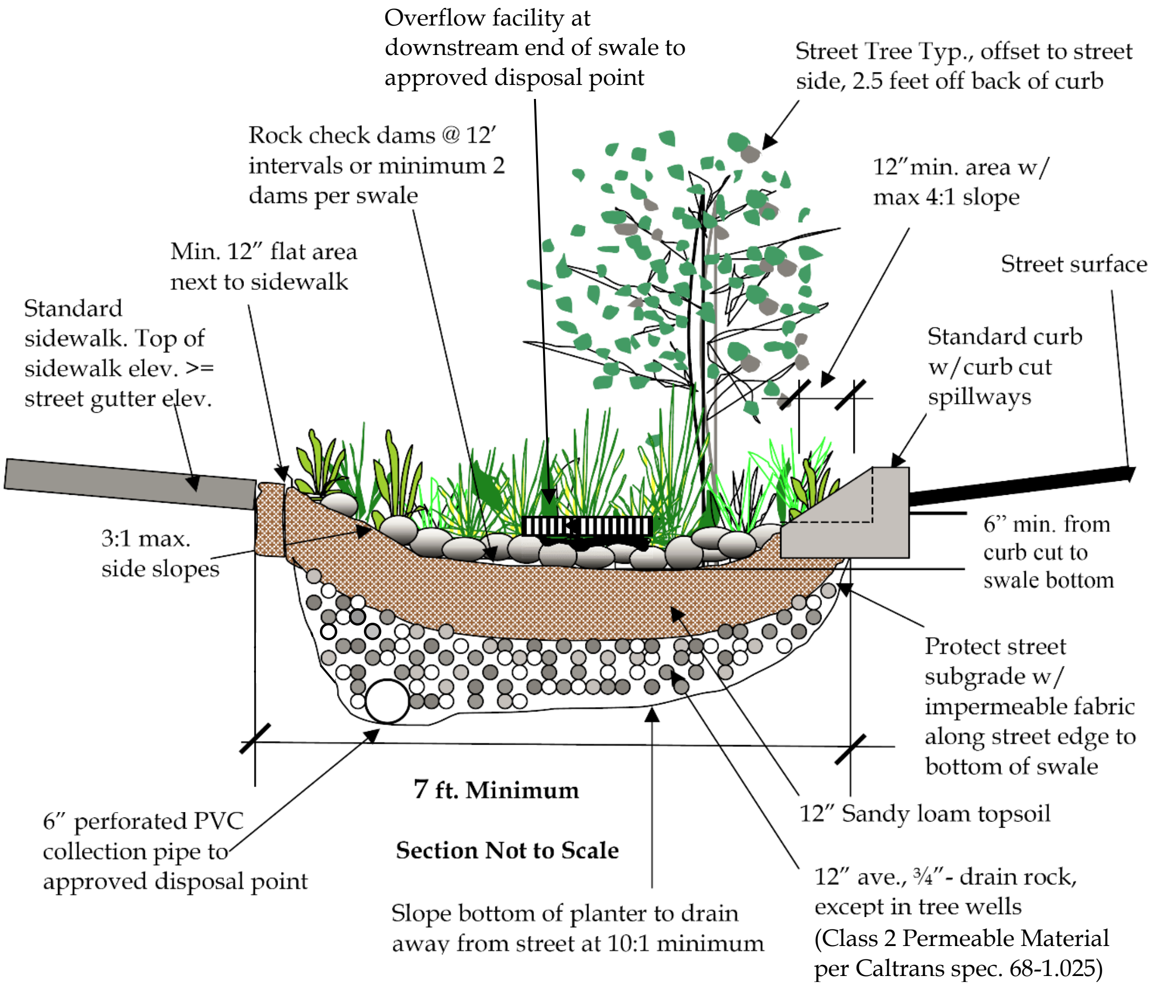


Figure L-7.2. ***Vegetated Street Swale with Underdrain.*** *Source: Vegetated Swale Specifications. City of Sandy, Oregon. (2021, October 23). Retrieved October 7, 2021, from https://www.ci.sandy.or.us/publicworks/page/vegetated-swale-specifications.*

Description

Grassy Swale. *Source: Ekka, S., & Hunt, B. (n.d.). Swale terminology for urban stormwater treatment: NC state extension publications. Swale Terminology for Urban Stormwater Treatment, NC State Extension Publications. Retrieved October 7, 2021, from https://content.ces.ncsu.edu/swale-terminology-for-urban-stormwater-treatment.*

A Grassy Swale is a shallow, open channel planted with dense, sod-forming vegetation and designed to accept stormwater 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, chemical, and biological 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 L-8.1** for a typical Grassy Swale configuration.

Other Names: Vegetated Swale, Bioswale

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.

> 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 retention practice. The latter provides only limited pollutant removal because of higher application rates, and it requires downstream treatment controls.

Limitations

- 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 a location where site topography allows for the design of a channel with a 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, and processing/manufacturing areas).
- Surface flow into the swale is preferred over underground conveyance.
- Irrigation is typically required to maintain the viability of the swale vegetation. Coordinate the design of the 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

The design criteria for the Grassy Swale are listed in **Table L-8.1**.

Table L-8.1. Grassy Swale Design Criteria

Design Parameter	Design 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	WQF	See **Section 7.4**
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 WQF	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 WQF	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 WQF and as a conveyance system to pass the peak hydraulic design flows if the swale is located "online".

Step 2 – Calculate Stormwater Quality Design Flow (WQF)

Using the procedures presented in **Section 7.4**, determine the contributing area and WQF.

Step 3 – Provide for peak hydraulic design flows

Using the Standard Calculations for Diversion Structure Design, calculate flows greater than WQF 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 L-8.1**) 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 = WQF

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 WQF 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 WQF.

$L = (t_c) \times (\text{flow velocity}) \times 60$

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 a 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 L-9.1** in L-9: Grassy Filter Strip for a 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 a 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 L** 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 Retention

Grassy Swales may be used to achieve the VRR in addition to treatment control requirements. The calculation procedure for volume retention for Grassy Swales is presented in **Table L-8.2**.

Table L-8.2. Grassy Swale Volume Retention Calculation

Design Parameter	Design Criteria	Notes
1. WQV for contributing area	WQV = _______________ ft^3	See **Section 7.4**
2. Volume retention 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 retention for Grassy Swale ($Vol_{Retention}$) $Vol_{Retention}$ = (WQV x V_{soils})	$Vol_{Retention}$ = ________________ ft^3	

Construction Considerations

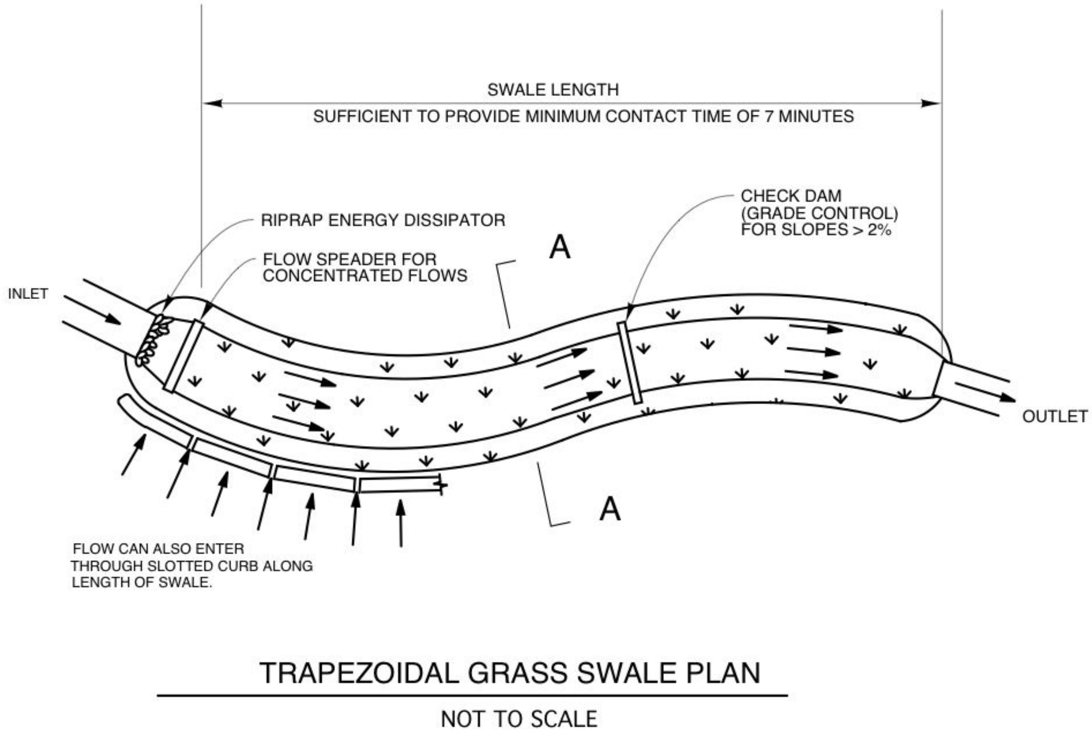
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the swale to prevent high sediment 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 requires execution of a maintenance agreement with the property owner prior to the 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 L-8.3.** The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City 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.

Table L-8.3. 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 WQF.	As required
Remove grass clippings.	As required
Use Integrated Pest Management 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.



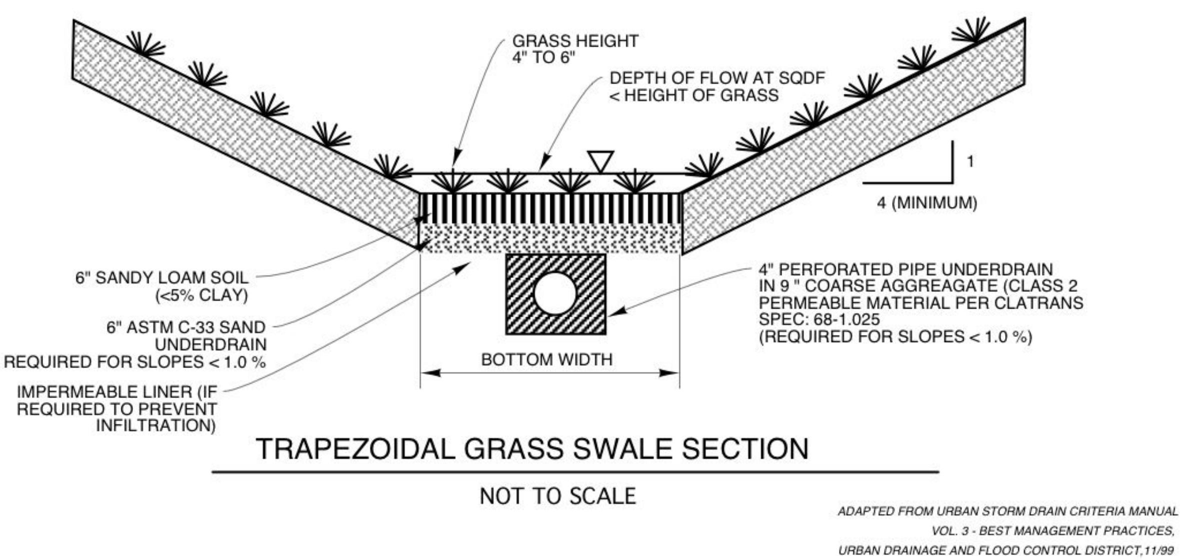


Figure L-8.1. ***Grassy Swale.*** *Source: Adapted from Urban Storm Drain Criteria Manual Vol. 3 – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Source: Filter strips/grassed riparian buffers (NRCS 393 & 390). AgBMPs. (n.d.). Retrieved October 7, 2021, from https://agbmps.osu.edu/bmp/filter-stripsgrassed-riparian-buffers-nrcs-393-390.

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 stormwater 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 L-9.1** 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 retention 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

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

Adopted by the City Council on Aug 26, 2025 by Resolution No. 2025-308

Planning and Siting Considerations

- Select a location where site topography allows for the design of filter strips with proper slopes in the 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 the viability of the filter strip vegetation. Coordinate the design of the 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 L-9.1**.

Table L-9.1. Grassy Filter Strip Design Criteria

Design Parameter	Design 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	WQF	See **Section 7.4**
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 (WQF)

Using the procedures presented in **Section 7.4**, determine the contributing area and WQF.

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 determined from the design WQF and the minimum application rate (q_a), as follows:

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

$W_{GFS} = (WQF)/0.005$ cfs/ft (minimum)

Where

WQF = water quality flow (ft3/s); and

qa = linear application rate (ft3/s/ft).

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

The 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 distribute flow evenly 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 L-9.1.**

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 a 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 L** 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 the viability of filter strip grass.

Volume Retention Calculation

Grassy Filter Strip may be used to achieve the VRR in addition to treatment control requirements. The calculation procedure for volume retention for Grassy Filter Strip is presented in **Table L-9.2**.

Table L-9.2. Grassy Filter Strip Volume Retention Calculation

Design Parameter	Criteria	Notes
1. WQV for contributing area	WQV = ____________ ft^3	See **Section 7.4**
2. Volume retention 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 retention for Grassy Filter Strip ($Vol_{Retention}$) $Vol_{Retention}$ = (WQV x VRF)	$V_{Retention}$= ____________ ft^3	

Construction Considerations

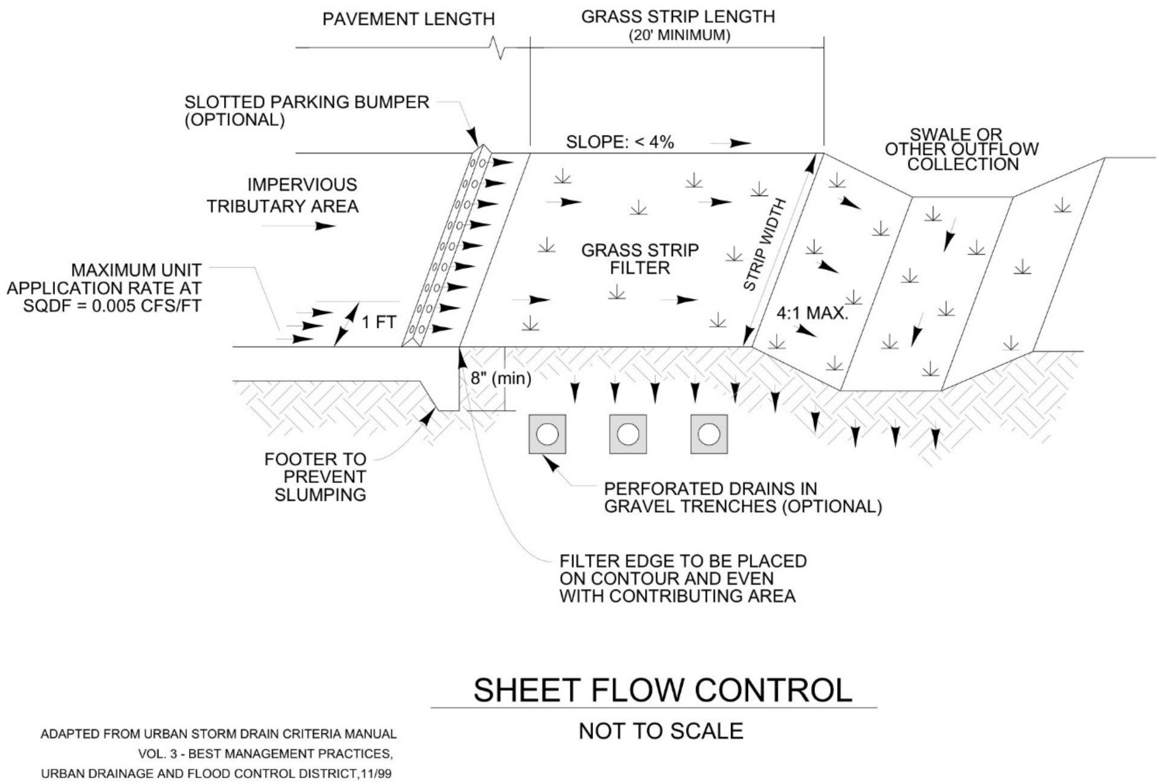
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the filter strip to prevent high 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 may require execution of a maintenance agreement with the property owner prior to the 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 L-9.3**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City 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.

Table L-9.3. 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 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.



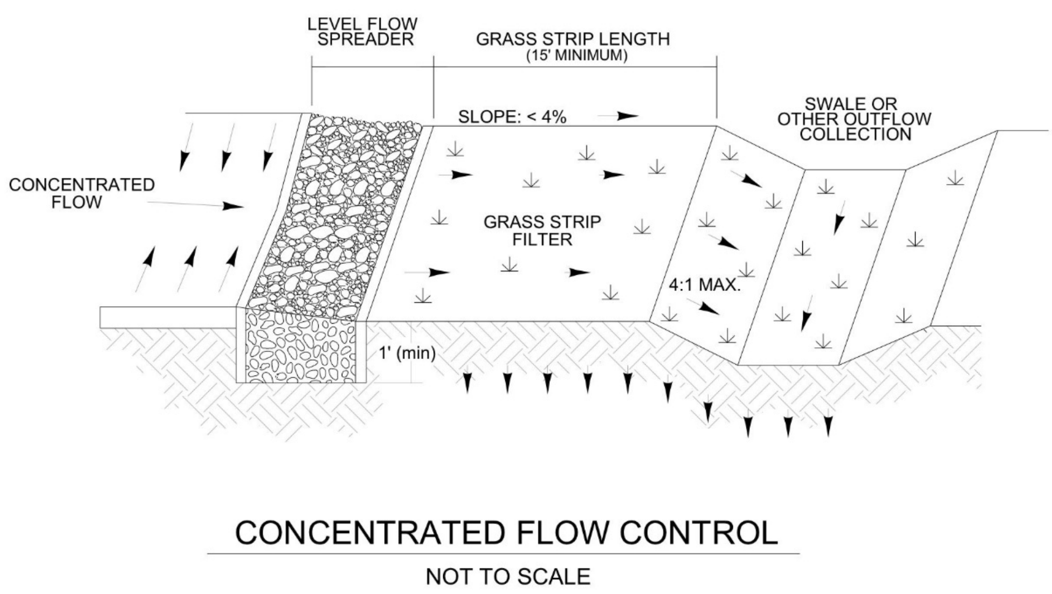


Figure L-9.1. Grassy Filter Strip. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Photo Credit - Laura Roll

Description

[Note: Infiltration wells cannot be used in City maintained areas]

An Infiltration Well, which is classified as Class V underground injection wells by USEPA, is typically a vertical bore, which contains a perforated vertical pipe, filled with gravel. Stormwater runoff is typically conveyed to a covered concrete catch basin containing the Infiltration Well. An overflow pipe conveys water from the catch basin into the Infiltration Well. Water infiltrates through the gravel media and into the underlying soil over a design drawdown period. Infiltration Wells are similar to the City's rockwells, but differ in that they are designed for the purpose of stormwater runoff treatment and retention as opposed to drainage.

Stormwater runoff treatment is primarily filtration as the stormwater runoff flows through the gravel media and into the underlying soil profile. To ensure adequate treatment and protect groundwater quality, the depth of the unsaturated soil between the Infiltration Well bottom and the maximum groundwater surface level should be a minimum of ten (10) feet. A schematic of an Infiltration Well configuration is presented in **Figure L-10.1.**

Other Names

Injection Well

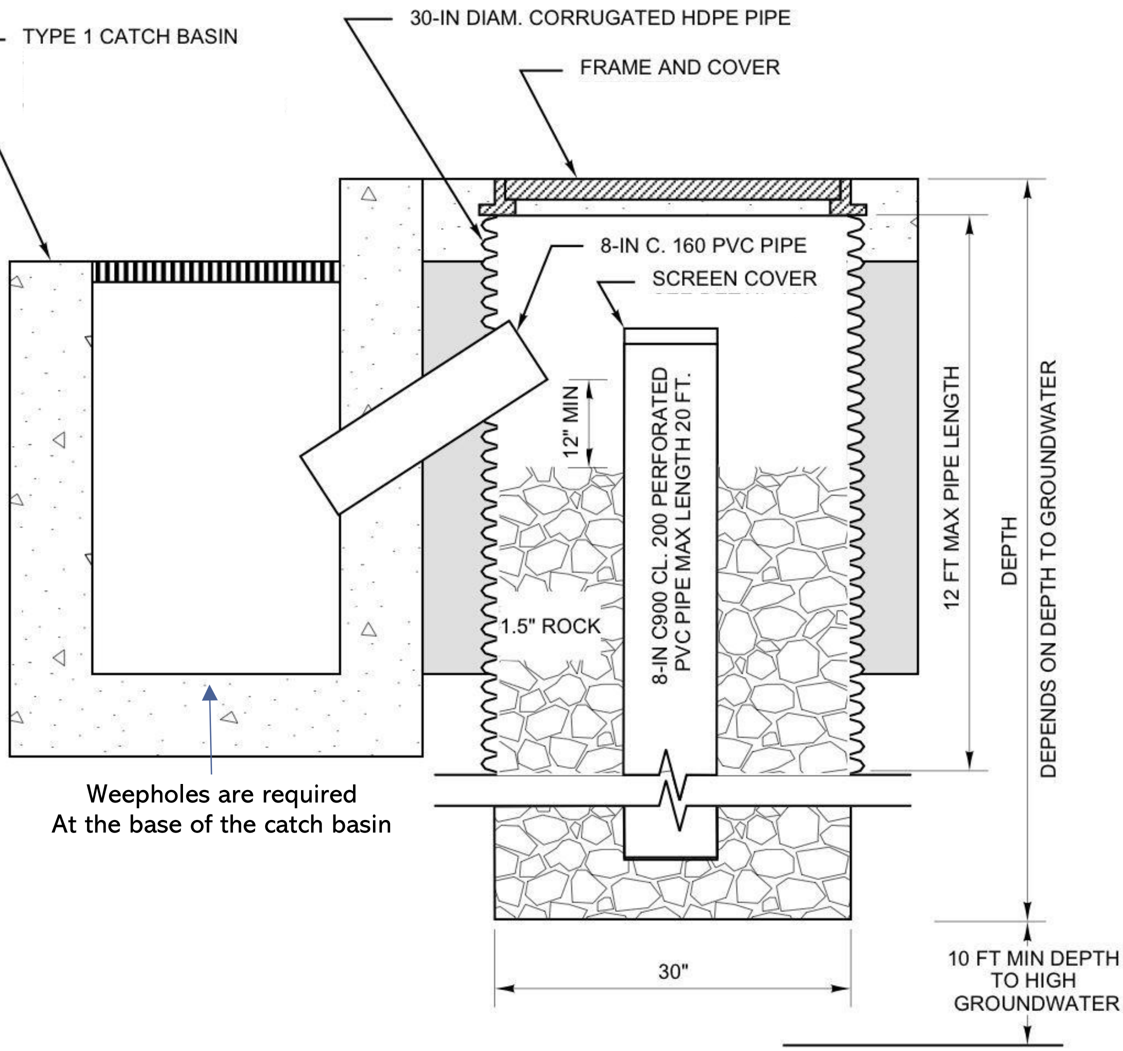
Advantages

- Provides effective treatment through filtration while requiring a small space.
- Is placed below ground.
- Reduces peak stormwater runoff flows during small storm events.
- Can be incorporated into site landscape features

Disadvantages

- Cannot be used in City maintained areas.
- Not appropriate for areas with low permeability soils (Type C or D soil) or high groundwater.
- Not appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.
- Must be protected from high sediment loads. Once clogged with sediment, restoration of infiltration capacity may be difficult.
- Not appropriate on fill or steep slopes.

Figure L-10.1. Infiltration Well Schematic (see City standard specifications)



Planning and Site Considerations

- Soil permeability, depth to groundwater, and design safety factors should be determined by a qualified geotechnical engineer or geologists to ensure that conditions conform to **Table L-10.1**.
- Pretreatment using Grassy Channels, Vegetated Buffer Strips, Vegetated Swales, Grassy Swales, and/or Vegetated Filter Strip is required to protect Infiltration Wells from high sediment loads.
- Plan for appropriate setback distances.

Design Criteria

Principal design criteria for Infiltration Wells are listed in **Table L-10.1**.

Table L-10.1. Infiltration Well Design Criteria

Design Parameter	Design Criteria	Notes
Drawdown time	48 hr (maximum)	
Water Quality Volume	80% annual capture (acre-ft)	Use Figure 6-1 at 48-hr drawdown.
Tributary drainage area	10,000 ft2 (maximum)	Per Infiltration Well
Bore diameter	36 in	
Groundwater separation	10 ft (minimum)	Between Infiltration Well bottom and historical seasonally high groundwater table
Soil permeability range	0.6-2.0 in/hr	Saturated vertical permeability
Slope	0%	
Core pipe diameter	8 in	Perforated PVC pipe with removable cap
Core pipe length	20 ft	Maximum length
Core pipe perforations (diameter)	0.5 in	Every 90° around the pipe
Core pipe perforations (number of rows)	4	
Gravel size (diameter)	1-2.5 in	
Setbacks	150 ft (minimum)	From domestic water supply wells
	20 ft (minimum)	Between all other vertical Infiltration Wells or rockwells
	20 ft	Down slope from foundation
	100 ft	Up slope from foundation

Design Procedure

Step 1 – Calculate WQV

Calculate the effective tributary drainage area and WQV based on a 48-hour drawdown period.

Step 2 – Calculate Minimum Surface Area of Infiltration Well Bottom (Amin)

$$A_{min} = \frac{WQV \times s \times 12}{t_{max} \times I}$$

Where

WQV = water quality volume (ft^3);

t_{max} = maximum drawdown time = 48 hours;

I = site infiltration rate (soil permeability, in/hr); and

s = safety factor.

In the formula above, the safety factor accounts for possible inaccuracies in the infiltration rate measurement. A larger safety factor should be used when the infiltration rate is less certain. 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 project site. Multiple Infiltration Wells may be necessary at a site to achieve the required total infiltration bottom area.

Step 3 – Design Overflow Pipe

An overflow pipe connecting the Infiltration Well to the catch basin must be installed to convey stormwater runoff from the tributary drainage area to the Infiltration Well. The overflow pipe entering the Infiltration Well should be a minimum of 12 inches above the top of the gravel layer.

Step 4 – Design Core Pipe

The core pipe should be a perforated-C900, Class 200 PVC pipe with an eight- (8-) inch diameter and 20 feet maximum length.

Step 5 – Design Gravel Layer

The washed gravel layer should be composed of 1-2.5-inch diameter stone.

Step 6 – Design Screen Cover

A screen cover is required on top of the core pipe. See the applicable City of Modesto Standard Specifications for details.

Volume Retention Calculation

Infiltration Wells may be used to achieve both the volume retention and treatment requirements. An Infiltration Well provides volume retention for the entire WQV calculated in Step 1 of the Design Procedure.

Construction Considerations

- Once construction is complete, stabilize the entire tributary area to the Infiltration Well before allowing stormwater runoff to enter the Infiltration Well.
- Store excavated material at least ten (10) feet from the Infiltration Well to avoid backsliding and cave-ins.
- Clean, washed gravel should be placed in the bore hole in lifts and lightly compacted. Use of unwashed gravel can result in clogging.
- Minimize compaction near the Infiltration Well to the maximum extent practicable during construction to prevent loss of infiltrative capacity.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as Infiltration Wells. Such agreements typically include requirements such as those outlined in **Table L-10.2**. The property owner or property owner's designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time.

Table L-10.2. Inspection and Maintenance Requirements for Infiltration Wells

Activity	Schedule
Monitor infiltration rate in Infiltration Well after storm events 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 beginning and end of wet season. Additional monitoring after periods of heavy stormwater runoff is desirable.
If drawdown period is observed to have increased significantly over the design drawdown period, clean the drop inlet, wash the top 18 inches of gravel, and clean the bore. This maintenance activity may be reduced by minimizing upstream erosion.	As required
Remove litter and debris from Infiltration Well area.	As required
Maintain pretreatment control measures in accordance to its respective "Long-Term Maintenance" section.	As required

Photo Credit: Canale Landscaping

Description

[Note: Dry wells cannot be used in City maintained areas]

A Dry Well is a bored, drilled, or driven shaft or hole whose depth is greater than its width. A Dry Well is designed specifically for alleviation of flooding and the disposal of stormwater runoff. Dry Wells design and function are similar to infiltration trenches in that they are designed to temporarily store and infiltrate stormwater runoff, primarily from rooftops and other impervious areas with low pollutant loadings. A Dry Well may either be a small excavated pit filled with aggregate or a prefabricated storage chamber or pipe segment.

Dry Wells can be used to reduce the increased volume of stormwater runoff caused by building roofs. While generally not a significant source of stormwater runoff pollution, roofs are one of the most important sources of new or increased stormwater runoff volume from land development sites. Dry Wells can be used to indirectly enhance water quality by reducing the amount of stormwater runoff volume to be treated by other downstream treatment control measures.

A Dry Well cross-section schematic is presented in **Figure L-11.1**.

Advantages

- Can be placed below ground.
- Reduces peak stormwater runoff flows during small storm events.

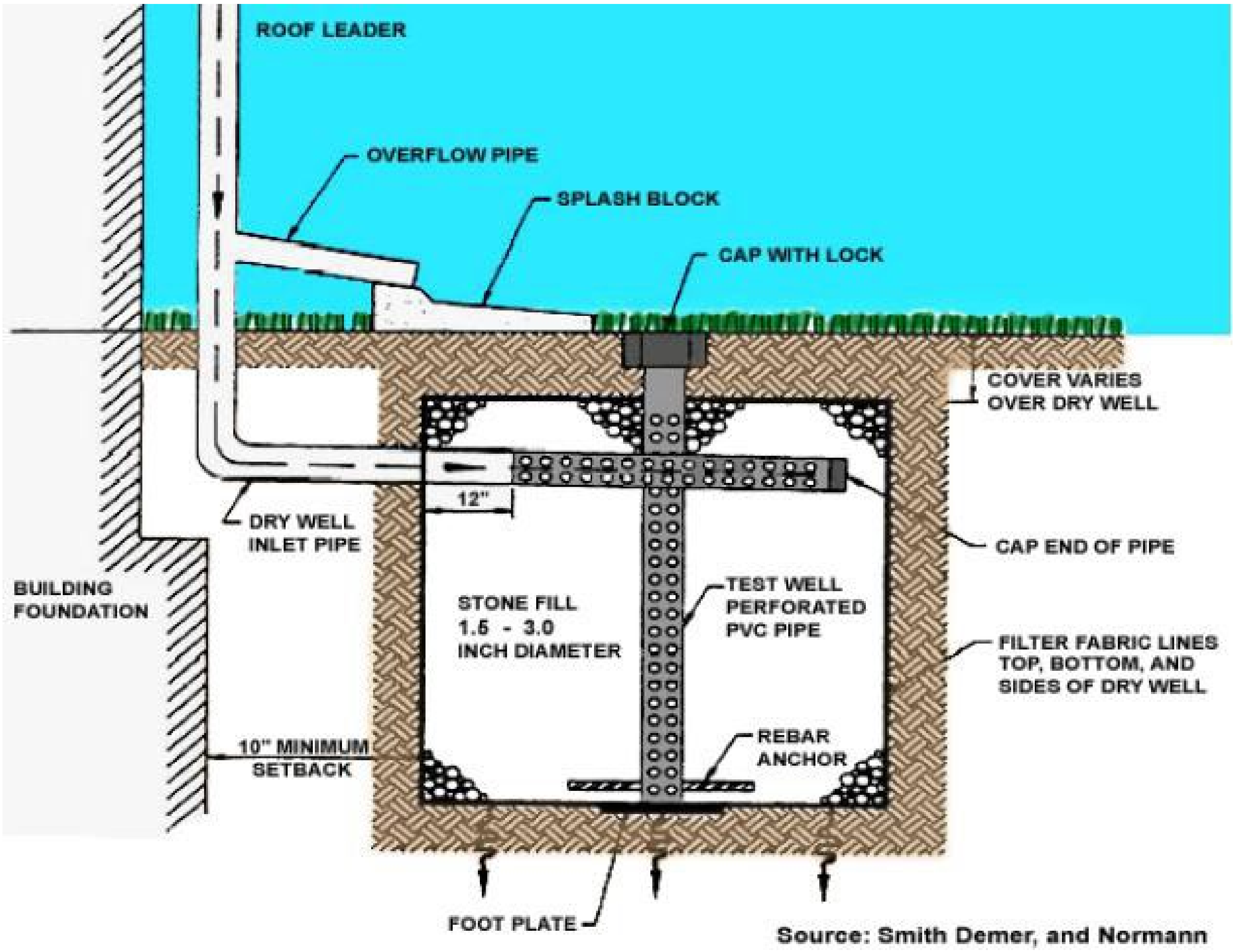
Disadvantages

- Cannot be used in City maintained areas.
- Not appropriate for areas with low permeability soils (Type C or D soils) or high groundwater.
- Cannot receive untreated stormwater runoff, except from rooftops.
- Rehabilitation of failed Dry Wells requires complete reconstruction.
- Not appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.

Planning and Site Considerations

- Integrate Dry Wells into open space buffers and other landscape areas when possible.
- Plan for appropriate setback distances presented in **Table L-11.1**.
- Pretreatment using Grassy Channels, Vegetated Buffer Strips, Vegetated Swales, Grassy Swales, and/or Vegetated Filter Strip is required to protect Dry Wells from high sediment loads.
- Install an observation well to check water levels, drawdown time, and evidence of clogging.

Figure L-11.1. Dry Well Schematic



One example is a subsurface retention/infiltration system installation under a parking lot similar to the one shown below.

Photo Credit: Contech Engineered Solutions, LLC
www.contechs.com

Design Criteria

Principal design criteria for Dry Wells are listed in **Table L-11.1**.

Table L-11.1. Dry Well Design Criteria

Design Parameter	Design Criteria	Notes
Tributary drainage area	≤ 10,000 ft2	
Design volume	WQV	
Drawdown time for WQV	12 hr (maximum)	
Soil permeability range	0.6-2.0 in/hr	Saturated vertical permeability
Groundwater separation	10 ft (minimum)	Between Dry Well bottom and historical seasonally high groundwater table
Trench surcharge depth (Dmax)	10 ft (maximum)	
Setbacks	100 ft	From wells, tanks, fields, springs
	20 ft	Down slope from foundation
	100 ft	Up slope from foundation
Filter media diameter	1.5-3 in	Gravel or prefabricated media
Observation well size	4-6 in	Perforated PVC pipe with removable cap
Pretreatment vegetated buffer strip length	10 ft (minimum)	Length in flow direction
Pretreatment vegetated buffer strip slope	5% (maximum)	Slope in flow direction

Design Procedure

Step 1 – Calculate WQV

Calculate the effective tributary drainage area and WQV based on a 12-hour drawdown period.

Step 2 – Calculate Minimum Surface Area of Dry Well Bottom (Amin)

$$A_{min} = \frac{WQV \times s \times 12}{t_{max} \times I}$$

Where

WQV = water quality volume (ft^3);

t_{max} = maximum drawdown time = 12 hours;

I = site infiltration rate (soil permeability, in/hr); and

s = safety factor

In the formula above, the safety factor accounts for possible inaccuracies in the infiltration rate measurement. A larger safety factor should be used when the infiltration rate is less certain. 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.

Step 3 – Calculate Design Depth of Water Surcharge in Dry Well (Dmax)

$$D_{max} = \frac{WQV}{P \times A_{min}}$$

Where

WQV = water quality volume (ft^3);

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

A_{min} = Minimum surface area for Dry Well bottom required (ft^2).

Note: D_{max} should not exceed ten (10) feet. If necessary, increase A_{min} 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 Dry Well on a footplate and with a locking, removable cap. The observation well is needed to monitor the infiltration rate in the Dry Well and is useful for marking the location of the Dry Well.

Step 5 – Design Diversion Structure

Provide bypass or overflow of stormwater runoff volumes in excess of the WQV by means of a screened overflow pipe connected to the downstream storm drain system or grated overflow outlet.

Volume Retention Calculation

Dry wells may be used to achieve both the volume retention and treatment requirements. A Dry Well provides volume retention for the entire WQV calculated in Step 1 of the Design Procedure.

Construction Considerations

- If possible, stabilize the entire tributary area to the Dry Well before construction begins. If this is not possible, divert flow around the Dry Well site to protect it from sediment loads during construction.
- Once construction is complete, stabilize the entire tributary area to the Dry Well before allowing stormwater runoff to enter the Dry Well.
- Store excavated material at least ten (10) feet from the Dry Well to avoid backsliding and cave-ins.
- Install geotextile fabric on sides, bottom, and one foot below the surface of the Dry Well (see Table 8-8). Provide generous overlap at all seams.
- Minimize compaction of the subgrade to the maximum extent practicable during construction to prevent loss of infiltrative capacity.
- Clean, washed gravel should be placed in the excavated Dry Well in lifts and lightly compacted with a plate compactor. Use of unwashed gravel can result in clogging.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as Dry Wells. Such agreements typically include requirements such as those outlined in **Table L-11.2**. The property owner or property owner's designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time.

Table L-11.2. Inspection and Maintenance Requirements for Dry Wells

Activity	Schedule
Monitor infiltration rate in well after storm events 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 beginning and end of wet season. Additional monitoring after periods of heavy stormwater runoff is desirable.
Clean Dry Well when loss of infiltrative capacity is observed. If infiltration rate is observed to have decreased significantly over the design rate, remove sediment and/or gravel from the Dry Well, and replace with washed gravel if necessary. Clogging is most likely occurring at the top Dry Well. This maintenance activity is expensive, and the need for it can be minimized through prevention of upstream erosion.	As required
Remove litter and debris from Dry Well area.	As required
Inspect Dry Well to identify potential problems such as standing water, trash, and debris, and sediment accumulation.	At beginning and end of wet season. Additional inspections after periods of heavy stormwater runoff are desirable.
Maintain pretreatment control measures in accordance to its respective “Long-Term Maintenance” section.	As required

APPENDIX F

Conventional Treatment Control Measure Fact Sheets (C1 – C6)

Description

Constructed Wetland. *Source: Constructed wetlands (NRCS 656). AgBMPs.(n.d.). Retrieved October 7, 2021, from https://agbmps.osu.edu/bmp/constructed-wetlands-nrcs-656.*

A Constructed Wetland is a single-stage treatment system consisting of a forebay and a permanent pool with aquatic plants. The function of a Constructed Wetland is similar to a Wet Pond in that influent stormwater runoff flow mixes with 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 water quality volume (WQV)). 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 C-1.1.**

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.

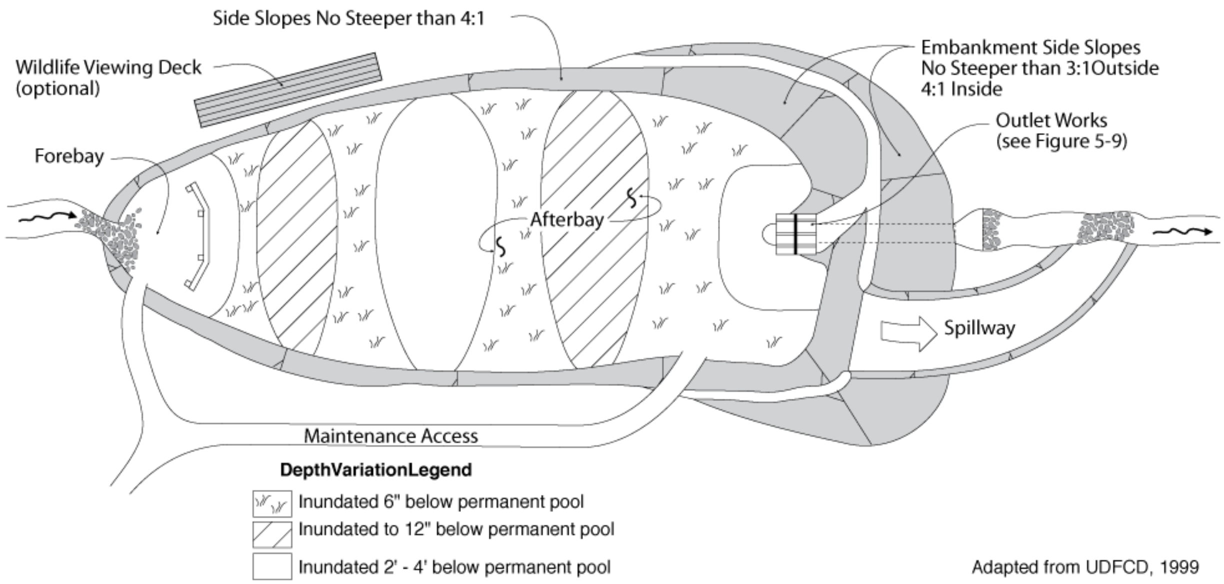
Limitations

- Constructed Wetlands must have a continuous base flow to maintain aquatic plants.
- There may be some aesthetic concerns about a facility that looks swampy.

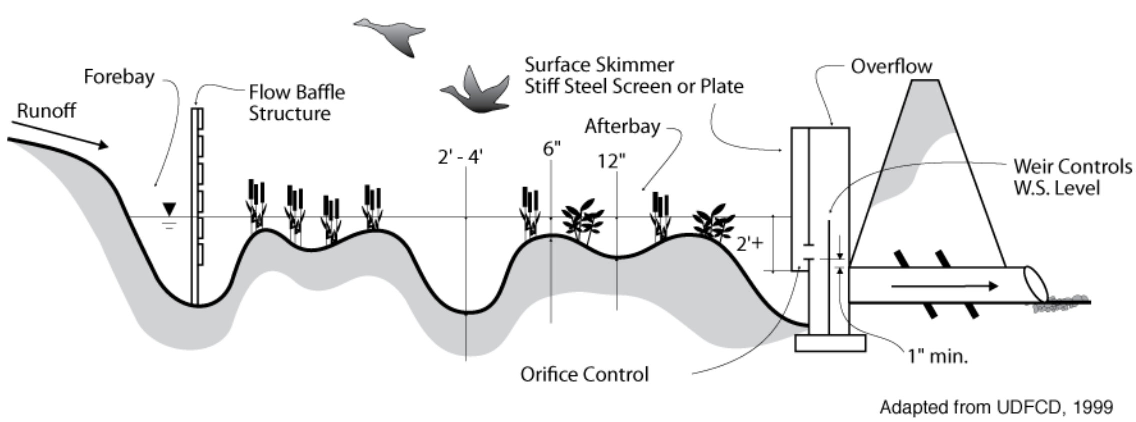
- There are public safety concerns when wetlands are constructed where there is public access.
- Mosquito and midge breeding is likely to occur in Constructed Wetlands.
- Constructed Wetlands cannot be placed on steep, unstable slopes and require a relatively large footprint.

Planning and Siting Considerations

- Appropriate land uses include large residential developments and commercial, institutional, and industrial areas where the incorporation of green space and a Constructed Wetland into the landscape is desirable and feasible.
- It can be used effectively in combination with upstream treatment controls, such as vegetated buffer strips and vegetated swales.
- Requires 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 C-1.1 Conceptual Layout of Constructed Wetland. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Design Criteria

Design criteria for Constructed Wetlands are listed in **Table C-1.1**. A Design Data Summary Sheet is provided at the end of this fact sheet.

Table C-1.1. Constructed Wetland Design Criteria

Design Parameter	Design Criteria	Notes
Design volume	WQV	See standard calculation fact sheet
Maximum drawdown time for WQV	24 hours	Based on WQV
Minimum permanent pool volume	75%	Percentage of WQV
Inlet/outlet erosion control	–	Provide energy dissipaters to reduce velocity
Forebay a. Volume b. Area c. Depth	 5-10% 5-10% 2-4 ft	Percentage of WQV Percentage of permanent pool surface area
Open-water Zone a. Area (including forebay) b. Depth	 10-40% 2-4 ft	Percentage of permanent pool surface area
Wetland Zone a. Area b. Depth	 50-70% 0.5-1 ft	Percentage of permanent pool surface area 30 to 50% should be 0.5 ft deep
Outlet Zone a. Area b. Depth	 5-10% 3 ft	Percentage of permanent pool surface area 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 ≥ 3:1	Inside 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 (WQV)

Using the *Fact Sheet T-0*, determine the tributary drainage area and WQV for 24-hour drawdown.

Step 2 – Determine Basin Minimum Volume for Permanent Pool (V_{PP})

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

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

Where

WQV = water quality volume (ft^3).

Step 3 – Determine Basin Depths and Surface Areas

Distribution of the Constructed 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)

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

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

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

Where

Vpp = volume of permanent pool (ft^3); and

Davg = average depth of permanent pool (ft).

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

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

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

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

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

Where

WQV = water quality volume (ft^3); and

App = surface area of permanent pool (ft^2).

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

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

c. Estimate maximum water surface area (A_{WQV}) with WQV based on basin shape.
d. Recalculate Final D_{WQV} based on A_{WQV} and A_{pp}. Note: V_{pp} and/or D_{avg} can be adjusted to yield Final $D_{WQV} \leq$ 2.0 feet.

$$\text{Final } D_{WQV} = WQV/((A_{WQV} + A_{pp})/2)$$

Where

WQV = water quality volume (ft^3);

AWQV = maximum water surface area (ft^2); and

App = surface area of permanent pool (ft^2).

e. Calculate maximum water surface elevation in the basin with WQV.

$$\text{WS Elev}_{WQV} = \text{WS Elev}_{pp} + \text{Final } D_{WQV}$$

Where

WS Elevpp = water surface elevation of permanent pool (ft); and

Final DWQV = final surcharge depth of WQV (ft).

Step 5 – Determine Inflow Requirement (Q_{inflow})

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-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 the sedimentation of larger particles and has a solid bottom surface to facilitate the 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 WQV. The depth of the 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 the 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 $Elev_{WQV}$. The Outlet Works are to be designed to release the WQV 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 WQV depth. A single orifice outlet control is depicted in **Figure C-1.2**.

a. For single orifice outlet control or a single row of orifices at the permanent pool elevation (WS $Elev_{pp}$) use the orifice equation based on the WQV (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 (in^2)

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

D = Depth of water above orifice centerline (D_{WQV} in ft)

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

$$A = \frac{WQV}{60.19\ x\ D^{0.5}\ x\ t}$$

Where

WQV = water quality volume (ft^3);

D = depth of water above orifice centerline (DWQV); and

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 WQV (acre-ft) and depth of water above centerline of the bottom perforation D (ft).

$$\text{Area/row (in}^2\text{)} = WQV/K_{24}$$

Where

WQV = water quality volume (acre-ft);

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

D = depth of water above orifice centerline (DWQV).

Select the 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:

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

Where

D = depth of water above orifice center line.

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

$$\text{Total Orifice Area} = A_r \times n_r$$

Where

A_r = required area per row of perforations; and

n_r = number of rows.

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

Step 11 – Design Security Fencing

Provide aesthetic security fencing around the basin to protect habitat except when specifically waived by the City. The fencing design shall be approved by the City.

Step 12 – Select Vegetation

Select vegetation from the list of approved plants – **Appendix L**. Select wetland vegetation appropriate for planting in the wetland bottom. A qualified wetland specialist should be consulted regarding the 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. The permanent pool water level should be controlled as necessary to allow the establishment of wetland plants and raised to the final operating level after plants are established.

Volume Retention Calculation

No volume retention credit is provided for a Constructed Wetland system because it does not fully retain the WQV. However, a Constructed Wetland may be used to meet treatment control requirements.

Construction Considerations

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

Maintenance Requirements

The City requires the 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 C-1.2**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix I**. The maintenance agreement and plan will provide the City designee with complete access to the Device and its immediate vicinity at any time.

Table C-1.2. Inspection and Maintenance Requirements for Constructed Wetlands

Activity	Schedule
Remove litter and debris	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 Wildlife 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

Detention Basins. *Source: Detention basin retrofitting. Detention Basin Retrofitting | City of Elgin, Illinois - Official Website. (n.d.). Retrieved October 7, 2021, from https://www.cityofelgin.org/1275/Detention-Basin-Retrofitting.*

Description

Extended Detention Basins are permanent basins formed by excavation and/or construction of embankments to temporarily detain the WQV 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 flow 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 storage capacity. The basic elements of an Extended Detention Basin are shown in **Figure C-2.1**. This configuration is most appropriate for large sites.

Advantages

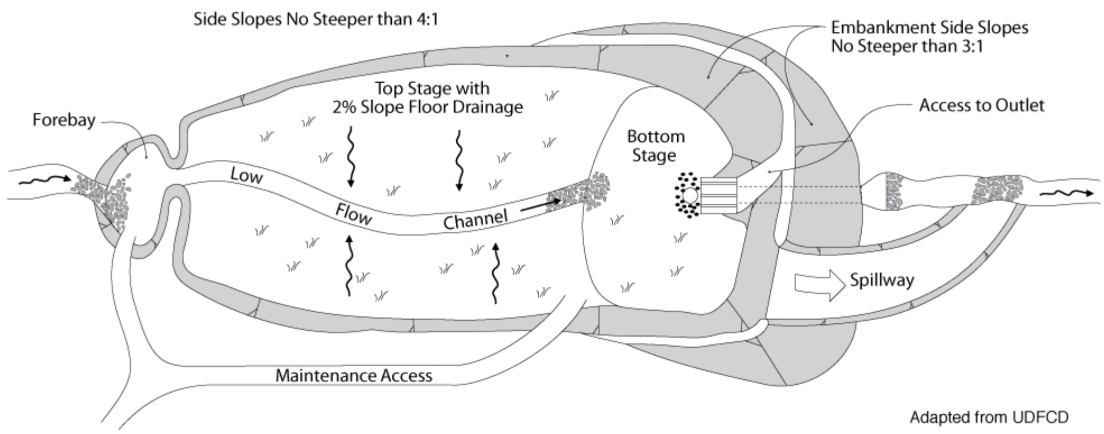
- May be designed to provide other benefits such as recreation (such as playfields), wildlife habitat, and open space. Safety issues must be addressed.
- Relatively easy and inexpensive to build and operate due to its simple design.
- Useful in retrofit situations where their low hydraulic head requirements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

Limitations

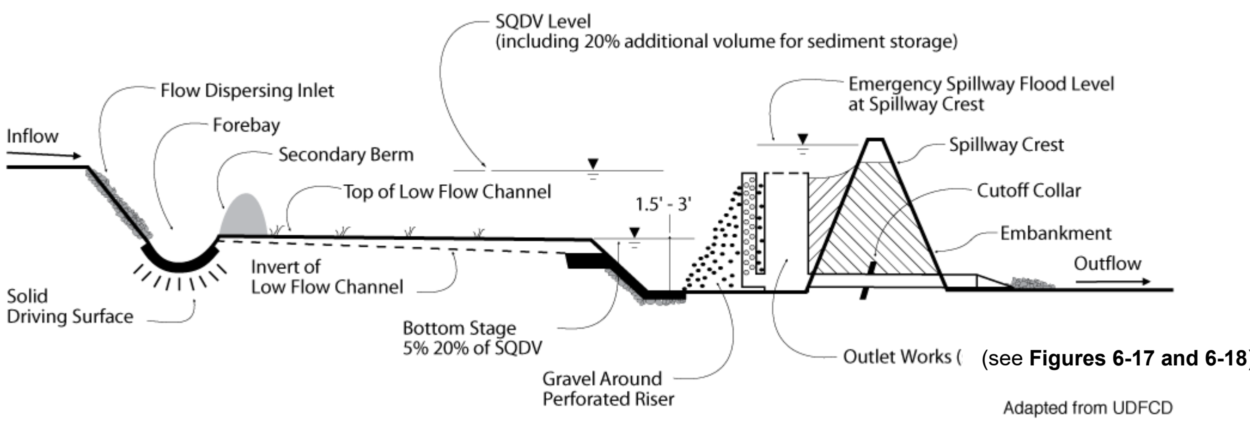
- Discharge from Extended Detention Basins may pose a risk to cold-water receiving waters because water retained in the permanent pool is typically heated over time.
- Although wet Extended Detention Basins can increase property values, dry Extended Detention Basins can adversely affect the value of nearby properties 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, Extended Detention Basins can serve as sediment trap 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 C-2.1. Extended Detention Basin Conceptual Layout. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Design Criteria

Principal design criteria for Extended Detention Basins are listed in **Table C-2.1**. Extended Detention Basins may also serve as a flood control detention basin under the City's Storm

Drainage System Engineer Design Standards. Such dual-purpose basins must also conform to design criteria for detention basins set forth in Chapter 4 of the City's Standard Specifications.

A Design Data Summary Sheet is provided at the end of this fact sheet.

Table C-2.1. Extended Detention Basin Design Criteria

Design Parameter	Design Criteria	Notes
Design volume	WQV	80% annual capture; 48-hr drawdown
Drawdown time for WQV	48 hr (minimum)	Outlet controls or pumping stations must be designed to withdraw WQV over a minimum period of 48 hours
Drawdown time for 50% WQV	12 hr (minimum)	Time before release of 50% WQV
Basin design volume	120%	Percentage of WQV. Provide 20% sediment storage volume.
Inlet/outlet erosion control	–	Provide energy dissipaters to reduce velocity
Forebay a. Volume b. Drain time	 5-10% < 45 min	 Percentage of WQV
Low-flow channel a. Depth b. Flow capacity	 9 in. 200%	 Percentage of forebay outlet release capacity
Upper stage a. Bottom slope b. Depth c. Width	 2% 2 ft 30 ft	 Minimum Minimum
Length to width ratio	2:1	Minimum (larger preferred)
Bottom stage a. Volume b. Depth	 5-20% 1.5-3 ft	 Percentage of WQV Deeper than Upper Stage
Freeboard	1 ft	Minimum
Embankment side slope (H:V)	≥ 4:1 ≥ 3:1	Inside 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 (for Trash Control see below)

Step 1 – Calculate Water Quality Volume (WQV)

Using *Fact Sheet T-0*, determine the tributary drainage area and WQV for 48-hour drawdown.

Step 2 – Determine Minimum Basin Storage Design Volume (V_{BS})

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

$V_{BS} = 1.2 \times WQV$

Where

WQV = water quality volume (ft^3).

Step 3 – Design Outlet Works

The outlet works are to be designed to release the WQV 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 WQV depth. Refer to **Figures C-2.2** and **C-2.3** 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 a single row of orifices at the basin bottom surface elevation (**Figure C-2.3**), use the orifice equation based on the WQV (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 (in^2)

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

D = Depth of water above orifice centerline (D_{WQV} in ft)

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

$$A = \frac{WQV}{60.19 \ x \ D^{0.5} \ x \ t}$$

Where

WQV = water quality volume (ft^3);

D = depth of water above orifice centerline (DWQV, ft); and

t = drawdown period (hrs) = 48 hrs

b. For perforated pipe outlets or vertical plates with multiple orifices (**Figure C-2.2),** use the following equation to determine the required area per row of perforations (A_r) based on the WQV (acre-ft) and depth of water above the centerline of the bottom perforation D (ft).

A_r (in^2) = WQV/K_{48}

Where

WQV = water quality volume (acre-ft); and

$K_{48} = 0.013D^2 + 0.22D – 0.10$

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 in the 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)

Where

D = depth of water above orifice center line (ft).

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

Total Orifice Area = A_r x n_r

Where:

A_r = required area per row of perforations; and

n_r = number of rows.

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. The trash rack shall be sized to prevent clogging of the primary water quality outlet without restricting 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 often fills 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. The 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 WQV. 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 the sedimentation of larger particles and has a solid bottom surface to facilitate the mechanical removal of accumulated sediment. The forebay has a volume comprising 5 to 10% of the WQV. Provide the 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. The 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

Select vegetation from the list of approved plants – **Appendix L**. 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 be provided with an energy dissipation structure and/or erosion protection.

Step 12 – Design Maintenance Access

Provide all-weather access for maintenance vehicles to the bottom and outlet works. The maximum grades of access ramps should be 10 percent and the 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 WQV. Spillway and overflow structures should be designed in accordance with the 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 C-2.2**.

Table C-2.2. 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 the Extended Detention Basin to protect habitat except when specifically waived by the City. Fencing design shall adhere to the City of Modesto Standard Specifications and be approved by the City.

Design Procedure – Trash Control[5]

Extended Detention Basins are also known as dry ponds, holding ponds, retarding basins, or dry detention basins. These are typically topographical depressions and may include an underground system of pipes, chambers, concrete vaults, or similar void structures designed to store water. Detention Basins incorporate filtration through media or infiltration to underlying soils. Detention Basins also include wet retention basins designed to contain water on its surface year-round.

[5] Based on the State Water Resources Control Board Categorically Certified Multi-Benefit Trash Treatment Systems – Detention Basin information sheet or any subsequent revisions.

Extended Detention Basins must be designed, constructed, and maintained in accordance with the following five (5) requirements:

1. Trap trash particles that are 5 millimeters or greater at any time during a storm event for the following:
    a. The peak flow rate generated by the region specific one-year, one-hour storm event from the applicable sub-drainage area (0.31 inches/hour); or
    b. The peak flow rate of the corresponding storm drain (if the Basin is designed to treat flows from the corresponding storm drain that is designed for less than the peak flow rate generated from a one-year, one-hour storm event).
2. Extended Detention Basins may include either or both of the following to trap particles for either flow described above in section 1.a or 1.b:
    a. A screen at the system's inlet, overflow, or bypass outlet; or
    b. An up-gradient structure designed to bypass flows exceeding the flows as described in section 1.a or 1.b[6]
3. The peak flow rates references in section 1.a shall be calculated using one of the following methods:
    a. For small drainage areas (generally less than 50 acres) - the Rational Equation Method, which is expressed as Q = CiA, where:
    Q = design flow rate (cubic feet per second),

       C = runoff coefficient (dimensionless),

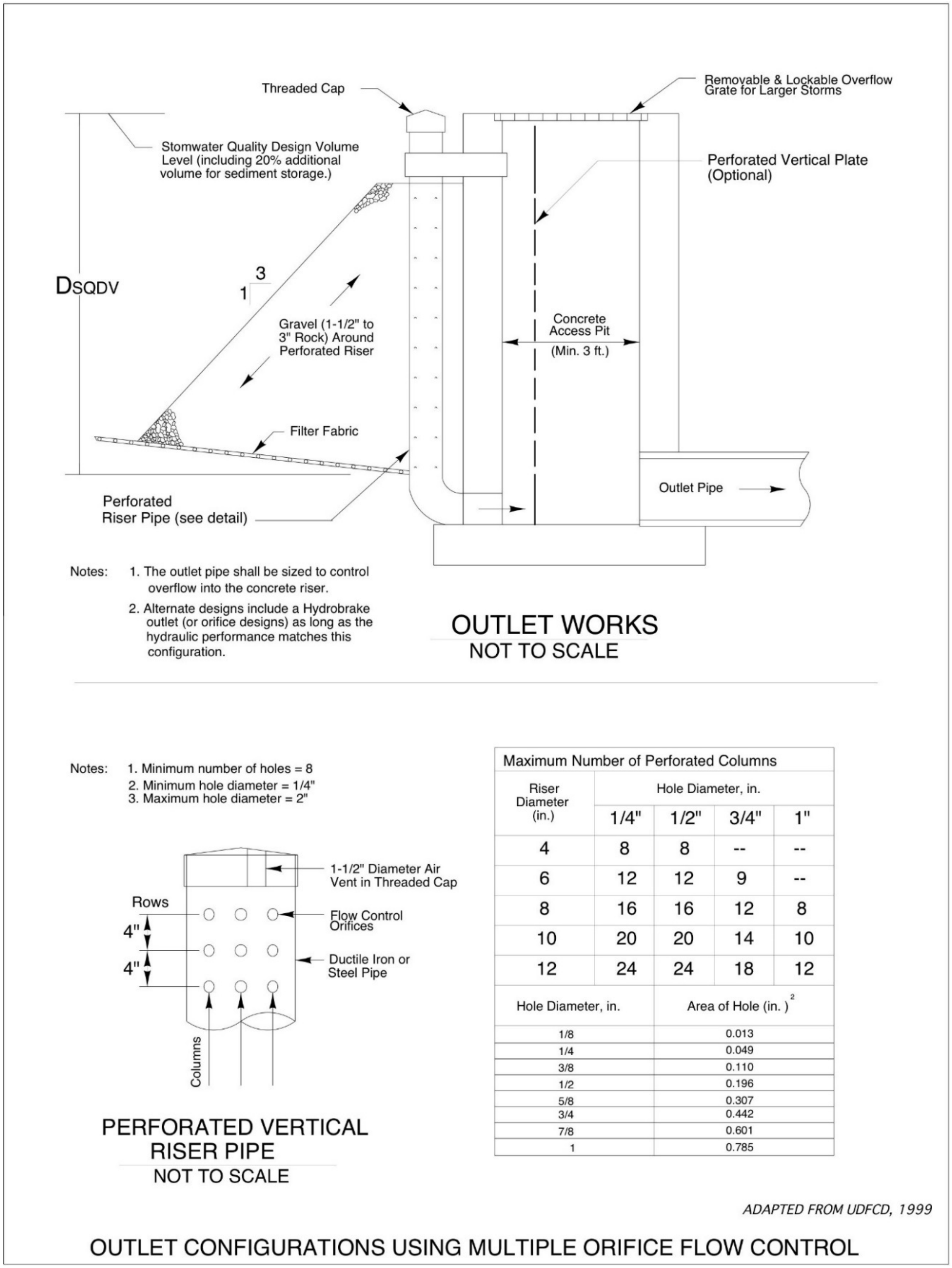
       i = design rainfall intensity (0.31 inches/hour), and

       A = subdrainage area (acres).
    b. For large drainage areas (generally 50 acres or more) – Other accepted hydrologic mathematical methods that more accurately calculate peak flow rates from large drainage areas, provided a registered California-licensed professional engineer documents the calculations within the design plans.
4. For Extended Detention Basins that incorporate groundwater recharge capacity into the sizing of the Basin for the purpose of requirements related to the peak flow rates in item 1, above, the percolation rate below the Basin must either be measured directly or estimated employing conservative hydrogeologic assumptions.
5. A registered California licensed Professional Engineer shall stamp and sign Bioretention System design plans as required by California Business & Professions Code section 6700, et seq.

[6] Upon approval by the appropriate Regional Water Quality Control Board Executive Officer, a 5 millimeter screen and/or upgradient structure may not be required if the Basin is designed for flood control from flows generated by very large storm events.

Vector breeding considerations must also be addressed due to the potential nuisance and human health effects.

Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets that are located within the boundaries of the parcel and that are operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public RoW if the City has agreed to enter into a maintenance agreement with the property owner (**Appendix I**).



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

Figure C-2.2. Perforated Pipe Outlet Structure. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

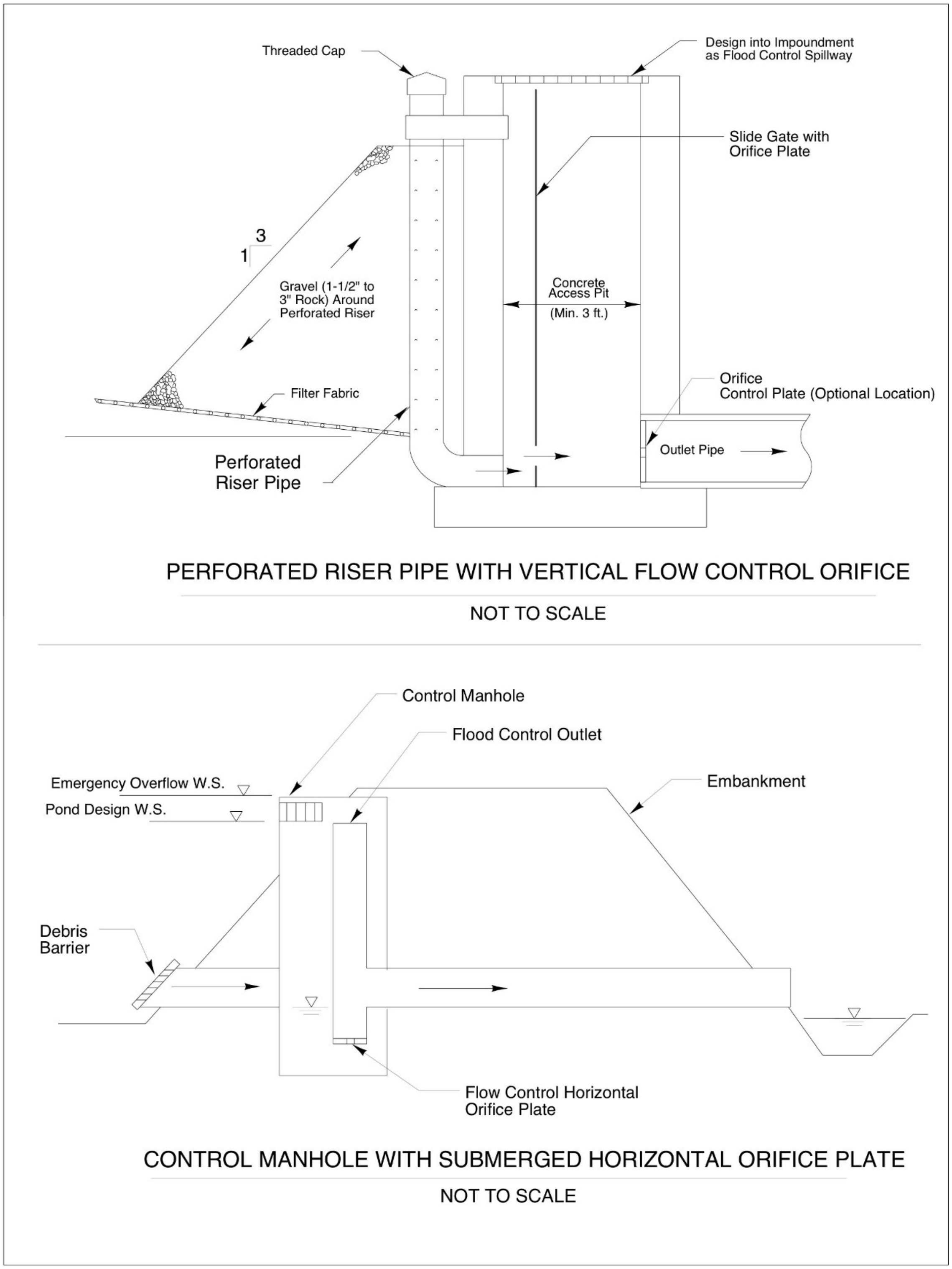


Figure C-2.3. Orifice Plate Outlet Configuration. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Volume Retention Calculation

No volume retention credit is provided for an Extended Detention Basin because it does not fully retain the WQV. However, an Extended Detention Basin may be used to meet treatment control requirements.

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 requires the execution of a maintenance agreement with the property owner prior to the 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 C-2.3**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City 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.

<u>Trash Considerations</u>

Because regular maintenance is required to maintain adequate trash capture capacity and to ensure that captured trash does not migrate offsite, the project applicant shall establish a maintenance schedule based on:

a. The maintenance frequency as required in the applicable State or Regional Water Board stormwater permit; and,

b. Site-specific factors including the design trash capture capacity of the Extended Detention Basin, local storm frequency, and characterization of trash and vegetation accumulation in the corresponding sub-drainage area.

Table C-2.3. 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 Wildlife 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

For trash control, regular maintenance is required to maintain adequate trash capture capacity and ensure that trapped trash does not migrate offsite. The owner should establish a maintenance schedule based on site-specific factors, including the size of the detention BMP, storm frequency, and estimated or measured trash loading area.

Description

Wet Pond - Charles River Watershed Association
Source: Low Impact Best Management Practice (BMP) Information Sheet. www.charlesriver.org

Wet Ponds are open earthen basins that feature a permanent pool of water that is displaced by stormwater runoff, in part or in total, during storm runoff events. Like Extended Detention Basins, Wet Ponds are designed to temporarily retain the WQV of stormwater runoff and slowly release this volume over a specified period (12 hours). Wet Ponds differ from Extended Detention Basins in that the influent stormwater runoff 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, but pollutant removal, particularly nutrients, also occur through biological activity in the pond. The basic elements of a Wet Pond are shown in **Figure C-3.1**.

Advantages

- Wet Ponds can be designed to provide other benefits such as recreation, wildlife habitat, and open space.
- Wet 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

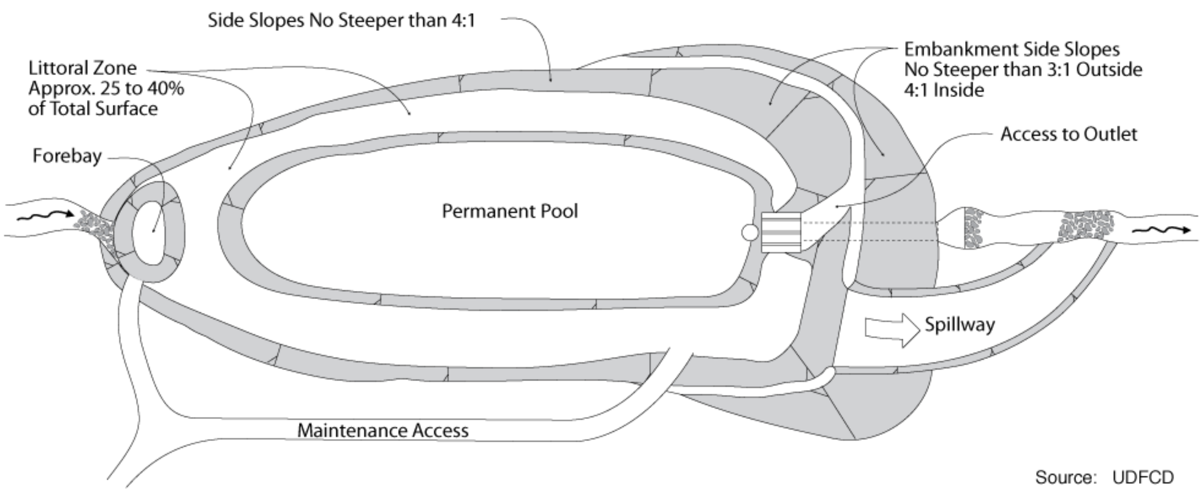
- Wet Ponds are appropriate for use in the following settings:
    - Where there is a need to achieve a reasonably high level of dissolved contaminant removal and/or sediment capture;
    - Where base flow rates or other channel flow sources are relatively consistent year-round; or
    - In residential settings where aesthetic and wildlife habitat benefits can be appreciated and maintenance activities are likely to be consistently undertaken.
- Wet Ponds are 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

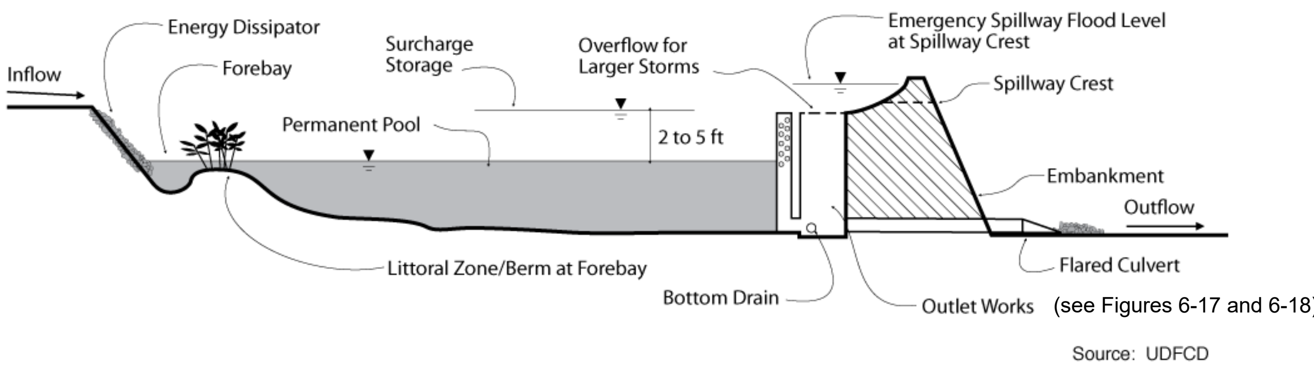
The principal design criteria for Wet Ponds are listed in **Table C-3.1**.

Table C-3.1. Wet Pond Design Criteria

Design Parameter	Design Criteria	Notes
Design volume	WQV	80% annual capture; and 12-hr drawdown
Maximum drawdown time for WQV	12 h	Based on WQV
Minimum permanent pool volume	100-150%	Percentage of WQV
Inlet/outlet erosion control	–	Provide energy dissipaters to reduce velocity
Forebay a. Volume b. Drain time c. Depth	 5-10% < 45 min 2 to 4 ft	Percentage of WQV
Littoral Zone a. Area b. Depth	 25-40% 6-18 in	Percentage of permanent pool surface area
Deeper Zone a. Area (including forebay) b. Depth c. Maximum depth	 55-65% 4-8 ft 12 ft	Percentage of permanent pool surface area Average depth
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 ≥ 3:1	Inside 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 C-3.1. Conceptual Layout of Wet Pond. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Design Procedure

Step 1 – Calculate Water Quality Design Volume (WQV)

Using the *Calculation of Stormwater Quality Design Flow and Volume Fact Sheet*, determine the tributary drainage area and WQV for 12-hour drawdown.

Step 2 – Determine Minimum Volume for Permanent Pool (V_{pp})

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

$$V_{pp} = 1.0 \text{ to } 1.5 \times WQV$$

Where

WQV = water quality volume (ft^3).

Step 3 – Determine Depth Zones

Distribution of the permanent pool area is needed to achieve the desired biodiversity. In addition to the forebay, two depth zones are required (**Figure C-3.2**). 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

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

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

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

Where

V_{pp} = minimum volume of permanent pool (ft^3); and

D_{avg} = average depth of permanent pool (ft).

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

Step 4 – Determine Inflow Requirement (Q_{inflow})

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 5 – Design Pond Forebay

The forebay provides a location for the sedimentation of larger particles and has a solid bottom surface to facilitate the mechanical removal of accumulated sediment. The forebay is part of the permanent pool and has a volume comprising 5 to 10% of the WQV. The depth of the permanent pool in the forebay should be 2 to 4 feet. Provide the 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 the dispersion of large trash articles throughout the basin.

Step 6 – Design Outlet Works

The outlet works are to be designed to release the WQV 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 WQV depth. An outlet works for a Wet Pond, is depicted in **Figure C-3.3**.

a. For single orifice outlet control or a single row of orifices at the permanent pool elevation (WS $Elev_{pp}$) use the orifice equation based on the WQV (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_{WQV})

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

$$A = \frac{WQV}{60.19 \ x \ D^{0.5} \ x \ t}$$

Where

t = drawdown period (hrs) = 12 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 WQV (acre-ft) and depth of water above centerline of the bottom perforation D (ft).

A_r (in^2) = WQV/K_{12}

Where

WQV = water quality volume (acre-ft); and

$K_{12} = 0.008D^2 + 0.056D – 0.012$

Select the 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 in center from the bottom perforation. Thus, there will be three rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

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

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

Total Orifice Area = $A_r \times n_r$

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 be provided with an energy dissipation structure and/or erosion protection.

Step 10 – Design Maintenance Access

Provide all-weather access for maintenance vehicles to the bottom and outlet works. The 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 WQV. Spillway and overflow structures should be designed in accordance with the 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 the volume lost due to sediment deposition.

Step 13 – Select Vegetation

Select vegetation from the list of approved plants – **Appendix L.** 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 the Wet Pond to protect habitat except when specifically waived by the City. Fencing design shall adhere to the City of Modesto Standard Specifications and be approved by the City.

Volume Retention Calculation

No volume retention credit is provided for a Wet Pond because it does not fully retain the WQV. However, Wet Ponds may be used to meet treatment control requirements.

Construction Considerations

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

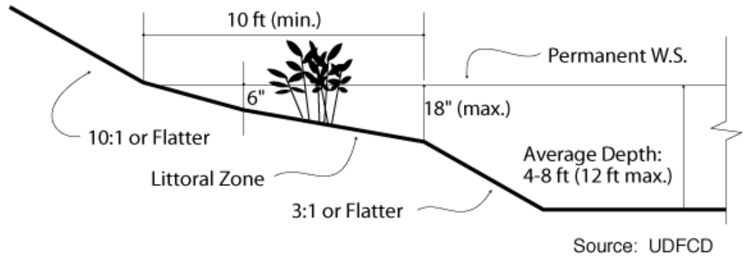


Figure C-3.2. Depth Zones for Wet Pond. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November)*

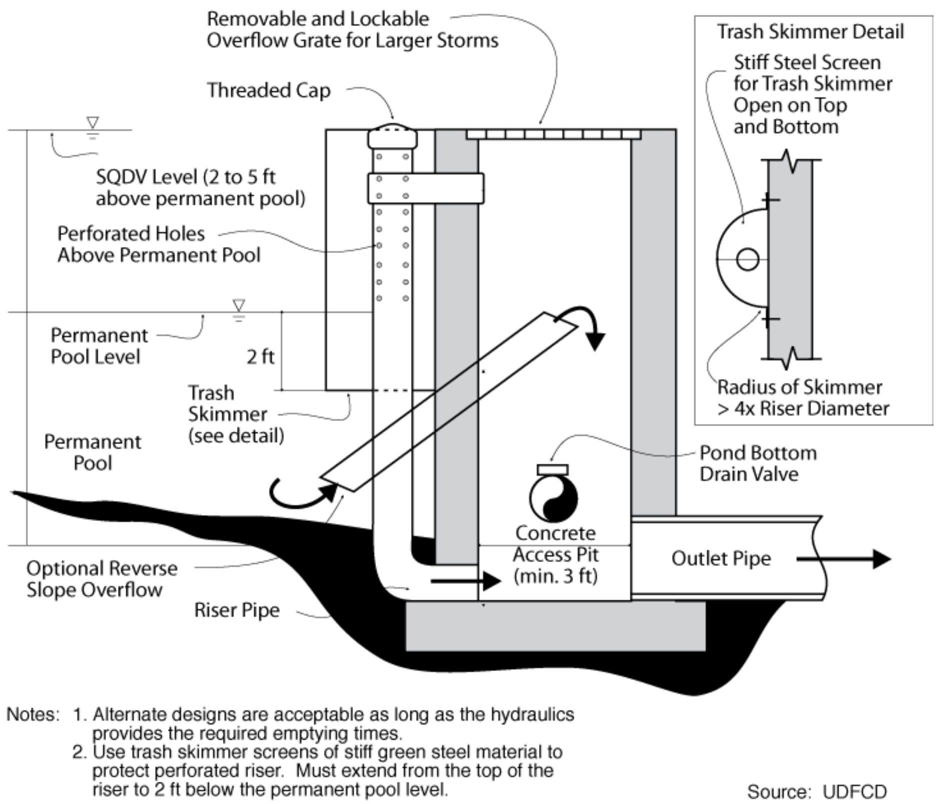


Figure C-3.3. Outlet Works for Wet Pond. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Maintenance Requirements

The City requires the execution of a maintenance agreement with the property owner prior to the 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 C-3.2**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City 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.

Table C-3.2. 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 Wildlife 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

This Development Guidance Manual provides guidance for the selection and design of some of the common on-site stormwater treatment control measures for development projects. The standard treatment control measures included in this Manual are non-proprietary (public domain) designs that have been reviewed and determined to be generally acceptable. As such, the plan check review and approval process will typically be routine for development projects that have selected one or more of these control measures.

However, the City recognizes that these non-proprietary treatment control measures may not be appropriate for all projects due to physical site constraints. The City will allow the use of Proprietary Control Devices if the following criteria are met:

- The VRR has been met through the use of VRMs (**Section 5**);
- The project applicant has demonstrated to the satisfaction of the City that the use of non-proprietary treatment controls is infeasible or impractical.

The most commonly encountered classes of proprietary stormwater quality control measures include hydrodynamic separation, catch basin insert technologies, cartridge filter-type controls, and proprietary biotreatment devices. It should be noted that vault systems should be avoided since they are typically equipped with high-flow rate media filters and are thus, less effective at pollutant removal and more challenging to maintain compared to the landscape-based LID type treatment controls. Therefore, vault systems should be considered only as a last resort, after all other viable alternatives have been thoroughly evaluated.

Proprietary Control Devices that are approved by the City for general use are listed in **Appendix N** along with the sizing criteria and criteria used for approval (Note: **Appendix N** does not include devices approved for trash control. For a list of certified and/or agency-approved devices contact the City). This list will be updated periodically when additional devices are added to the approved list.

In general, any Proprietary Control Device must be designed to treat the WQV or the water quality flow (WQF)[7]. Procedures to calculate the WQV and WQF are provided in Fact Sheet T-0. Stormwater runoff in excess of the WQV or WQF 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 encourages the development of innovative Proprietary Control Devices and may consider an alternative Proprietary Control Device that is not in **Appendix N**, on a ‘pilot basis.’ In order for a pilot project to be considered, the manufacturer and property owner must commit to participating in and funding a monitoring program to verify the device’s performance. Site designers should anticipate additional review time and contact the City early in the process to request consideration of pilot installation projects. If unsuccessful, the property owner will be required to install stormwater control measures as needed to meet the standards outlined in this Manual.

[7] Use of alternative sizing criteria is allowed for certain devices as indicated in **Appendix N**.

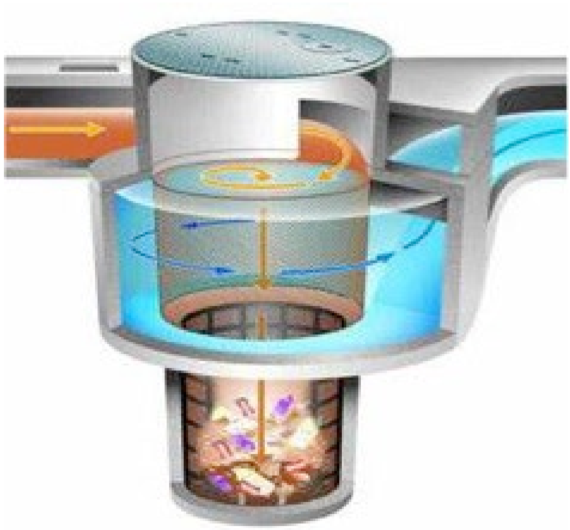


Image 6-16. Diagram of a Hydrodynamic Trash Separator. *Source: Environmental Protection Agency. (n.d.). Trash Capture Technologies. EPA. Retrieved October 7, 2021, from https://www.epa.gov/trash-free-waters/trash-capture-technologies.*

Description

A Trash Capture Device is a type of treatment control that either (a) removes pollutants and/or solids from stormwater runoff or (b) captures, infiltrates, and/or reuses stormwater runoff. A Trash Capture Device can include Full Capture Systems (FCS) or Low Impact Development (LID) controls.

For the purposes of this fact sheet and the use of these controls within the City, C-5 Trash Capture Devices must be FCS (see below) [note: multi-benefit, LID, or public domain projects are defined in Factsheets L-1, L-4, L-5, and C-2].

A Trash Capture Device that is an FCS is a treatment control, or series of treatment controls, including but not limited to, a multi-benefit project (e.g., a bioretention facility that meets volume retention and trash control requirements, see L-1) or an LID control measure that traps all particles that are 5 mm or greater, and has a design treatment capacity that is either:

a) of not less than the peak flow rate, Q, resulting from a one-year, one-hour storm in the subdrainage area, or

b) appropriately sized to and designed to carry at least the same flows as the corresponding storm drain.

Trash Capture Devices are typically proprietary-based controls that meet the design and maintenance criteria of the Statewide Trash Amendments.[4]

Only those devices that have been approved by the State Water Resources Control Board may be implemented to meet the Statewide Trash Amendment requirements and within the City. For a current list of certified and/or agency-approved devices, contact the City (depending on the location of the project).

Advantages

- Prevents trash from being transported into and through the storm drain system (for trash particles >5 mm) into the receiving waters.
- A wide range of proprietary devices provides options and flexibility to allow for site-specific conditions.
- Devices may be sized and custom-fit to existing stormwater infrastructure.

[4] https://www.waterboards.ca.gov/water_issues/programs/trash_control/documentation.html

- Some devices may be selected or configured to provide additional benefits, such as metal sorption or sediment capture.

Limitations

- Existing storm drain infrastructure may limit the types, size, and/or treatment capacity of some Trash Capture Devices.
- Optimal device performance requires routine maintenance consistent with the manufacturer's specifications.
- Some devices have not been widely used or tested in the field, which could increase the risk for flooding or infrastructure issues.

Planning and Siting Considerations

- Land area and size of the upstream catchment area draining to the Trash Capture Device.
- Dimensions and/or condition of the catch basin/vault where the device will be installed.
- The degree to which the proposed catch basin is connected to other catch basins.
- Other requirements such as permitting, construction, and utility clearance (especially for retrofits).
- Cost of construction and long-term maintenance.

Design Criteria[5]

Principal design criteria for Trash Capture Devices are defined by the manufacturer. Refer to the list of State Water Resources Control Board certified devices that can be installed and consult with the applicable manufacturer. In order for the Trash Capture Device to meet the requirements of the Statewide Trash Amendments, the device must be designed, constructed, and maintained in accordance with the following four (4) requirements:

1. Trap trash particles that are 5 millimeters or greater at any time during a storm event for the following:
    a. The peak flow rate generated by the region specific one-year, one-hour storm event from the applicable sub-drainage area (0.31 inches/hour); or
    b. The peak flow rate of the corresponding storm drain (if the Basin is designed to treat flows from the corresponding storm drain that is designed for less than the peak flow rate generated from a one-year, one-hour storm event).
2. Trash Capture Devices may include either or both of the following to trap particles for either flow described above in section 1.a or 1.b:
    a. A screen at the system’s inlet, overflow, or bypass outlet; or

[5] Based on the State Water Resources Control Board Categorically Certified Multi-Benefit Trash Treatment Systems – List of Certified Trash Full Capture Systems Available to the Public

b. An up-gradient structure designed to bypass flows exceeding the flows as described in section 1.a or 1.b[6].

3. The peak flow rates references in section 1.a shall be calculated using one of the following methods:

   a. For small drainage areas (generally less than 50 acres) - the Rational Equation Method, which is expressed as Q = CiA, where:
   Q = design flow rate (cubic feet per second),

   C = runoff coefficient (dimensionless),

   i = design rainfall intensity (0.31 inches/hour), and

   A = subdrainage area (acres).

   b. For large drainage areas (generally 50 acres or more) – Other accepted hydrologic mathematical methods that more accurately calculate peak flow rates from large drainage areas, provided a registered California-licensed professional engineer documents the calculations within the design plans.

4. A registered California licensed Professional Engineer shall stamp and sign the design plans as required by California Business & Professions Code section 6700, et seq.

Vector breeding considerations must also be addressed due to the potential nuisance and human health effects. Prior to installation of any Trash Capture Device, the local mosquito vector control district should be contacted to ensure the installation conforms to the local district's visual inspection, treatment, and vector breeding minimizing guidelines.

Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets that are located within the boundaries of the parcel and that are operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public RoW if the City has agreed to enter into a maintenance agreement with the property owner (**Appendix I**).

Design Procedure

While the design procedure for a given project may vary, a general process for the design of Trash Capture Devices has been outlined below.

Step 1 – Evaluate maps and site location.

Evaluate the site location for stormwater infrastructure connectivity (i.e., storm drain lines, inlets, outfalls, and catchments) and identify the potential locations for the installation of a Trash Capture Device.

[6] Upon approval by the appropriate Regional Water Quality Control Board Executive Officer, a 5 millimeter screen and/or upgradient structure may not be required if the Basin is designed for flood control from flows generated by very large storm events.

Step 2 – Delineate catchment drainage areas.

Conduct a GIS Desktop analysis or field visit to define the boundary of each stormwater catchment associated with a potential Trash Capture Device.

Step 3 – Identify appropriate Trash Capture Devices for catchment drainage areas.

Obtain the list of certified and/or agency-approved Trash Capture Devices from the City and identify the number and type of devices needed to treat the catchment drainage areas.

Step 4 – Conduct field evaluations/surveys to further identify site constraints and design criteria required by the manufacturer of the selected Trash Capture Device.

Using design criteria and specifications for the selected Trash Capture Devices, conduct a field evaluation to identify any potential site constraints and to obtain the design criteria specified.

Construction Considerations

- If a site is deemed to be technically infeasible for installation, the relocation of a Trash Capture Device upstream may be able to account for site-specific constraints.
- Trash Capture Devices shall be installed within the boundary of the project site location and not within the public right-of-way unless a prior agreement with the City has been reached.

Long-Term Maintenance

The City requires the execution of a maintenance agreement with the property owner prior to the final acceptance of a private development project, which includes treatment controls such as Trash Capture Devices. Such agreements will typically include requirements such as those outlined in **Table C-5.1;** however, the requirements are expected to be specific to each device and based on the manufacturer's recommendations.

The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City 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.

Table C-5.1. Example Inspection and Maintenance Requirements for Trash Capture Devices

Activity	Schedule
Cleaning devices	A minimum of once per seasonal cycle. Additional inspections after periods of heavy runoff are desirable.
Cleaning of inlet filters	A minimum of three times per seasonal cycle. Additional inspections after periods of heavy runoff are desirable.
Inspection and cleaning (applicable to all devices)	Follow manufacturers' recommendations to ensure devices operate at desired effectiveness. Make necessary repairs in a timely manner.

Media Filter
Photo Credit: Sacramento Stormwater Quality Partnership

Description

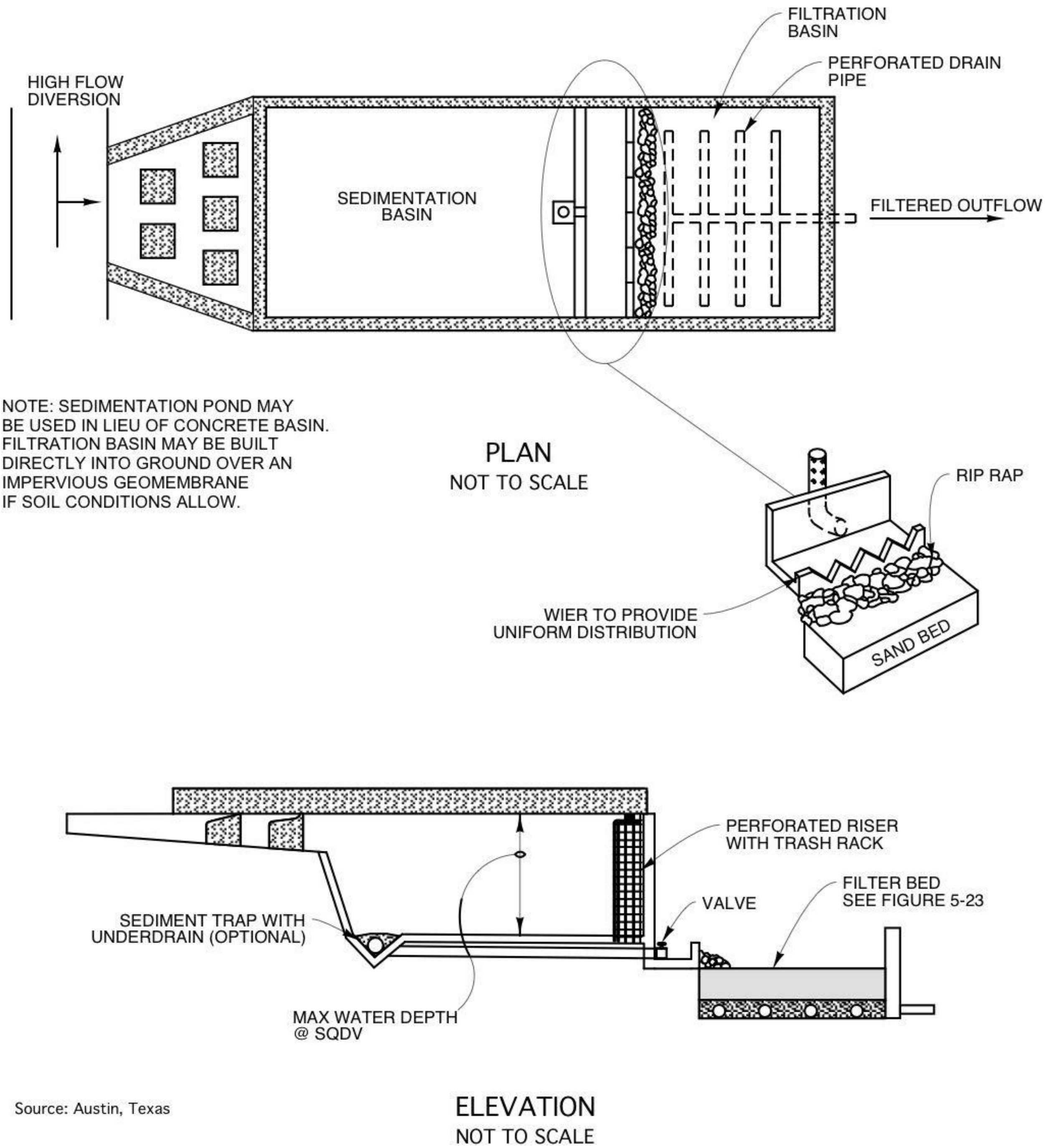
A Media Filter is a two-stage treatment system including a pretreatment settling basin and a filter bed containing sand or other absorptive filtering media. The filter bed is supported by a gravel base with an underdrain system. As stormwater runoff flows into the system, large particles settle out in the first basin and finer particles and other pollutants are removed in the filtration bed. Three variations of public domain Media Filters are presented – above-ground Austin Sand Filter, DC Underground Sand Filter, and the linear or perimeter (Delaware) Sand Filter.

A typical configuration for an Austin sand filter is presented in **Figure C-6.1**. Principal components of the unit include a sedimentation basin and a filter bed. The sedimentation basin is designed to hold the entire WQV and to release that volume to the filter bed over the design drawdown time of 48 hours. Large sediment is removed through settling in the sedimentation basin. Fine particles and other pollutants are removed in the filtration basin as stormwater runoff passes through the filter media. Stormwater runoff volumes in excess of the WQV are bypassed around the unit.

A typical District of Columbia (DC) Underground Sand Filter, which was developed by the DC Environmental Regulation Administration, is presented in **Figure C-6.2**. The DC Underground Sand Filter is in a structural shell with three chambers. The shell may consist of precast or cast-in-place concrete. The plunge pool in the first chamber and the throat of the chamber, which are hydraulically connected by an underwater rectangular opening, absorb energy, and provide pretreatment, trapping grit and floating organic material such as oil, grease, and leaves. The second chamber contains a typical sand filter with a subsurface drainage system consisting of a perforated PVC pipe in a stone bed. The third chamber, or clearwell, collects the flow from the underdrain pipes, and overflow pipes when installed, and directs treated stormwater runoff to the storm drain system.

A typical Delaware sand filter is presented in **Figure C-6.3**. The system consists of two parallel concrete trenches, sedimentation, and filter, divided by a close-spaced wall. Stormwater runoff enters the sedimentation trench and causes the sedimentation pool to rise and overflow into the filter trench through weir notches at the top of the dividing wall. The weirs allow stormwater runoff to enter the filter bed as sheet flow to prevent scouring the sand. The permanent pool in the sedimentation trench is dead storage, which inhibits resuspension of particles deposited from earlier storm events and prevents heavier sediment from being washed into the filtration trench. Floatable materials can reach the filter media through the surface overflow. Stormwater runoff entering the filtration trench is treated with media filtration and removed from the filtration unit through an underdrain pipe where it can be discharged to the storm drain system. Stormwater runoff volumes larger in excess of the WQV are bypassed around the filtration unit.

Figure C-6.1. Austin Sand Filter Schematic



Source: Austin, Texas

Figure C-6.2. DC Underground Sand Filter Schematic

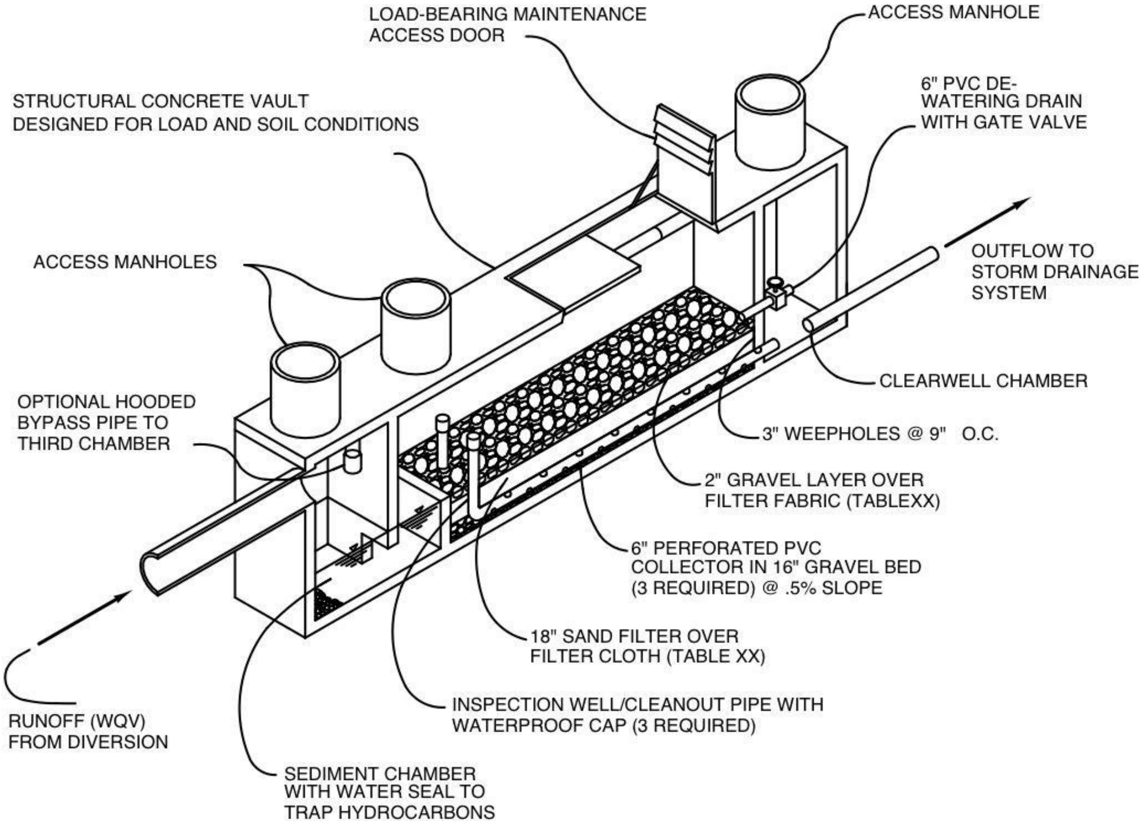
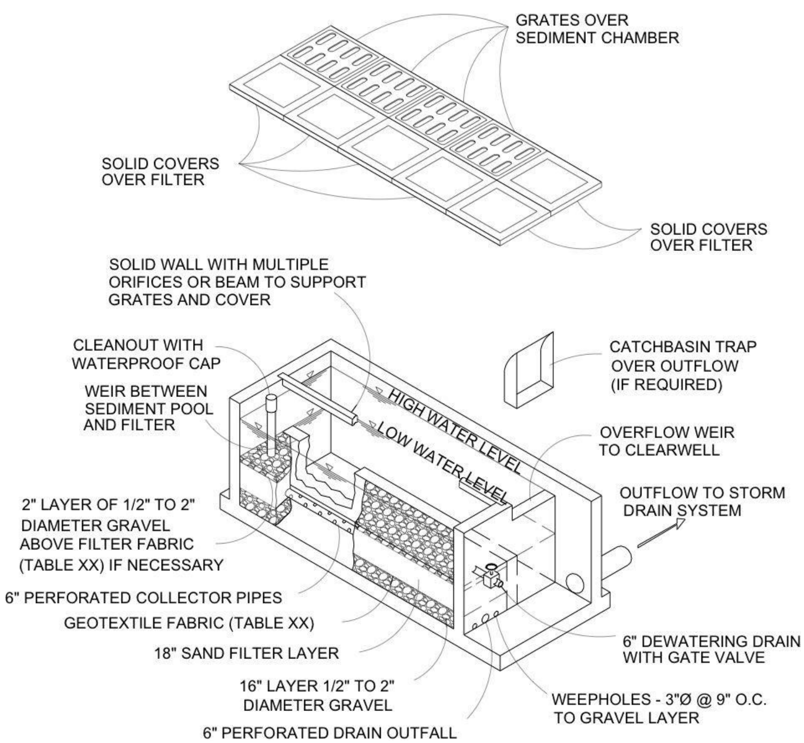


Figure C-6.3. Delaware Sand Filter Schematic



Advantages

- Provides effective treatment 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 site conditions. The presence of permeable soils is not a requirement.
- Reduces peak stormwater runoff flows during small storm events.

Disadvantages

- Potential for clogging of media. Pretreatment or upstream treatment control measures to remove large sediment may be required to minimize or prevent media clogging.
- Significant head loss through treatment units may limit use on flat surfaces.
- May be more expensive to construct than many other types of treatment control measures.

Planning and Site Considerations

- Media sand filters are generally suited for sites where there is no base flow, and the sediment load is relatively low.
- Media sand filters are well suited for drier areas and/or urban areas because they do not require vegetation and require less surface space than many other treatment control measures.
- Selection of a media sand filter type depends on the size of the drainage area and the facility location. For large watersheds (i.e., up to 50 acres), an Austin Sand Filter is recommended. For small catchments requiring underground facilities (i.e., up to 1.5 acres), a DC Underground Sand Filter is recommended. Delaware Sand Filters are especially suitable for paved sites and industrial sites (up to 5 acres) because they can be situated to accept sheet flow from adjacent pavement.
- Because the filter media is imported sand or engineered adsorptive material, Media Filters are suited for most soil conditions, and the presence of permeable soils is not a requirement.
- Approximately four (4) feet of hydraulic head is required to achieve design flow through the Austin and DC Underground Sand Filters. Delaware Sand Filters can operate with as little as two (2) feet of hydraulic head.
- For underground Media Filters, the load-carrying capacity of the filter structure must be considered if it is located under parking lots, driveways, roadways, and certain sidewalks.
- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the Media Filter is properly designed, constructed, and operated to maintain its infiltration capacity.

Design Criteria

Principal design criteria for Austin Sand Filters are presented in **Table C-6.1.**

Principal design criteria for DC Underground Sand Filters are presented in **Table C-6.2**.

Principal design criteria for Delaware Sand Filters are presented in **Table C-6.3**.

Table C-6.1. Austin Sand Filter Design Criteria

Design Parameter	Design Criteria	Notes
Sedimentation Basin		
Tributary drainage area	≤ 50 acres	
Design volume	WQV	
Sedimentation basin drawdown time	40 hr (maximum)	Based on WQV
Basin water depth	3-10 ft	
Length to width ratio	2:1 (minimum)	
Freeboard	1 ft	Above maximum water surface elevation
Inlet velocity	3 ft/sec (maximum)	Provide inlet energy dissipater as required to limit inlet velocity
Filtration Basin		
Storage volume above filter bed	20% (minimum)	Based on WQV
Storage depth above filter bed	3 ft (minimum)	
Gravel depth over sand filter	2 in (minimum)	
Sand depth in filter bed	18 in (minimum)	
Permeability coefficient for sand filter	3.5 ft/day	
Sand filter surface slope	3.5 ft/day	
Sand filter surface slope	0%	
Grave cover over underdrain	2 in (minimum)	
Sand size (diameter)	0.02-0.04 in	
Underdrain gravel size (diameter)	0.5-2 in	
Inside diameter of underdrain	6 in (minimum)	
Underdrain pipe type	PVC	Schedule 40 or heavier
Underdrain slope	1% (minimum)	
Underdrain perforation diameter	3/8 in (minimum)	
Perforations per row	6 (minimum)	
Space between perforation rows	6 in (minimum)	
Gravel bed depth	16 in (minimum)	

Table C-6.2. DC Underground Sand Filter Design Criteria

Design Parameter	Design Criteria	Notes
Tributary drainage area	≤ 1.5 acres	
Design volume	WQV	
Drawdown time	48 hr (maximum)	Based on WQV
Gravel depth over filter media	2 in (minimum)	
Sand filter depth	18 in (minimum)	
Depth of cover gravel over underdrain pipe	2 in (minimum)	
Filter coefficient	2 ft/day	
Volume of WQV in sediment chamber	20% (minimum)	
Underdrain slope	1% (minimum)	
Diameter of upper level gravel cover	1 in (maximum)	
Clearwell length	3 ft (minimum)	
Filter sand sizing	–	ASTM C 33 concrete sand
Gravel diameter size in underdrain	0.5-2 in (minimum)	
Underdrain pipe size	6 in (minimum)	Schedule 40 reinforced PVC pipe
Perforation diameter in drainage pipe	3/8 in (minimum)	
Spacing between perforations	6 in (maximum)	
Spacing between underdrain pipes	27 in (maximum)	Center to center

Table C-6.3. Delaware Sand Filter Design Criteria

Design Parameter	Design Criteria	Notes
Tributary drainage area	≤ 5 acres	
Design volume	WQV	
Drawdown time	48 hr	Based on WQV
Weir height between sedimentation chamber and sand filter	2 in	
Gravel depth over sand	2 in (minimum)	
Sand depth	18 in (minimum)	
Gravel underdrain depth	16 in (minimum	
Filter coefficient	2 ft/day	
Top layer/underdrain gravel size, diameter	0.5-2 in	
Sand size	-	ASTM C33 concrete sand
Top layer slope	0%	
Underdrain or bottom of filter slope	0.5% (minimum)	
Underdrain pipe size, diameter	6 in (minimum)	PVC Schedule 40
Perforation size, diameter	3/8 in (minimum)	
Number of holes per row	6 (minimum)	
Spacing between rows	6 in (minimum)	
Weephole diameter	3 in (minimum	
Spacing between weepholes	9 in (minimum)	Center to center
Sedimentation chamber and sand filter width	18-30 in	

Design Procedures

The design procedures for an Austin sand filter system are listed below:

Step 1 – Calculate WQV

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV.

Step 2 – Determine Sedimentation Basin Volume (V_{sb})

The sedimentation basin volume must be greater than or equal to the WQV.

$$V_{sb} \geq WQV$$

Where

WQV = water quality volume (ft^3)

Step 3 – Determine Sedimentation Basin Depth (d_{sb})

The allowable depth of water in the sedimentation basin (dsb) is limited by the available hydraulic head at the project site, which is based on the difference in elevation between the sedimentation basin inlet and filter bed outlet. The design sedimentation basin depth should be between three (3) and ten (10) feet. Select a design depth in the allowable range that yields the required Vsb given any footprint area constraints for the project site.

Step 4 – Determine Sedimentation Basin Area (A_{sb})

$$A_{sb} = \frac{V_{sb}}{d_{sb}}$$

Where

V_{sb} = sedimentation basin volume (ft^3); and

d_{sb} = sedimentation basin depth (ft)

Step 5 – Determine Sedimentation Basin Shape

Determine overall length (L_{sb}) and width (W_{sb}) dimensions to yield the A_{sb} for any given footprint constraints for the project site.

$$A_{sb} = L_{sb} \times W_{sb}$$

Where

L_{sb} = sedimentation basin length (ft); and

w_{sb} = sedimentation basin width (ft).

The length-to-width ratio should be a minimum of 2:1. Internal baffling may be necessary to achieve this ratio and to mitigate short-circuiting and/or dead storage problems.

If the sedimentation basin is not rectangular, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. The sedimentation basin design should maximize the distance from where the heavier sediment is deposited near the inlet to where the outlet structure is located. This configuration will improve basin performance and reduce maintenance requirements.

Step 6 – Determine Sedimentation Basin Inlet/Outlet Design

The sedimentation basin inlet and outlet points should be provided with energy dissipation structures and/or erosion protection. Energy dissipation devices may be necessary to reduce inlet velocities that exceed three (3) feet per second.

An outlet works must be provided that is designed to release the WQV to the filtration basin over a 40-hour period. See Fact Sheet C-3 Extended Detention Basin for outlet works design procedures.

Step 7 – Determine Sedimentation Basin Outlet Trash Rack Design

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 the purpose of inspection and cleaning. Trash racks shall be sized to prevent clogging of the primary water quality outlet without restricting the hydraulic capacity of the outlet control orifices.

Step 8 – Determine Sediment Trap Design (Optional)

A sediment trap is a storage area that captures and removes sediment from the basin flow regime. In doing so, the sediment trap inhibits resuspension of solids during subsequent stormwater runoff events and improves long-term removal efficiency. The trap also maintains adequate volume to hold the WQV that would otherwise be partially lost due to sediment storage. Sediment traps may reduce maintenance requirements by reducing the frequency of sediment removal. It is recommended that the sediment trap volume be equal to ten (10) percent of the sedimentation basin volume. All water collected in the sediment trap shall drain within 40 hours. The drain pipe invert should be above the filtration basin sand bed surface. The minimum piping grading to the filtration basin should be 1/4 inch per foot, or two (2) percent slope. Access for cleaning the sediment trap drain system is necessary.

Step 9 – Determine Sedimentation Basin Liner Design

If the sedimentation basin is an earthen structure, and an impermeable liner is required to protect groundwater quality, the impermeable liner shall provide a maximum permeability of 1×10^{-6} cm/sec (ASTM Method D-2434). If an impermeable liner is not required, then a geotextile fabric liner, which meets the specifications listed in **Table C-6.4**, shall be installed unless the sedimentation basin is excavated to bedrock.

Step 10 – Determine Minimum Filtration Basin Storage Volume (V_{fbs})

The filtration basin storage capacity above the filter media surface should be greater than or equal to 20 percent of the WQV. This capacity is necessary to account for backwater effects resulting from partially clogged filter media.

$$V_{fbs} \geq 0.2 \times WQV$$

Where

WQV = water quality volume (ft^3)

Step 11 – Determine Filter Bed Surface Area (A_{vbs})

Surface area is the primary design parameter for the filter bed and is a function of sand permeability, filter bed depth, hydraulic head, and filtration rate. The filter bed area should be the larger of the minimum area required for storage (A_{ff}) and the minimum area required for flow (A_{fbs}).

Determine minimum filter surface area required for storage (A_{fbs})

$$A_{fbs} = \frac{V_{fbs}}{d_{fbs}}$$

Where

V_{fbs} = Storage volume above filter bed (ft^3); and

d_{fbs} = Depth of storage above filter bed (ft), 3 ft minimum

Determine minimum filter surface area required for flow (A_{ff}).

$$A_{ff} = \frac{WQV \times d_f}{k \times (d_{fbs} + d_f) \times t_f}$$

Where

WQV = water quality volume (ft^3);

d_f = filter bed depth (ft);

k = sand filter permeability coefficient (ft/hr) = 0.146 ft/hr;

d_{fbs} = depth of storage above filter bed (ft); and

t_f = drawdown time for filter (hr) = 40 hr.

Use the larger of A_{fbs} or A_{ff} as the design value for filter bed area.

Step 12 – Design Filtration Basin Inlet Structure

The inlet structure should spread flow uniformly across the filter media surface. Flow spreaders, weirs, or multiple orifice openings are recommended.

Step 13 – Design Filter Bed

The filter (sand) bed may be either of the two configurations described below. Note that sand bed depths are final, consolidated depths. Consolidation effects must be taken into account.

<u>Configuration A –Sand Bed with Underdrain</u>

The sand layer shall be a minimum depth of 18 inches and shall consist of 0.02-0.04 inch diameter sand. Below the sand is a layer of 0.5-2 inch diameter gravel that provides a minimum of two (2) inches of cover over the top of lateral underdrain pipes.

No gravel is required under the lateral pipes. A layer of geotextile fabric meeting the specifications in **Table C-6.4** must separate the sand and gravel and must be wrapped around the lateral pipes.

Drainage matting meeting the specifications in **Table C-6.4** should be placed under the lateral pipes to provide adequate vertical and horizontal hydraulic conductivity to the later pipes.

In areas with high sediment load (total suspended solids concentrations greater than or equal to 200 mg/L0, the two- (2-) inch layer of stone on top of the sand filter should be underlain with Enkadrain 9120 filter fabric or equivalent meeting the specifications in **Table C-6.4.**

Configuration B –Sand Bed with Trench Underdrain (**Figure C-6.4**)

The top layer shall be 12-18 inches of 0.02-0.04 inch diameter sand. Lateral pipes shall be placed in trenches with a covering of 0.5-2 inch diameter gravel and geotextile fabric. The lateral pipes shall be underlain by a layer of drainage matting (**Table C-6.4**).

In areas with high sediment load (total suspended solids concentrations greater than or equal to 200 mg/L, the two- (2-) inch layer of stone on top of the sand filter should be underlain with Enkadrain 9120 filter fabric or equivalent meeting the specifications in **Table C-6.4**.

Figure C-6.4. Austin Sand Filter Bed with Underdrain

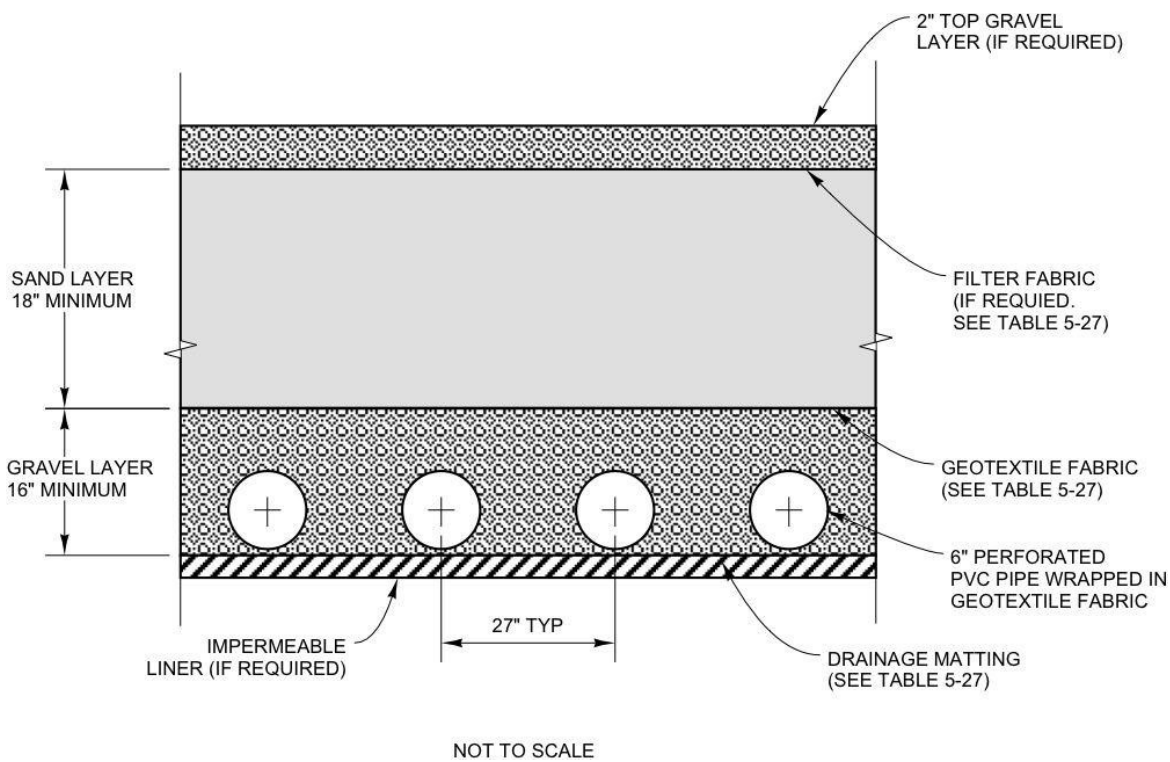
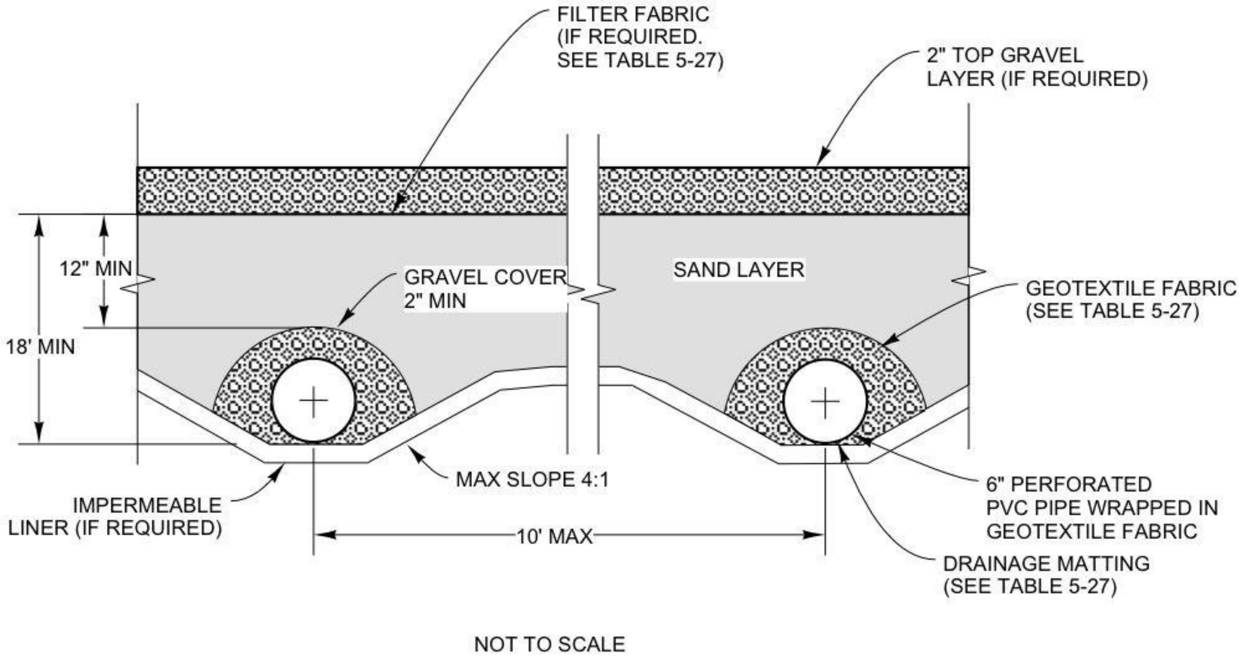


Figure C-6.5. Austin Sand Filter Bed with Trench Underdrain



Step 14 – Design Filtration Basin Underdrain Piping

Underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand the weight of the overburden. Internal diameters of lateral branch pipes should be six (6) inches or greater and perforations should be 3/8 inch. Each row of perforations should contain at least six (6) holes, and the maximum spacing between rows of perforations should not exceed six (6) inches. All piping is to be Schedule 40 PVC or greater strength. The minimum grade of piping shall be 1/8 inch per foot, or one (1) percent slope (slopes down to one-half [0.5] percent are acceptable with prior approval). Access for cleaning all underdrain piping is needed.

Note: No drawdown time is associated with the sand filter, only the sedimentation basin. Thus, it is not necessary to have a specific-design orifice for the filter bed outlet structure.

Step 15 – Design Filtration Basin Liner

If the filtration basin is an earthen structure and an impermeable liner is required to protect groundwater quality, the liner shall provide a maximum permeability of 1×10^{-6} cm/sec (ASTM Method D-2434). If an impermeable liner is not required, then a geotextile fabric liner shall be installed that meets the specifications listed in **Table C-6.5** unless the basin has been excavated to bedrock.

Table C-6.4. Geotextile Fabric Specifications for Media Filters

Parameter	Test Method	Specifications
Geotextile Fabric		
Material		Nonwoven geotextile fabric
Unit weight		8 oz/yd^3 (minimum)
Filtration rate		0.08 in/sec (minimum)
Puncture strength	ASTM D-751 (Modified)	125 lbs (minimum)
Mullen burst strength	ASTM D-751	400 lb/in^2 (minimum)
Tensile strength	AST D-1682	300 lbs (minimum)
Equiv. opening size	US Standard Sieve	No. 80 (minimum)
Drainage Matting		
Material		Non-woven geotextile fabric
Unit weight		20 oz/yd^3 (minimum)
Flow rate (fabric)		180 gpm/ft^2 (minimum)
Permeability	ASTM D-2434	12.4×10^{-2} cm/sec
Grab strength	ASTM D-1682	Dry: Lg 90/Wd 70 Wet: Lg 95/Wd 70
Puncture strength	COE CW-02215	42 lbs (minimum)
Mullen burst strength	ASTM D-1117	400 lb/in^2 (minimum)
Equiv. opening size	ASTM D-1682	No. 100 (70-120)
Flow rate (drainage **core)**	Drexel University	14 gpm/ft width
Filter Fabric		
Material		Non-woven geotextile fabric
Unit weight		4.3 oz/yd^3 (minimum)
Filtration rate		120 gpm/ft^2 (minimum)
Puncture strength	ASTM D-751 (Modified)	60 lbs (minimum)
Thickness		0.8 in (minimum)

The design procedures for a DC Underground Sand Filter system are listed below:

Step 1 – Determine Maximum Water Depth

Determine maximum allowable depth of water (2h) in the filtration basin considering elevation differences between inlet and outlet invert elevations. This height will establish weir height or elevation of inlet invert for bypass and orifices.

Step 2 – Determine Sand Filter Area (A_{fm})

Determine the minimum area of the DC Underground Sand Filter using the Austin Filter formula for partial sedimentation treatment.

$$A_{fm} = \frac{WQV \times d_f}{k \times (h + d_f) \times t_f}$$

Where

WQV = water quality volume (ft^3);

d_f = filter sand bed depth (ft);

k = sand filter permeability coefficient (ft/hr) = 0.0833 ft/hr;

h = one-half the maximum allowable water depth (2h) (ft); and

t_f = drawdown time for filter (hr) = 40 hr.

Step 3 – Determine Filter Width (w_f)/Length (L_f)

Considering site constraints, select a filter width (W_f). Calculate the filter length (L_f) using the minimum area required (A_{fm}).

$$L_f = \frac{A_{fm}}{W_f}$$

Where

A_{fm} = filter surface area based on flow (ft^2); and

W_f = filter bed width (ft).

Round the length and determine the adjusted area (A_f).

$$A_f = W_f \times L_f$$

Where

W_f = filter bed width (ft); and

L_f = filter bed length (ft).

Note: From this point forward, formulae assume a rectangular cross-section of the filter shell.

Step 4 – Determine Storage Volume

Above filter voids (V_{tf}):

$$V_{tf} = A_f \times 2h$$

Where

A_f = adjusted filter surface area (ft^2); and

h = one-half the maximum allowable water depth (2h) (ft).

In filter voids (V_V), assuming 40% voids:

$$V_v = 0.4 \times A_f \times (d_f + d_g)$$

Where

A_f = adjusted filter surface area (ft^2);
d_f = filter sand bed depth (ft); and
d_g = filter gravel bed depth (ft).

Step 5 – Determine Flow-through Filter Volume during Filling (V_Q)

$$V_Q = \frac{k \times A_f \times (d_f + d_g) \times t_f}{d_f}$$

Where

k = 2 ft/day = 0.0833 ft/hr;
A_f = adjusted filter surface area (ft^2);
d_f = filter sand bed depth (ft);
d_g = filter gravel bed depth (ft); and
t_f = 1 hr (to fill voids).

Step 6 – Determine Net Volume to be Stored in Sediment Chamber awaiting Filtration (V_{st})

$$V_{st} = WQV - V_{tf} - V_v - V_Q$$

Where

WQV = water quality volume (ft^3);
V_{tf} = storage volume above filter voids (ft^3);
V_v = storage volume in filter voids (ft^3); and
V_Q = flow-through filter volume during filling (ft^3).

Step 7 – Determine Minimum Permanent Pool Length (L_{pm})

$$L_{pm} = \frac{V_{st}}{2h \times W_f}$$

Where

V_{st} = net volume stored in sediment chamber (ft^3);

h = one-half the maximum allowable water depth (2h) (ft); and

W_f = filter bed width (ft).

See Figure C-6.6 for dimensional relationships.

Step 8 – Determine Minimum Sediment Chamber Length (L_s)

If V_{st} > 0.2 x WQV:

$$L_s = \frac{V_{st}}{2h \times W_f}$$

If V_{st} < 0.2 x WQV:

$$L_s = \frac{0.2 \times WQV}{2h \times W_f}$$

Where

V_{st} = net volume stored in sediment chamber (ft^3);

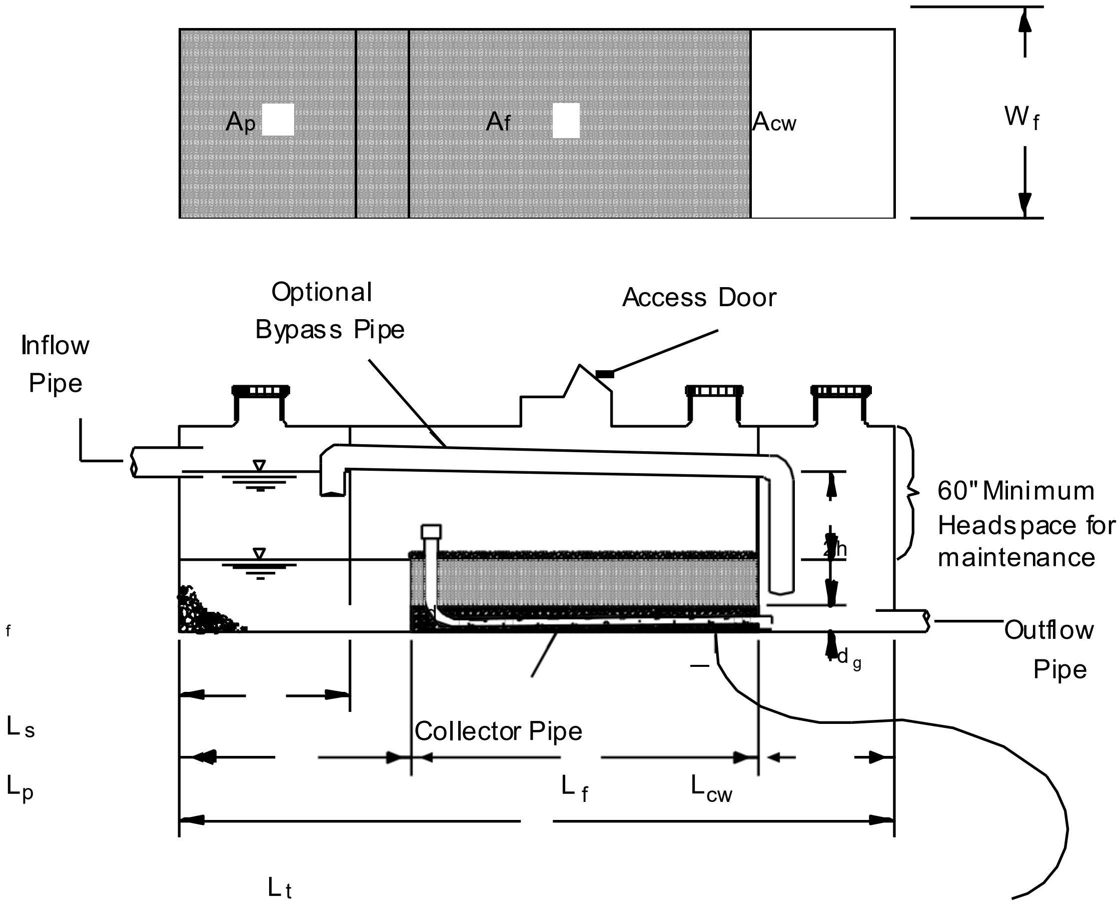
h = one-half the maximum allowable water depth (2h) (ft);

W_f = filter bed width (ft); and

WQV = water quality volume (ft^3).

Note: It may be economical to adjust final dimensions to correspond with standard precast structures or to round off results to simplify measurements during construction.

Figure C-6.6. DC Underground Sand Filter Dimensional Relationships



Underdrain @ minimum 0.5% slope

Where

- A_p = Area of sediment chamber
- A_f = Area of sand filter
- A_{cw} = Area of clearwell
- W_f = Width of filter
- L_s = Minimum length of sediment chamber
- L_p = Final length of permanent pool
- L_f = Filter length
- L_{cw} = Length of clearwell
- L_t = Total length, sum of $L_{cw} + L_p + L_f$
- $2h$ = Maximum achievable ponding depth over filter
- d_f = sand bed depth
- d_g = gravel depth

Step 9 – Determine Final Permanent Pool Length (L_p)

If $L_{pm} < (L_s + 2)$:

$$L_p = L_{pm}$$

If $L_{pm} > (L_s + 2)$:

$$L_p = L_s + 2$$

Where

L_{pm} = minimum permanent pool length (ft); and

L_s = minimum sediment chamber length (ft).

Step 10 – Determine Clearwell Length (L_{cw})

Set the clearwell length (L_{cw}) for adequate maintenance and/or access for monitoring flow rate and effluent water chemistry (minimum 3 feet).

Step 11 – Design Filter bed

Top Gravel Layer

The washed gravel at the top of the filter should be two (2) inches thick, and composed of 0.5-2-inch diameter stone. In areas with high sediment load (total suspended solids concentrations greater than or equal to 200 mg/L), the 2-inch layer of stone on top of the sand filter should be underlain with filter fabric meeting the specifications in **Table C-6.4**.

Sand Layer

The sand layer should be a minimum depth of 18 inches consisting of ASTM C33 concrete sand. A layer of geotextile fabric meeting the specifications in **Table C-6.4** must separate the sand and gravel layer below.

Gravel Layer

The gravel layer surrounding the underdrain pipes should be at least 16 inches thick, and composed of 0.5-2-inch diameter stone that provides at least a two (2) inch cover over the tops of the underdrain pipes.

Step 12 – Design Underdrain Piping

Underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand overburden weight. Internal diameters of lateral branch pipes should be six (6) inches or greater with perforations of 3/8 inch. Each row of perforations should contain at least six (6) holes, and the maximum spacing between rows of perforation should not exceed six (6) inches. All piping must be Schedule 40 PVC or greater strength. The minimum grade of piping shall be 1/8 inch per foot, or one (1) percent slope (slopes down to one-half [0.5] percent are acceptable with prior approval). Access for cleaning all underdrain pipes is needed.

Step 13 – Design Weepholes

In addition to an underdrain system, weepholes should be installed between the filter chamber and the clearwell to provide relief in case of pipe clogging. The weepholes should be three (3) inches in diameter with a minimum spacing of nine (9) inches center to center. The openings on the filter side of the dividing wall should be covered to the width of the trench with 12-inch high plastic hardware cloth of ¼-inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, No. 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded a minimum of six (6) inches back under the bottom stone.

Step 14 – Design Dewatering Drain

A six (6) inch diameter DIP or PVC dewatering drain with a gate valve must be installed at the top of the stone/sand filter bed through the partition separating the filtration chamber from the clearwell chamber.

Step 15 – Design Bypass Pipe

Where a bypass pipe is needed, it shall be DIP or PVC with supports at a minimum of every 18 inches.

The design procedures for a Delaware sand filter system are listed below:

Step 1 – Determine Maximum Water Depth

Based on site constraints, determine the maximum ponding depth over the filter (2h). If an overflow device is built into the filter shell, size the overflow weir.

Step 2 – Determine Sand Filter/Sediment Chamber Surface Area (A_{sm})

The filter shell must have the capacity to accept and store the WQV. The dimensions are sized to provide a filter area, which process the WQV in the desired drawdown time (48 hours). The areas of the sedimentation chamber and filter bed are typically set equal. The required areas are calculated as follows depending on the maximum depth of water above the filter bed:

If 2h < 2.67 ft:

$$A_{sm} = A_{fm} = \frac{WQV}{4.1h + 0.9}$$

If 2h > 2.67 ft:

$$A_{sm} = A_{fm} = \frac{WQV \times d_f}{k \times (h + d_f) \times t_f}$$

Where

A_{fm} = filter surface area based on flow (ft^2);

WQV = water quality volume (ft^3);

h = one-half the maximum allowable water depth (2h) (ft);

d_f = filter bed depth (ft);

k = sand filter permeability coefficient (ft/hr) = 0.0833 ft/hr; and

t_f = drawdown time for filter (hr) = 48 hr.

Step 3 – Determine Sediment Chamber and Filter Width

Site considerations usually dictate final dimensions of the facility. Sediment chambers and filter chambers are normally 18 to 30 inches wide. Use of standard grates requires a width of 26 inches.

Step 4 – Determine Sediment Chamber and Filter Length and Adjusted Area

$$L_s = L_f = \frac{A_{fm}}{W_f}$$

Where

L_f = filter length (ft);

A_{fm} = filter surface area based on flow (ft^2); and

W_f = filter width (ft).

Round the length upward as appropriate, and calculate the adjusted area.

$$A_s = A_f = W_f \times L_f$$

Where

A_f = adjusted filter surface area (ft^2);

L_f = filter length (ft); and

W_f = filter width (ft).

Step 5 – Determine Storage Volume in Filter Voids (V_v)

Assuming 40% voids:

$$V_v = 0.4 \times A_f \times \left(d_f + d_g\right)$$

Where

A_f = adjusted filter surface area (ft^2);

d_f = filter sand bed depth (ft); and

d_g = filter gravel bed depth (ft).

Step 6 – Determine Flow-through Filter during Filling (V_Q)

$$V_Q = \frac{k \times A_f \times (d_f + d_g) \times t_f}{d_f}$$

Where

k = 2 ft/day = 0.0833 ft/hr;

A_f = adjusted filter surface area (ft^2);

d_f = filter sand bed depth (ft);

d_g = filter gravel bed depth (ft); and

t_f = 1 hr (to fill voids).

Step 7 – Determine Net Volume to be Stored in Chambers awaiting Filtration (V_{st})

$$V_{st} = WQV - V_v - V_Q$$

Where

WQV = water quality volume (ft^3);

V_V = storage volume in filter voids (ft^3); and

V_Q = flow-through filter volume during filling (ft^3).

Step 8 – Determine Available Storage in Chambers (V_{sf})

$$V_{sf} = 2h \times (A_f + A_s)$$

Where

h = one-half the maximum allowable water depth (2h) (ft);

A_f = adjusted filter surface area (ft^2); and

A_s = adjusted sediment chamber area (ft^2).

If $V_{sf} \geq V_{st}$, proceed with design.

If $V_{sf} < V_{st}$, adjust width and/or length, and repeat Steps 3-8.

Step 9 – Design Filter bed

<u>Top Gravel Layer</u>

The washed gravel at the top of the filter should be two (2) inches thick, and composed of 0.5-2-inch diameter stone. In areas with high sediment load (total suspended solids concentrations greater than or equal to 200 mg/L), the 2-inch layer of stone on top of the sand filter should be underlain with filter fabric meeting the specifications in **Table C-6.4**.

Sand Layer

The sand layer should be a minimum depth of 18 inches consisting of ASTM C33 concrete sand. A layer of geotextile fabric meeting the specifications in **Table C-6.4** must separate the sand and gravel layer below.

Gravel Layer

The gravel layer surrounding the underdrain pipes should be at least 16 inches thick, and composed of 0.5-2-inch diameter stone that provides at least a two (2) inch cover over the tops of the underdrain pipes.

Step 10 – Design Underdrain Piping

Underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand the weight of the overburden. Internal diameters of lateral branch pipes should be six (6) inches or greater and perforations should be 3/8 inch. Each row of perforations should contain at least six (6) holes, and the maximum spacing between rows of perforations should not exceed six (6) inches. All piping is to be Schedule 40 PVC or greater strength. The minimum grade of piping shall be 1/8 inch per foot, or one (1) percent slope (slopes down to one-half [0.5] percent are acceptable with prior approval). Access for cleaning all underdrain piping is needed.

Note: No drawdown time is associated with the sand filter, only the sedimentation basin. Thus, it is not necessary to have a specific-design orifice for the filter bed outlet structure.

Shallow rectangular drain tiles may be fabricated from such materials as fiberglass structural channels, saving several inches of filter depth. Drain tiles should be in two (2) foot lengths and spaced to provide gaps 1/8-inch less than the smallest gravel size on all four sides. Sections of tile may be cast in the dividing wall between the filter and the sedimentation chamber to provide shallow outfall orifices.

Step 11 – Design Weepholes

In addition to an underdrain system, weepholes should be installed between the filter chamber and the sedimentation chamber to provide relief in case of pipe clogging. The weepholes should be three (3) inches in diameter with a minimum spacing of nine (9) inches center to center. The openings on the filter side of the dividing wall should be covered to the width of the trench with 12-inch high plastic hardware cloth of ¼-inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, No. 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded a minimum of six (6) inches back under the bottom stone.

Step 12 – Design Grates and Covers

Grates and cast steel covers are designed to take the same wheel loads as adjacent pavement. Where possible, use standard-sized grates to reduce costs. Grates and covers should be supported by a galvanized steel perimeter frame.

Step 13 – Design Hood/Traps

In applications where trapping of hydrocarbons or other floating pollutants is required, large-storm overflow weirs should be equipped with a 10-gauge aluminum hood or commercially available catch basin trap. The hood or trap should extend a minimum of one (1) foot into the sedimentation chamber.

Step 14 – Design Dewatering Drain

A six (6) inch diameter dewatering drain with gate valve is to be installed at the top of the stone/sand filter bed through the partition separating the filter chamber from the sedimentation chamber.

Volume Retention Calculation

No volume retention credit is available for Media Filters because they do not fully retain the WQV. However, Media Filters may be used to meet treatment control requirements.

Construction Considerations

- Erosion and sediment control measures must be configured to prevent any inflow of stormwater runoff into the Media Filter during its construction.
- The Media Filter must be adequately protected once constructed and not placed in service until all soil surfaces in the drainage watershed have been stabilized with vegetated cover. If stormwater runoff from the project site enters the Media Filter system prior to site revegetation, all contaminated materials must be removed and replaced with new, clean materials.
- The top of the Media Filter must be completely level. No grade is allowed.
- The inverts of the notches, multiple orifices, or weirs dividing the sedimentation chamber from the filter chamber must be completely level. Otherwise, water will not arrive at the filter as sheet flow, and only the downgradient end of the filter will function.
- Inflow grates or slotted curbs may conform to the grade of the completed pavement as long as the filters, notches, multiple orifices, and weirs connecting the sedimentation and filter chambers are completely level.
- If precast concrete lids are used, lifting rings or threaded sockets must be provided to allow easy removal with lifting equipment. Lifting equipment must be readily available to the facility operators.
- Where underdrains are used, the minimum slope of the pipe shall be one-half (0.5) percent. Where only gravel-filtered water conveyance is provided, the filter floor must be sloped towards weepholes at a minimum slope of one-half (0.5) percent.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as Media Filters. Such agreements typically include requirements such as those outlined in **Table C-6.5**. The property owner or property owner's designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in **Appendix I**.

Table C-6.5. Inspection and Maintenance Requirements for Media Filters

Activity	Schedule
Remove cover grates or precast lids on the chambers and inspect to determine if the system is functioning properly.	Quarterly during first year of operation
Inspect for standing water, sediment, trash, and debris. Identify and correct observed problems.	Semiannually after first year of operation
Inspect facility after a large storm even to determine if the facility is draining completely within its design drawdown period.	At least once during the wet season
Prevent grass and vegetative waste from washing into the filter.	As required
Remove trash and debris collected on the inlet grates to maintain the inflow capacity of the filter.	At least weekly during the wet season or before significant storm events
Remove top two (2) inches of sand and dispose of sediment if the facility drain time exceeds its design drawdown period. Restore media depth to 18 inches when overall media depth drops to 12 inches.	As required. Discoloration of the filter may be an indication of clogging
Remove accumulated sediment in the sedimentation basin.	Every ten (10) years or when sediment occupies ten (10) percent of the basin volume, whichever is less
Dispose of sand, gravel, or filter cloth contaminated with petroleum hydrocarbons in accordance with applicable laws.	As required

APPENDIX G

VOLUME RETENTION REQUIREMENT WORKSHEET

APPENDIX G. VOLUME RETENTION REQUIREMENT WORKSHEET

Note: If $VRR_{REMAIN} > 0$, the volume retention requirement is not fully met. Meeting the volume retention requirement may be an iterative process. Designers should return to prior steps to explore alternative combinations of VRWs and LID-Based Volume

Project: ______________________________

Detail: ______________________________

Design by: ______________________________

Date: ______________________________

1. Project Drainage Area Characteristics: **Pre-project** a. Weighted Runoff Coefficient (C_{rPRE}) b. Total Drainage Area (A_{PRE}) c. Pre-project Runoff Volume (Vol_{PRE})* $Vol_{PRE} = (0.50/12) \times A_{PRE} \times C_{rPRE}$	C_{rPRE} = ____________ A_{PRE} = ____________ ft^2 Vol_{PRE}= ____________ ft^3
2. Project Drainage Area Characteristics: **Post-project** a. Weighted Runoff Coefficient (C_{ra}) b. Total Drainage Area (A_{POST}) c. Post-project Runoff Volume (Vol_{POST}) $Vol_{POST} = (0.50/12) \times A_{POST} \times C_{ra}$ d. **Volume Retention Requirement*** **$VRR = Vol_{POST} - Vol_{PRE}$**	C_{ra} = ____________ A_{POST} = ____________ ft^2 Vol_{POST}= ____________ ft^3 **VRR = ____________ ft^3**
3. Volume Retention Measures: Total number of VRMs in project Total Volume Retention Credits from VRMs ($\sum Vol_{VRM}$) Total Tributary Impervious Area Reduction Credits for application to effective area calculation ($\sum Area_{credit}$) Remaining Volume retention required from LID Treatment Controls (VRR_{TREAT}) $VRR_{TREAT} = VRR - \sum Vol_{VRM}$	No. VRMs = __________ $\sum Vol_{VRM}$ = ____________ ft^3 $\sum Area_{credit}$ = __________ ft^2 **VRR_{TREAT} = ____________ ft^3**
4. Volume Retention Credits Total Volume retention Credits from LID Treatment Controls ($\sum Vol_{TREAT}$) Total Volume retention Provided ($VRR_{PROVIDED}$) $VRR_{PROVIDED} = \sum Vol_{VRM}$ (line 3b) $+ \sum Vol_{TREAT}$ (line 4a) Volume retention remaining (VRR_{REMAIN}) $VRR_{REMAIN} = VRR - VRR_{PROVIDED}$	$\sum Vol_{TREAT}$ = __________ ft^3 $VRR_{PROVIDED}$ = __________ ft^3 **VRR_{REMAIN} = __________ ft^3**

Retention Control Measures. If the meeting of the full volume retention requirement is infeasible, a Volume Retention Requirement Waiver Application must be submitted.

*Apply reductions to VRR as appropriate for Significant Redevelopment in **Section 5**

APPENDIX H

VOLUME RETENTION REQUIREMENT WAIVER APPLICATION

APPENDIX H. VOLUME RETENTION REQUIREMENT WAIVER APPLICATION

A waiver may be granted if the volume retention requirement (VRR) cannot be met due to site constraints, as described in **Section 5**.

Meeting the VRR is an iterative process. Designers should return to prior steps to explore alternative combinations of volume retention measures (VRMs) and low impact development (LID) Treatment Controls prior to submitting a waiver application request.

If the project cannot meet the full VRR, the project must still retain the volume to the maximum extent practicable and treat the full water quality volume (WQV)/water quality flow (WQF). In addition, projects that cannot fully meet the VRR must select Treatment Controls with a medium to high removal efficiency for the pollutant of concern (**Tables 3-1 and 7-2**).

The burden of proof is on the project applicant to demonstrate that it is technically infeasible to meet the VRR. Economic hardship is not an acceptable reason for noncompliance. In general, the City does not expect to grant waivers for the VRR.

The final determination will be made by City of Modesto Community and Economic Development Department. The City has the authority to reject a VRR Waiver request if VRM and/or LID Treatment Controls are considered feasible at the project site.

Consideration of a waiver request requires applicants to do the following:

- Reduce volume to the maximum extent practicable, even if the full VRR cannot be met.
- Treat the full WQV/WQF.
- Consider all of the VRM and LID Treatment Controls. Applicants must show why certain VRM and/or LID Treatment Controls are not feasible at the development site.
- Demonstrate that site conditions warrant technical infeasibility, as described in **Section 5**.
- 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 Retention Design Worksheet (**Appendix G**) along with this application.

Volume Retention Requirement Waiver Application

Property Owner/Developer Information	Plan Preparer Information
Name of Business:______________________________	Name of Business: ______________________________
Contact Person:________________________________	Contact Person:________________________________
Street: ______________________________________	Street: ______________________________________
City:_______________State:________Zip:_________	City:_______________State:________Zip:_________
Phone Number:_________________________________	Phone Number:_________________________________
Email Address:_________________________________	Email Address:_________________________________
Mailing Address: ______________________________	Mailing Address: ______________________________
City:_______________ State:_______Zip:___________	City:_______________
	State:_________Zip:____________

Project Name:____

Project Category (***check all that apply*** *– see Section 2 of the Stormwater Quality Control Criteria Plan for project definitions)*:

A) Priority Land Use Projects	☐ High Density Residential	☐ Industrial	☐ Commercial	☐ Mixed Urban	☐ Public Transportation Station
B) Priority Projects	☐ Residential Subdivision	☐ Commercial/ Industrial	☐ Automotive Repair Shops	☐ Retail Gasoline Outlets	☐ Restaurants
	☐ Parking Lots	☐ Significant Redevelopment			

Property Description ***(include location, size, land uses, etc.):***

Volume Retention Requirement _________ *(Volume Retention Worksheet, line 2e)*

Volume Retention Provided _________ *(Volume Retention Worksheet, line 4b)*

Volume Retention Remaining _________ *(Volume Retention Worksheet, line 4c)*

Types of BMPs Implemented on Project Site ***(check all that apply)***

Type and Number of LID Treatments Proposed	
☐ Bioretention (L-1)	☐ Porous Pavement Filter (L-6)
☐ Stormwater Planter (L-2)	☐ Vegetated (Dry) Swale (L-7))
☐ Tree-well Filter (L-3)	☐ Grassy Swale (L-8)
☐ Water Quality Infiltration Basin (L-4)	☐ Grassy Filter Strip (L-9)
☐ Water Quality Infiltration Trench (L-5)	

Type and Number of Volume Retention Proposed	
☐ Rain Garden (V-1)	☐ Grassy Channel (V-4)
☐ Rain Barrel/Cistern (V-2)	☐ Vegetated Buffer Strip (V-5)
☐ Interception Trees (V-3)	

Describe Why a Volume Retention Requirement Waiver is Needed
(include specifics on site conditions that warrant technical infeasibility & attach supporting documentation:

Describe Alternative Compliance Design
The portion of the volume that cannot be reliably retained on-site (Volume Retention Worksheet, line 4c) must be treated and temporarily held on-site and released into the City stormwater network once the storm event passed. Attach supporting documentation:

APPLICATION FEE PER CURRENT CITY OF MODESTO FEE STRUCTURE

CERTIFICATION

I hereby certify that the information provided in this Application is correct.

Application Prepared by:

Print Name and Firm	***Signature of Project Engineer in Above-Named Firm***
Professional Title	***Affix Professional Registration Stamp of Above-Named Person with Signature and Expiration Date***

Adopted by the City Council on Aug 26, 2025 by Resolution No. 2025-308

APPENDIX I

MAINTENANCE AGREEMENTS AND FORMS

This appendix includes the following maintenance agreements and forms:

I-1: Stormwater Treatment Device Access and Maintenance Agreement

I-2: Stormwater Quality Control Plan Owner’s Certification Statement

A template agreement is provided in this Appendix, however it is recommended that the project proponent use the most recent template agreement available on the City website https://www.modestogov.com/1263/Forms

APPENDIX I-1: STORMWATER TREATMENT DEVICE ACCESS AND MAINTENANCE AGREEMENT TEMPLATE

APPENDIX I-2: SWQCP OWNER'S CERTIFICATION STATEMENT

OWNER'S CERTIFICATION

STORMWATER 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 Modesto Development Standards for new development and redevelopment projects.

The undersigned understands that stormwater pollution control measures are enforceable requirements under the Development Standards. 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 Development Standards.

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 ___________________________________

RECORDING REQUESTED BY:
City of Modesto

PLEASE RETURN TO / MAIL TO:
City of Modesto City Clerk
P.O. Box 642
Modesto, CA 95353

SPACE ABOVE THIS LINE FOR RECORDER'S USE

ACCESS AND MAINTENANCE AGREEMENT FOR:
(CHECK ALL THAT APPLY)

❑ **VOLUME RETENTION MEASURE (V1-V5)**
❑ **TREATMENT CONTROL MEASURE (L1-L11 and C1-C6)**
❑ **TRASH FULL CAPTURE SYSTEM / MULTI-BENEFIT PROJECT**

OWNER: ____
PROPERTY ADDRESS: ______________________________________
APN: ____

THIS AGREEMENT is made and entered into in Modesto, California, this__________ day of __________, _____, by and between ________________________________, hereinafter referred to as "Owner" and the CITY OF MODESTO, a municipal corporation, located in the County of Stanislaus, State of California hereinafter referred to as "CITY";

WHEREAS, the Owner owns real property ("Property") in the City of Modesto, County of Stanislaus, State of California, more specifically described in Exhibit "A" and depicted in Exhibit "B", each of which exhibits is 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 of Modesto City Council Resolution No. ______________________________ *or* Planning Commission Resolution No. __________________________________ *or* Planning Department Certificate of Approval No.________________________ required the project to employ on-site volume retention measures to reduce or contain all storm water runoff on site and/or Treatment Control Measures and/or Trash Full Capture System/Multi-Benefit Project(s) to minimize pollutants in urban runoff.

VOLUME RETENTION MEASURE - TREATMENT CONTROL MEASURE – TRASH FULL CAPTURE SYSTEM

WHEREAS, the Owner has chosen to install a ______________________________ ____, hereinafter referred to as "Device(s), as the on-site control measure(s) to minimize pollutants in urban runoff;

WHEREAS, said Device(s) has/have been installed in accordance with plans and specifications accepted by the City;

WHEREAS, said Device(s), with installation on private property and draining only private property, is a private facility with all maintenance or 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 consistent with the Device requirements/protocols, including, but not necessarily limited to, filter material replacement and sediment removal, is required to assure peak performance of Device(s) 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. The recitals set forth above, the exhibits set forth in the recitals, the introductory paragraph preceding the recitals, and all defined terms set forth in both, are hereby incorporated into this Agreement as set forth herein in full.

2. Owner hereby provides the City or City's designee complete access, of any duration, to the Device(s) and its immediate vicinity at any time, upon reasonable notice, or in the event of emergency, as determined by City's Utilities Director no advance notice, for the purpose of inspection, sampling, testing of the Device(s), and in case of emergency, to undertake all necessary repairs or other preventative measures at Owner's expense as provided in paragraph 4 below. City shall make every effort at all times to minimize or avoid interference with Owner's use of the property.

3. Owner shall use its best efforts diligently to maintain the Device(s) 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(s) and the ultimate disposal of the material(s) in a manner consistent with all relevant laws and regulations in effect at the time. As may be requested in writing 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.

4. 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 thereof 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.

5. 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 state 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 respect to the property on which the Device(s) has/have been installed until such time as Owner repays to City its reasonable cost incurred in accordance with paragraph 3 above.

6. This Agreement shall be recorded in the Office of the Recorder of Stanislaus County, California at the expense of the City and shall constitute notice to all successors and assigns of the title to said Property of the obligation herein set forth, as 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.

7. 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 part of the lien against said Property.

8. 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.

9. 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.

10. Time is of the essence in the performance of this Agreement.

11. Any notice 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 the address set forth below. 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.

IF TO CITY:	IF TO OWNER:
City of Modesto	________________________________
Utilities Department	________________________________
P.O. Box 642	________________________________
Modesto, CA 95353	________________________________
	________________________________

IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

CITY OF MODESTO, a Municipal Corporation

By:____________________________
JOSEPH P. LOPEZ
City Manager

ATTEST:

By:__________________________
DIANE NAYARES-PEREZ, CMC, City Clerk

(SEAL)

OWNER: ______________________________

By:________________________________
(Signature)

____
(Print Name & Title)

By:________________________________
(Signature)

____
(Print Name & Title)

**Corporations – signature of two (2) officers required or one (1) officer plus corporate seal.*
Partnership – signature of a partner required
Sole Proprietorship – signature of proprietor required
LLC – signature of proprietor or partner required

Approved as to Form:

By:________________________
JOSE M. SANCHEZ
City Attorney

Approved as to sufficiency:

By:___________________________
Toby Wells,
City Engineer

Exhibit A
Legal Description of Property

Exhibit B
Property Map

APPENDIX J

STORMWATER QUALITY CONTROL PLAN and MAINTENANCE PLAN SUBMITTAL GUIDANCE

APPENDIX J. SWQCP AND MAINTENANCE PLAN SUBMITTAL GUIDANCE

This appendix includes the following templates and forms:

J-1: Stormwater Quality Control Plan Guidance

J-2: Stormwater Quality Control Plan [Template]

J-3: Stormwater Maintenance Plan Guidance

J-4: Stormwater Maintenance Plan [Template]

APPENDIX J-1: STORMWATER QUALITY CONTROL PLAN GUIDANCE

This appendix identifies the information and format that must be submitted to the City as a part of the Project Stormwater Quality Control Plan (SWQCP). The SWQCP must be submitted to and approved by the City of Modesto (City) stormwater staff prior to issuance of building or use permits for the project.

The full Guidance Manual for Development Stormwater Quality Control Measures is available for download at https://www.modestogov.com/1515/Storm-Water.

I. Cover Page

The cover page must include the following information:

- Project name, address, and Assessor's Parcel Number (APN)
- Property owner/developer's name and contact information
- Brief property description (should be consistent with Section III)
- Plan preparer's name and contact information
- Dates submitted, revised (first and subsequent submittals, as needed)
- Signed and stamped by a licensed California Engineer

II. Owner's Certification Statement

The owner's certification statement requires the owner to legally accept responsibility for inspection and maintenance of the identified stormwater control measures. Required information includes:

- Project name
- Property owner's name, contact information, and signature

III. Project Description

The project description provides general information about the project type, description of the project, and site information. The following information must be included:

1. Project Category – type of development, type of project, City zoning, and associated pollutant categories of concern
2. Project Information – location, project and drainage area, receiving water(s), topography, depth to groundwater, etc.
3. Project Narrative – narrative description about the proposed project including the size, location, land uses, expected pollutant-generating activities, and any other pertinent information
4. 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. Delineates and describes the drainage management areas (DMAs) with arrows showing the flow direction.

f. With legend, indicate types and locations of structural stormwater control measures that will be built to permanently control stormwater pollution.

IV. Stormwater Control Measures

Identify the types of control measures provided for the project site.

1. Summary Matrix – identify each type of control measure provided.
2. Site Design Control Measures
    a. Describe each Site Design Control Measure that will be utilized and how each conforms to design criteria.
    b. If a Site Design Control Measure is not applicable to the project, provide a statement of justification describing why the control measure is not applicable.
    c. If implementation of an applicable Site Design Control Measure is not feasible due to project site conditions, provide a statement of justification describing why implementation is not feasible.
3. Source Control Measures
    a. Describe each Source Control Measure that will be utilized and how each conforms to the design criteria. (Note: Source Control S-1 is required for all projects)
4. Volume Retention Measures
    a. Describe each Volume Retention Measure (VRM) that will be utilized.
    b. Provide the summary sheet in **Appendix G** to track conformance with the Volume Reduction Requirement (VRR). This sheet must show:
        a. Pre- and post-project stormwater runoff volume
        b. Applicable volume retention credits
        c. Volume retention requirement

c. If implementation of VRMs is not feasible and/or the VRR cannot be met, use the Waiver Application in **Appendix H** to justify why implementation is not feasible. All VRMs must be taken into consideration.

5. Treatment Control Measures

   a. Describe each Treatment Control Measure to be provided.

   b. If the VRR was not fully met through the use of VRMs, LID-based Treatment Controls must be used. The summary sheet in **Appendix G** should be used to continue tracking conformance with the VRR. If implementation of VRMs is not feasible and/or the VRR cannot be met, use the Waiver Application in **Appendix H** to justify why implementation is not feasible. All VRMs must be taken into consideration.

   c. Summarize design data for Treatment Control Measures on appropriate design procedure forms. Provide detailed supporting calculations for design data values in a clear and organized manner.

V. Maintenance Plan and Responsibility

The Project SWQCP must include information on the responsible party(ies) that will operate, inspect, and maintain stormwater control measures. The owner/developer must sign a certified, legally-binding maintenance agreement [**Appendix I**].

1. Provide a summary of the control measures to be provided and responsible parties responsible for maintenance of each control.
2. Provide complete contact information for each identified responsible party.
3. Indicate any anticipated transfer of responsibility due to future transfer of ownership or annexation.
4. Provide a statement that a detailed Maintenance Plan will be prepared in accordance with SWQCCP requirements.

APPENDIX J-2: STORMWATER QUALITY CONTROL PLAN TEMPLATE

The following worksheets and sections are required for a SWQCP submittal.

Section I. Cover Page

Stormwater Quality Control Plan

Project Name: ______________________________

Street: ______________________________

City: Modesto State: California Zip Code: ______________

Assessor's Parcel Number (APN): ______________________________

Property Owner/Developer Information:	**Plan Preparer Information:**
Name of Business:__________	**Name of Business:**__________
Contact Person:__________	**Contact Person:**__________
Street:__________	**Street:**__________
City:________**State:**______**Zip:**______	**City:**________**State:**______**Zip:**______
Phone Number:__________	**Phone Number:**__________
Email Address:__________	**Email Address:**__________

Property Description (location, size, land uses, etc.)

Submittal Information	
Date of First Submittal	______________________________
Date(s) Revised	______________________________

The cover page must be signed and stamped by a licensed California Engineer

Section 2. Owner's Certification

Stormwater Quality Control Plan

For

Project Name:____

This Project Stormwater Quality Control Plan (Plan) was prepared for __________________________ by _______________________________. This Plan is intended to comply with all requirements specified in the City of Modesto Development Guidance Manual for new development and redevelopment projects.

The undersigned understands that stormwater pollution control measures are enforceable requirements under the Development Guidance Manual. 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 Development Guidance Manual.

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: ____

Email Address of Owner: ____

Signature: ____________________________________

Print Name: ____________________________________

Title: ____________________________________

Date: ____________________________________

Section 3. Project Description

1. Development
(select one – Development Guidance Manual Section 2.1)

☐ - New Development ☐ - New Development Infill ☐ - Significant Redevelopment

2. Project Category
(select all that apply – Development Guidance Manual Section 2.1)

Priority Land Use

☐ - High Density Residential
☐ - Industrial
☐ - Commercial
☐ - Mixed Urban
☐ - Public Transportation Station

Priority Project

☐ - Residential Subdivision
☐ - Commercial/Industrial
☐ - Automotive Repair Shops
☐ - Retail Gasoline Outlets
☐ - Restaurants
☐ - Parking Lots
☐ - Significant Redevelopment

City Zoning:	

3. PLU and Priority Project Categories and Associated Pollutants of Concern
(select all that apply – Development Guidance Manual Table 3-1)

Project Category	Pollutant Category of Concern						
	Sediment	Nutrients	Metals	Trash	Oxygen Demand	Toxic Organics	Bacteria
Residential	X	X	X[1]	X	X		X
Commercial/Industrial (any size) (including auto repair, RGO, restaurants)	X	X	X	X	X	X	X
Parking Lots (≥ 5,000 SF or 25 spaces)	X	X	X	X	X		
Mixed Urban	X	X	X	X	X	X	X
Public Transportation Stations				X			

X = Pollutant assumed to be present in stormwater runoff from project area unless applicant demonstrates otherwise.
1 – Metals are a pollutant category of concern for the street and road infrastructure portion of the residential development.

If applicable, identify other pollutants of concern specific to this project site not mentioned above.

2. Project Information

General Project Site Information Table 1					
Latitude:	____________	Longitude:	____________	Elevation:	____________
Total Project Area (A_T)(acres)	____________	Total Drainage Area (acres)	____________		
Total Existing (Pre) Impervious Area (acres)	____________	Total Post-Project Impervious Area (acres)	____________		
Project Location	____________				
Receiving Water(s)	____________				

General Project Site Information Table 2	
Post-Project Land Use Type(s)	____________
Topography	____________
Hydraulic Head	____________
Depth to Ground Water	____________
Type of Soil	____________

3. Project Narrative

Provide a narrative description of the proposed project, including the size, location, land uses found in the drainage area, expected pollutant-generating activities, and any other pertinent information.

4. Site Maps

Provide the following types of maps and information:

- *Vicinity map showing the location of the project relative to principal landmarks.*
- *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.*
- *Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.*
- *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 that have contaminated soil or where toxins are stored or have been stored/disposed of in the past.*
- *Delineates and describes the site Drainage Management Areas (DMAs) with arrows showing the direction of flow on the site.*
- *With legend, indicate types and locations of structural stormwater control measures that will be built to permanently control stormwater pollution.*

Section 4. Stormwater Control Measures

1. Summary Matrix of Control Measures

Category	Control Measure	Applicable	Not Applicable	Quantity
Site Design Control Measures	(G-1) Conserve Natural Areas**			
	(G-2) Protect Slopes and Channels**			
	(G-3) Minimize Soil Compaction**			
	(G-4) Minimize Impervious Areas**			
Source Control Measures	(S-1) Storm Drain Message and Signage**			
	(S-2) Outdoor Material Storage Area			
	(S-3) Outdoor Trash Storage & Waste Handling**			
	(S-4) Outdoor Loading/Unloading Dock Area			
	(S-5) Outdoor Repair/Maintenance Area			
	(S-6) Outdoor Vehicle/ Equipment Wash Area			
	(S-7) Fuel and Maintenance Area			
Volume Retention Measures	(V-1) Rain Garden			
	(V-2) Rain Barrel/Cistern			
	(V-3) Interception Trees			
	(V-4) Grassy Channel			
	(V-5) Vegetated Buffer Strip			
LID-Based Treatment Control Measures	(L-1) Bioretention*			
	(L-2) Stormwater Planter			
	(L-3) Tree-well Filter			
	(L-4) Water Quality Infiltration Basin*			
	(L-5) Water Quality Infiltration Trench*			
	(L-6) Porous Pavement Filter			
	(L-7) Vegetated (Dry) Swale			
	(L-8) Grassy Swale			
	(L-9) Grassy Filter Strip			
	(L-10) Infiltration Well			
	(L-11) Dry Well			
Conventional Treatment Control Measures	(C-1) Constructed Wetland			
	(C-2) Extended Detention Basin*			
	(C-3) Wet Pond			
	(C-4) Proprietary Treatment Control*			
	(C-5) Trash Capture Device			
	(C-6) Media Filter			

* Can be designed to meet trash control requirements; ** Provide justification if the control measure is not applicable to the project.

2. Site Design Controls

a) *Describe each Site Design Control Measure that will be utilized and how each conforms to the design criteria.*
b) *If a Site Design Control Measure is not applicable to the project, provide a statement of justification describing why the control measure is not applicable.*
c) *If implementation of an applicable Site Design Control Measure is not feasible due to project site conditions, provide a statement of justification describing why implementation is not feasible.*

Add space as needed

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

3. Source Control Measures

Describe each Source Control Measure that will be utilized and how each conforms to the design criteria (Note: Source Control S-1 is required for all projects). Add space as needed.

Description of Source Controls Provided	
S-1 Storm Drain Message and Signage	

4. Volume Retention Measures

a) *Describe each Volume Retention Measure (VRM) that will be utilized.*
b) *Provide the summary sheet in* ***Appendix G*** *to track conformance with the Volume Reduction Requirement (VRR). This sheet must show:*
    a. *Pre- and post-project stormwater runoff volume*
    b. *Applicable volume retention credits*
    c. *Volume retention requirement*
c) *If implementation of VRMs is not feasible and/or the VRR cannot be met, use the Waiver Application in* ***Appendix H*** *to justify why implementation is not feasible. All VRMs must be taken into consideration.*

Add space as needed.

Description of Volume Retention Measures	

5. Treatment Control Measures

a) *Describe each Treatment Control Measure to be provided.*
b) *If the VRR was not fully met through the use of VRMs, LID-based Treatment Controls must be used. The summary sheet in* ***Appendix G*** *should be used to continue tracking conformance with the VRR. If implementation of VRMs is not feasible and/or the VRR cannot be met, use the Waiver Application in* ***Appendix H*** *to justify why implementation is not feasible. All VRMs must be taken into consideration.*
c) *Summarize design data for Treatment Control Measures on appropriate design procedure forms. Provide detailed supporting calculations for design data values in a clear and organized manner.*

Add space as needed.

Description of Treatment Control Measures	

Section 5. Maintenance Plan and Responsibility

Provide a summary of the control measures to be implemented and responsible parties responsible for maintenance of each control measure.

Control Measures Implemented

Responsible Party Contact Information
Contact Person: ______________________
Street: ______________________
City: __________ State: __________ Zip Code: __________
Phone Number: ______________________
Email Address: ______________________

Indicate any anticipated transfer of responsibility due to future transfer of ownership or annexation.

APPENDIX J-3: STORMWATER MAINTENANCE PLAN GUIDANCE

This appendix identifies the information that shall be included in a maintenance plan. Refer to the Fact Sheets for individual control measure and device-specific maintenance requirements.

I. Cover Page

- Project Name, address, and Assessor's Parcel Number (APN)
- Property Owner/Developer's name and contact information
- Operations and Maintenance name and contact information

II. Baseline Descriptions

- List responsible parties for operation and maintenance of the stormwater control measures on site and associated contact information.
- Identify the intended method of providing financing for operation, inspection, routine maintenance, and upkeep of stormwater control measures.
- Provide a description of the types of O&M activities that will take place at this site.
- List all permanent stormwater control measures (see **SWQCP Section 4**).

III. Routine Maintenance

Provide the following for each stormwater control measure:

- List and describe all maintenance and waste disposal activities that will be performed and 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.
- Identification of the equipment and materials required to perform the maintenance.
- Parties responsible for the O&M plan and number of years for which records will be retained.
- 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.

IV. Training

Identify persons to be trained and when the training occurs. Training shall 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.

V. Inspections

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 (see Example Maintenance Log). Maintenance activities may include, but not be limited to the following:

- Perform annual testing of any mechanical or electrical devices prior to wet weather.
- 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.
- Note any significant maintenance requirements due to spills or unexpected discharges.
- 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.
- Assure *unauthorized* low-flow discharges from the property do not by-pass stormwater control measures.
- 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.
- For trash controls, regular maintenance is required to maintain adequate trash capture capacity and ensure that trapped trash does not migrate offsite. The owner should establish a maintenance schedule based on site-specific factors, including the size of the detention BMP, storm frequency, and estimated or measured trash loading area.

VI. Additional Information

<u>Spill Plan</u>

- Provide a spill plan and include spill plan documents as an appendix, if applicable.
- Provide emergency notification procedures (phone and agency/persons to contact).
- As appropriate for site, provide emergency containment and cleaning procedures.

Facility Changes

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.

Revisions to Pollution Mitigation Measures

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.

Monitoring & Reporting Program

The City may conduct a site inspection to evaluate compliance with the SWQCP Report and/or require a Monitoring & Reporting Program to assure the stormwater control measures approved for the site are performing according to design.

If required, the Maintenance Plan shall include performance testing and reporting protocols.

Site Map

- 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.
- Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.
- 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.
- 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.

APPENDIX J-4: STORMWATER MAINTENANCE PLAN TEMPLATE

Stormwater Maintenance Plan – Cover Page

Project Name: ____

Street: ____

City: ____________________ State: ____________________ Zip Code: ____________________

Assessor's Parcel Number (APN): ____

Property Owner/Developer Information:	Operations & Maintenance Contact Person:
Name: __________________________________	Name: __________________________________
Title:___________________________________	Title:___________________________________
Street: _________________________________	Street: _________________________________
City:_________ State:______ Zip:_________	City:________ State:______ Zip:__________
Phone Number:__________________________	Phone Number:__________________________
Email Address: __________________________	Email Address: __________________________

II. Baseline Descriptions

If applicable list persons responsible for operation and maintenance of the stormwater control measures on site not mentioned above. Include contact information for each person listed (phone number, emails, and address).
Identify the intended method of providing financing for operation, inspection, routine maintenance, and upkeep of stormwater control measures.
Provide a description of the types of O&M activities that will take place at this site

List all permanent stormwater control measures (see **SWQCP Section D**).	
Quantity	Stormwater Control Measure

III. Routine Maintenance

List and describe all maintenance and waste disposal activities that will be performed and distinguish between the maintenance appropriate for a 2-year establishment period and expected long-term maintenance.

Routine Maintenance Activities for:		
No.	**Maintenance Task**	**Frequency of Task**

Identification of the equipment and materials required to perform the maintenance.

Parties responsible for the O&M plan shall retain records for at least:		Years.

List all housekeeping procedures for prohibiting illicit discharges or potential illicit discharges to the storm drain system. Identify housekeeping BMP's that reduce maintenance of treatment control measures.

IV. Training

Identify appropriate persons to be trained and when the training shall occur.

V. Inspections

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 (see Example Maintenance Log).

VI. Additional Information

<u>Spill Plan</u>

Provide a spill plan and include spill plan documents as an appendix, if applicable.

Downstream Receiving Body of Water:	
1. Provide emergency notification procedures (phone number and agency/person(s) to contact).	
2. As appropriate for site, provide emergency containment cleaning procedures.	

<u>Facility Changes</u>

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.

<u>Revisions to Pollution Mitigation Measures</u>

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 discharge to by-pass or otherwise impede existing stormwater control measures.

<u>Monitoring and Reporting Program</u>

The City may conduct a site inspection to evaluate compliance with the SWQCP Report and/or require a Monitoring & Reporting Program to assure the stormwater control measures approved for the site are performing according to design.

If required, the Maintenance Plan shall include performance testing and reporting protocols.

Site Map

- *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.*
- *Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.*
- *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.*
- *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.*

Example Maintenance Log

Facility Name:			
Address:			
BMP Type/ID:			
Year:		**Maintenance Log No.**	

Date of Inspection	Inspectors Name	Trash (Y/N)	Sediment (Y/N)	Blocked Inlet/Outlet (Y/N)	Performed All Routine Maintenance (Y/N)	Comments / Notes

APPENDIX K

HYDROLOGIC SOIL GROUPS

APPENDIX K. HYDROLOGIC SOIL GROUPS

This appendix includes information on the Hydrologic Soil Groups in the City of Modesto 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	Infiltration Rate *(in/hr)*
A	1.00 – 8.3
B	0.50 – 1.00
C	0.17 – 0.27
D	0.02 – 0.10

Infiltration rates shown represent the range covered by multiple sources such as ASCE.

Hydrologic Soil Groups

The hydrologic soil groups are classified by the United States Department of Agriculture (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.

<u>Soil Groups A and B</u>

- Group A soils 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.
- Typically the best candidate soils for construction of infiltration facilities
- Have high infiltration rates, unless the soils under consideration have been compacted during construction.

<u>Soil Groups C and D</u>

- Group C soils 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 permanently high water table and shallow soils over nearly impervious material.
- Usually more appropriate for detention basins.

This information is a general overview. For more specific information, consult the City of Modesto or contact the NRCS at (530) 662-3986.

APPENDIX L

PLANTS SUITABLE FOR VEGETATIVE CONTROL MEASURES

APPENDIX L. 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 the selection of appropriate vegetation and specifically with the Public Works Department - Trees and Forestry Services to identify which trees are appropriate for a given location and desired outcome/use [209-342-2253].

Table L-1 provides a sample list of appropriate vegetative covers. Additional suggested vegetative species are listed in **Table L-2 and L-3.**[1]

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.

Table L-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

[1] California Native Plant Society https://calscape.org/loc-37.9176,-121.171%20(san%20joaquin%20county)/cat-all-plants/ord-popular

Table L-2. Additional Sample List of Appropriate Vegetative Covers

Plant Name Common (Latin)	Appropriate Species	Usage Notes
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.

Table L-3. Stanislaus County Native Plant List (obtained from the California Native Plant Society)

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Annual Herbs										
Achyrachaena mollis	Blow Wives	1 - 1.3 ft			X		X			
Acmispon americanus	American Bird's-foot Trefoil	1 ft			X	X	X	X		
Amaranthus blitoides	Procumbent Pigweed									
Amaranthus palmeri	Palmer's Amaranth									
Ammannia coccinea	Valley Redstem	1.6 ft								
Amsinckia douglasiana	Douglas' Fiddleneck	0.7 - 3.9 ft								
Amsinckia eastwoodiae	Eastwood's Fiddleneck	0.7 - 3.9 ft					X			
Amsinckia intermedia	Common Fiddleneck	0.7 - 3.9 ft			X		X			
Amsinckia lycopsoides	Bugloss-flowered Fiddleneck	0.7 - 3 ft								
Amsinckia menziesii	Menzies' Fiddleneck	0.7 - 3.9 ft					X			
Amsinckia tessellata	Fiddleneck	0.7 - 3.9 ft					X			
Amsinckia tessellata var. tessellata	Desert Fiddleneck	0.7 - 3.9 ft								
Ancistrocarphus filagineus	Woolly Fishhooks									
Astragalus didymocarpus	Dwarf White Milkvetch	1 - 11.8 in								
Astragalus gambelianus	Gambel's Dwarf Milk Vetch	0.8 - 11.8 in					X			
Astragalus tener	Alkali Milkvetch	0.8 - 11.8 in								
Astragalus tener var. tener	Alkali Milkvetch	1.6 - 11.8 in								

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			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Annual Herbs (continued)										
Athysanus pusillus	Common Sandweed									
Atriplex argentea	Silver Saltweed	0.49 - 2.6 ft					X	X		
Atriplex argentea var. expansa	Silverscale	0.49 - 2.6 ft					X			
Atriplex cordulata	Heartscale	0.33 - 1.6 ft								
Atriplex coronata	Crownscale	4 - 11.8 in								
Atriplex coronata var. coronata	Crownscale	4 - 11.8 in								
Atriplex depressa	Brittlescale	11.8 in								
Atriplex minuscula	Lesser Saltscale	1.3 ft								
Atriplex persistens	Vernal Pool Smallscale	9.8 in								
Atriplex serenana	Tractscale	1 - 3.3 ft					X			
Atriplex serenana var. serenana	Bractscale	1 - 3.3 ft								
Atriplex subtilis	Subtle Orach	11.8								
Bidens frondosa	Sticktight	0.7 - 4 ft								
Blennosperma nanum	Common Stickyseed									
Blennosperma nanum var. nanum	Common Blennosperma									
Blepharizonia laxa	Glandular Big Tarweed									
Bowlesia incana	Hoary Bowlesia									
Calandrinia menziesii	Red Maids	1.3 ft			X		X			
Callitriche marginata [a]	Winged Water Starwort									
Camissonia campestris	Field Primrose	1.9 - 9.8 in								

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			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Annual Herbs (continued)										
Camissonia campestris ssp. campestris	Mojave Suncup									
Camissonia contorta	Plains Evening Primrose	1.2 - 11.8 in								
Castilleja attenuata	Valley Tassels	1.6 ft								
Castilleja exserta	Purple Owl's Clover	1.5 ft		X	X		X			
Castilleja exserta ssp. exserta	Pale Purple Owlclover									
Centromadia fitchii	Fitch Spikeweed	1.6 ft								
Centromadia pungens	Common Spikeweed	4 ft					X			
Centromadia pungens ssp. pungens	Common Spikeweed									
Chenopodium berlandieri	Pitseed Goosefoot	0.33 - 9.8 ft								
Clarkia modesta	Waltham Creek Clarkia	1.6 ft								
Clarkia purpurea	Purple Clarkia	3.3 ft			X		X			
Clarkia purpurea ssp. purpurea	Winecup Clarkia	3.3 ft			X		X			
Clarkia purpurea ssp. quadrivulnera	Purple Clarkia	3.3 ft					X			
Clarkia speciosa	Red Spotted Clarkia	2 ft		X			X	X		
Clarkia unguiculata	Elegant Clarkia	3.3 ft			X		X	X		
Claytonia perfoliata	Miner's Lettuce	1 - 1.3 ft			X	X		X		
Claytonia perfoliata ssp. perfoliata	Miner's Lettuce	1.3 ft						X	X	
Collinsia bartsiifolia	White Blue-eyed Mary									
Collinsia bartsiifolia var. bartsiifolia	White Blue Eyed Mary	0.33 - 1.2 ft								
Collinsia sparsiflora	Spinster's Blue-eyed Mary									

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			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Annual Herbs (continued)										
Collinsia sparsiflora var. collina	Spinster's Blue Eyed Mary	1.9 - 7.9 in								
Convolvulus simulans	Small-flowered Morning-glory									
Croton Setiger	Turkey Mullein	7.9 in		X			X	X		
Crassula aquatica [c]	Water Pygmyweed									
Crassula connata [c]	Pygmy-weed	0.8 - 4 in								
Cryptantha nevadensis	Nevada Catseye	1.6 ft								
Cucurbita foetidissima [a]	Missouri Gourd	1 ft		X	X		X			
Cuscuta californica [d]	Chaparral Dodder									
Cuscuta campestris [d]	Field Dodder									
Cuscuta indecora [d]	Bigseed Alfalfa Dodder									
Cuscuta subinclusa [d]	Canyon Dodder									
Deinandra kelloggii	Kellogg's Tarweed	3.3 - 4.9 ft					X			
Descurainia pinnata	Western Tansymustard									
Downingia bella	Hoover's Downingia									
Downingia bicornuta	Doublehorn Calicoflower	9.6 in								
Downingia bicornuta var. picta	Doublehorn Calicoflower									
Downingia ornatissima	Folded Calicoflower									
Downingia ornatissima var. ornatissima	Folded Calicoflower									
Downingia pulchella	Flatface Calicoflower									
Eclipta prostrata	False Daisy	3.3 ft					X			
Epilobium brachycarpum	Panicled Willow Herb	0.7 - 7 ft					X	X		
Epilobium campestre	Smooth Boisduvalia	0.33 - 1.8 ft								

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			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Annual Herbs (continued)										
Epilobium cleistogamum	Selfing Willowherb	0.49 - 1.1 ft								
Epilobium densiflorum	Denseflower Willowherb	0.16 - 3.3 ft								
Eriastrum pluriflorum	Many Flowered Eriastrum	0.07 - 1 ft					X	X		
Eriogonum gracile	Slender Woolly Buckwheat	1 - 2 ft	X	X			X			D
Eriogonum nudum var. pubiflorum	Fremont's Wild Buckwheat	1 - 3.3 ft								
Eriogonum roseum	Wand Buckwheat	1.6 - 2.6 ft						X		
Eryngium racemosum [a]	Delta Button-celery									
Erysimum capitatum [a]	Sanddune Wallflower							X		
Erythranthe guttata [a]	Seep Monkey Flower	2 - 5 ft				X	X	X		D
Eschscholzia californica [a]	California Poppy	0.16 - 2 ft		X	X		X			D
Eschscholzia lobbii	Fryingpans	1.9 - 6 in		X			X			
Galium aparine	Common Bedstrawm Cleavers	10.8 in								
Gilia capitata	Blue Field Gilia	0.33 - 3 ft		X			X			
Gilia capitata ssp. staminea	Bluehead Gilia									
Gilia tricolor	Tricolor Gilia	0.33 - 1.2 ft			X		X			
Gilia tricolor ssp. tricolor	Bird's-eye Gilia									
Gnaphalium palustre	Western Marsh Cudweed	11.8 in								
Gutierrezia californica [b]	California Matchweed	1 - 2 ft		X			X			D
Helianthus annuus	Sunflower	5 - 10 ft			X		X			

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			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Annual Herbs (continued)										
Hesperevax caulescens	Hogwallow Starfish									
Hesperomecon linearis	Narrow-leaved Meconella	0.1 - 1.3 ft								
Heterotheca sessiliflora [a]	False Goldenaster	2 - 4 ft		X			X	X		
Holocarpha obconica	San Joaquin Tarweed	3.9 ft								
Holocarpha virgata	Pitgland Tarweed	0.7 - 4 ft					X			
Holocarpha virgata ssp. virgata	Narrow Tarplant	4 ft					X			
Laennecia coulteri	Coulter's Horseweed									
Lasthenia californica	California Goldfields	0.5 - 1.3 ft		X	X		X	X		
Lasthenia chrysantha	Alkali-sink Goldfields	11 in								
Lasthenia ferrisiae	Ferris' Goldfields	1.3 ft								
Lasthenia fremontii [a]	Fremont's Goldfields	1.2 ft								
Lasthenia glaberrima	Smooth Goldfields	1.2 ft								
Lasthenia gracilis	Common Goldfields									
Lasthenia microglossa	Small-ray Goldfields	9.8 in								
Lasthenia minor	Coastal Goldfields	1.2 ft								
Lasthenia platycarpha	Alkali Goldfields	11.8 in								
Layia chrysanthemoides	Smooth Tidy Tips	1.7 ft					X			
Layia fremontii	Fremont's Tidytips	1.3 ft								
Lepidium acutidens [a]	Alkali Pepperwort									
Lepidium dictyotum	Alkali Pepperweed									
Lepidium latipes	San Diego Pepperweed	4 in								
Lepidium nitidum	Peppergrass	1.3 ft					X			
Leptosiphon bicolor	Bicolor Linanthus	0.8 - 6 in					X	X		

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			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Annual Herbs (continued)										
Lessingia nemaclada	Slenderstem Lessingia	1.2 in								
Lessingia pectinata										
Lessingia pectinata var. tenuipes										
Limnanthes douglasii	Common Meadowfoam	1.6 ft			X	X	X	X		
Limnanthes douglasii ssp. rosea	Douglas' Meadowfoam	1.6 ft					X			
Limosella acaulis	Owyhee Mudwort									
Lindernia dubia	Yellowseed False Pimpernel	10.7 - 11.8 in								
Lupinus benthamii	Spider Lupine	0.7 - 2.3 ft		X			X			
Lupinus bicolor [a]	Miniature Lupine	0.26 - 1.3 ft			X		X			
Lupinus microcarpus	Chick Lupine	0.33 - 2.6 ft		X			X			
Lupinus microcarpus var. densiflorus	Dense Flowered Platycarpos	0.33 - 2.6 ft			X		X			
Lupinus microcarpus var. microcarpus	Valley Lupine	0.33 - 2.6 ft			X		X			
Lupinus succulentus	Succulent Lupine	2 - 4 ft			X		X	X		
Matricaria discoidea	Pineapple Weed									
Mentzelia affinis	Yellowcomet	1.9 in								
Micropus californicus	Q-tips									
Micropus californicus var. californicus	Cottontop									
Microseris campestris	San Joaquin Silverpuffs	1.6 ft								
Microseris douglasii	Douglas' Silverpuffs	1.9 in								

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			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Annual Herbs (continued)										
Microseris douglasii ssp. douglasii										
Mimulus latidens	Broadtooth Monkeyflower	4 - 10.7 in								
Mimulus pilosus	False Monkeyflower	0.07 - 1.2 ft								
Mimulus tricolor	Tricolor Monkeyflower	5.5 in								
Monolopia lanceolata	Common Monolopia	2.6 ft			X		X	X		
Monolopia major	Cupped Monolopia	2.6 ft								
Montia fontana	Water Chickweed									
Myosurus minimus	Tiny Mousetail	2.4 - 4.8 in								
Myosurus sessilis	Vernal Pool Mousetail	4 in								
Najas guadalupensis	Southern Waternymph	1 ft								
Navarretia leucocephala	Whitehead Pincushionplant	1.2 - 5.9 in								
Navarretia pubescens	Downy Pincushionplant	0.46 - 1.1 ft					X			
Nemophila pedunculata	Littlefoot Nemophila						X	X		
Oenothera deltoides [a]	Dune Primrose	0.33 - 3.3 ft	X	X			X			
Oenothera deltoides ssp. Cognata [a]	Birdcage Evening Primrose									
Pectocarya penicillata	Northern Pectocarya	0.8 - 9.8 in								
Persicaria lapathifolia	Willow Weed	0.2 - 2.6 ft								
Phacelia ciliata	Great Valley Phacelia	0.33 - 1.8 ft					X			

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Annual Herbs (continued)										
Phacelia ciliata var. ciliata	Phacelia ciliata var. ciliata						X	X		
Phacelia distans	Wild Heliotrope	0.16 - 2.6 ft		X			X			
Phacelia tanacetifolia	Lacy Phacelia	2 - 4 ft		X			X			
Pholistoma membranaceum	White Fiesta Flower	0.16 - 3 ft								
Plagiobothrys acanthocarpus	Adobe Popcornflower	0.33 - 1.3 ft								
Plagiobothrys bracteatus	Bracted Popcornflower	0.33 - 1.3 ft								
Plagiobothrys canescens	Valley Popcornflower	0.33 - 2 ft								
Plagiobothrys fulvus	Field Popcornflower	2 ft								
Plagiobothrys humistratus	Low Popcornflower	0.33 - 1.3 ft								
Plagiobothrys leptocladus	Alkali Plagiobothrys	4 - 11.8 in								
Plagiobothrys nothofulvus	Rusty Popcornflower	0.7 - 2.3 ft								
Plagiobothrys stipitatus	Stalked Popcornflower	0.33 - 1.6 ft								
Plagiobothrys stipitatus var. micranthus	Stalked Popcornflower	0.33 - 1.6 ft								
Plagiobothrys stipitatus var. stipitatus	Showy Great Valley Popcornflower	0.33 - 1.6 ft								
Plagiobothrys tenellus	Pacific Popcornflower	1.9 - 11.8 in								
Plagiobothrys trachycarpus	Rough-nutlet Popcornflower	0.16 - 1.3 ft								

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			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Annual Herbs (continued)										
Plantago elongata	Coast Plantain	7.1 in					X			
Platystemon californicus	Creamcups	0.7 - 1 ft			X		X			
Plectritis ciliosa	Longspur Seablush	1.6 - 2.6 ft								
Plectritis macrocera	Longhorn Seablush	2 - 2.6 ft								
Pluchea odorata [a]	Marsh Fleabane	2 - 4 ft				X	X			
Pluchea odorata var. odorata [a]	Saltmarsh-fleabane	4.9 ft								
Pogogyne douglasii	Douglas' Pogogyne	0.8 - 1.5 ft					X			
Pogogyne zizyphoroides	Sacramento Beardstyle	1.9 - 6.2 in								
Psilocarphus brevissimus	Short Woollyheads	1.2 in								
Psilocarphus brevissimus var. brevissimus	Dwarf Woollyheads									
Psilocarphus chilensis	Round Woolly-marbles									
Psilocarphus oregonus	Oregon Woollyheads									
Psilocarphus tenellus	Slender Woolly-marbles									
Ranunculus sceleratus	Cursed Buttercup	1 - 2 ft								
Rorippa curvisiliqua [a]	Curvepod Yellowcress	1 ft								
Rorippa palustris [a]	Bog Yellowcress	3.3 ft								
Rotala ramosior	Lowland Rotala									
Rigiopappus leptocladus	Wireweed									
Salvia carduacea	Thistle Sage	0.33 - 3.3 ft		X			X			
Salvia columbariae	Chia	0.33 - 1.6 ft	X	X			X			

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			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Annual Herbs (continued)										
Solanum americanum [b]	American Black Nightshade	2.6 - 4.9 ft				X	X			
Spergularia marina	Saltmarsh Sand-spurrey									
Stebbinsoseris heterocarpa	Grassland Silverpuffs									
Stephanomeria virgata	Rod Wirelettuce	1.9 - 11.8 in					X			
Stellaria nitens	Shining Chickweed	9.8 in								
Stephanomeria virgata ssp. pleurocarpa	Wand Wirelettuce									
Symphyotrichum subulatum	Eastern Annual Saltmarsh Aster									
Thysanocarpus curvipes	Hairy Lacepod	0.33 - 2.6 ft					X			
Trichostema lanceolatum	Vinegarweed	3.3 ft					X			
Trifolium albopurpureum	Indian Clover	6 in					X	X		
Trifolium ciliolatum	Foothill Clover				X		X			
Trifolium depauperatum	Cowbag Clover									E
Trifolium depauperatum var. amplectens	Pale Sack Clover									
Trifolium depauperatum var. depauperatum	Dwarf Sack Clover									
Trifolium depauperatum var. truncatum	Truncate Sack Clover									
Trifolium gracilentum	Pinpoint Clover					X	X			
Trifolium variegatum	Whitetip Clover									
Trifolium willdenovii	Tomcat Clover				X		X			
Triphysaria eriantha	Johnny-tuck	1.2 ft								
Triphysaria eriantha ssp. eriantha	Butter'n Eggs									

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			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Annual Herbs (continued)										
Tropidocarpum gracile	Dobie Pod	0.33 - 1.6 ft								
Uropappus lindleyi	Uropappus	2.3 ft					X			
Veronica peregrina	Neckweed	11.8 in								
Veronica peregrina ssp. xalapensis	Purslane Speedwell									
Wislizenia refracta	Spectacle Fruit	0.16 - 6.6 ft								
Wislizenia refracta ssp. californica	Spectacle Fruit									
Xanthium strumarium	Cocklebur									
Ferns										
Azolla filiculoides	Mosquito Fern	2.4 in					X			
Marsilea vestita	Hairy Waterclover	1.1 ft					X			
Marsilea vestita ssp. vestita	Hairy Waterclover	1.1 ft					X			
Pilularia americana	American Pillwort									
Grasses										
Agrostis exarata	Spike Bentgrass	1 - 3.3 ft					X	X		
Alopecurus carolinianus	Carolina Foxtail	1.7 ft								
Alopecurus saccatus	Pacific Foxtail	1.5 ft								
Bolboschoenus maritimus	Alkali Bulrush	3 ft				X	X			E
Bromus arizonicus	Arizona Brome	1.3 - 3 ft					X			
Carex barbarae	Valley Sedge	1.6 - 3.3 ft			X	X		X		E
Cyperus eragrostis	Tall Flatsedge	3 ft				X	X			E
Cyperus erythrorhizos	Red Rooted Cyperus	2.5 - 3.3 ft					X			

Table L-3. Stanislaus County Native Plant List (obtained from the California Native Plant Society)

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Grasses (continued)										
Cyperus esculentus	Chufa Sedge	8.4 in								
Cyperus niger	Black Flatsedge	1.6 ft								
Deschampsia danthonioides	Annual Hair Grass	1.3 - 2 ft								
Distichlis spicata	Saltgrass	1.1 - 1.6 ft				X	X			
Eleocharis acicularis	Spike Rush	5.9 - 8.4 in					X	X		
Eleocharis macrostachya	Common Spikerush	1.6 - 3.3 ft				X	X			E
Elymus multisetus	Big Squirreltail	2 ft		X			X			
Eragrostis hypnoides	Creeping Love Grass	4 in								
Eragrostis mexicana	Mexican Lovegrass									
Eragrostis mexicana ssp. virescens	Chilean Love Grass									
Eragrostis pectinacea	Tufted Lovegrass	0.33 - 2.6 ft								
Eragrostis pectinacea var. pectinacea	Carolina Love Grass									
Eriochloa acuminata	Tapertip Cupgrass									
Festuca microstachys	Pacific Fescue	2.5 ft		X			X			
Fimbristylis vahlii	Vahl's Fimbry	1.2 in								
Hordeum depressum	Low Barley	1.8 ft				X	X			
Juncus acuminatus	Taper Tip Rush	1.5 - 3 ft					X			
Juncus balticus	Baltic Rush	3 ft				X		X		E
Juncus balticus ssp. ater	Baltic Rush									
Juncus bufonius	Toad Rush	1 ft				X	X			
Juncus bufonius var. bufonius	Toad Rush						X			

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Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Grasses (continued)										
Juncus bufonius var. congestus	Clustered Toad Rush	1 ft					X			
Juncus effusus	Soft Rush	4.9 - 6.6 ft				X		X		E
Juncus occidentalis	Slender Juncus Rush	1 - 2 ft				X	X			
Juncus bufonius var. occidentalis	Western Toad Rush									
Juncus oxymeris	Pointed Rush	2 ft				X	X	X		
Juncus xiphioides	Irisleaf Rush	1 - 3 ft				X		X		E
Leersia oryzoides	Rice Cutgrass	3.3 - 5 ft					X			
Leptochloa fusca	Bearded Sprangletop									
Leptochloa fusca ssp. fascicularis	Bearded Sprangletop	3.3 ft								
Melica californica	California Melicgrass	1 - 4.3 ft		X			X	X		
Muhlenbergia rigens	Deergrass	4 - 5 ft			X		X			E
Panicum capillare	Witch Grass	3.3 ft								
Paspalum distichum	Knotgrass	0.9 - 2 ft					X			
Phalaris lemmonii	Lemmon's Canary Grass	2.5 - 4.9 ft								
Poa secunda	One Sided Blue Grass	1.4 - 3.3 ft			X					
Poa secunda ssp. secunda	Pine Bluegrass	3.3 ft						X		
Puccinellia simplex	California Alkaligrass	9.8 in								
Schoenoplectus acutus	Hardstem Bulrush	3 - 10 ft				X	X			E
Schoenoplectus acutus var. occidentalis	Tule	13 ft					X			
Stipa cernua	Nodding Needle Grass	1.7 - 3.3 ft		X			X	X		D

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Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Perennial Herbs										
Alisma triviale	Water Plantain	1 ft					X	X		
Allium serra	Jeweled Onion			X			X			
Ambrosia psilostachya	Western Ragweed	3.5 - 7 ft			X	X	X			D
Artemisia douglasiana	Douglas' Sagewort	8 ft			X	X	X	X	X	D
Asclepias fascicularis	Narrow Leaf Milkweed	1.7 - 3.3 ft			X	X	X			D
Astragalus asymmetricus	San Joaquin Milk Vetch	1.6 - 3.9 ft					X	X		
Astragalus douglasii	Douglas' Milkvetch	0.7 - 3.3 ft								
Atriplex fruticulosa	Ballscale	1 - 1.6 ft								
Baccharis glutinosa	Saltmarsh Baccharis	3.3 - 7 ft				X		X		
Bacopa eisenii	Gila River Water Hyssop									
Bidens laevis	Bur Marigold	0.5 - 8 ft				X	X			
Brodiaea elegans	Harvest Brodiaea	1.6 ft			X		X	X		
Brodiaea elegans ssp. elegans	Harvest Brodiaea	1.6 ft					X	X		
Callitriche marginata [a]	Winged Water Starwort									
Castilleja affinis [a]	Indian Paintbrush	2 ft					X			
Castilleja affinis ssp. Affinis [a]	Coast Indian Paintbrush	2 ft					X			
Ceratophyllum demersum	Hornwort	3.3 - 9.8 ft								
Chenopodium californicum	California Goosefoot	0.7 - 3.3 ft								
Clematis ligusticifolia [h]	Virgin's Bower	1 - 30 ft			X			X	X	D
Cressa truxillensis	Alkali Weed	9.8 in			X		X			
Cucurbita foetidissima [a]	Missouri Gourd	1 ft		X	X		X			

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Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Perennial Herbs (continued)										
Datura wrightii	Toluaca	1 - 5 ft			X		X	X		
Delphinium parryi	San Bernardino Larkspur	2 - 4 ft					X	X		
Delphinium parryi ssp. parryi	Parry's Larkspur	0.5 - 3.5 ft					X	X		
Delphinium variegatum	Royal Larkspur	1.6 - 2.8 ft			X		X	X		
Delphinium variegatum ssp. variegatum	Royal Larkspur									
Dichelostemma capitatum ssp. capitatum	Blue Dicks						X	X		
Dipterostemon capitatus	Blue Dicks	1.5 - 2 ft			X		X			D
Elatine californica	California Waterwort									
Elodea canadensis	Elodea						X			
Epilobium ciliatum	Northern Willow Herb	1.6 - 6 ft			X	X	X			
Epilobium ciliatum ssp. ciliatum	Fringed Willowherb	6 ft					X			
Erigeron foliosus	Leafy Fleabane	0.7 - 3.3 ft						X		
Erigeron foliosus var. foliosus [e]	Leafy Fleabane									
Eryngium castrense	Great Valley Coyote-thistle	1.6 ft								
Eryngium racemosum [a]	Delta Button-celery									
Eryngium vaseyi	Coyotethistle									
Erysimum capitatum [a]	Sanddune Wallflower							X		
Erythranthe guttata [a]	Seep Monkey Flower	2 - 5 ft				X	X	X		D
Eschscholzia californica [a]	California Poppy	0.16 - 2 ft		X	X		X			D

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Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Perennial Herbs (continued)										
Euthamia occidentalis	Western Goldentop	3.5 - 7 ft				X	X			
Frankenia salina	Alkali Heath	1 ft				X	X			D
Fritillaria agrestis	Stinkbells	1.6 ft					X			
Galium trifidum	Threepetal Bedstraw	0.8 - 1.6 ft						X		
Glycyrrhiza lepidota	Wild Licorice	1.3 - 4 ft				X	X			
Grindelia camporum	Great Valley Gumweed	2 - 6.6 ft		X			X			D
Gutierrezia californica [b]	California Matchweed	1 - 2 ft		X			X			D
Helenium puberulum	Sneezeweed	5 ft				X	X			
Helianthus petiolaris [a]	Prairie Sunflower									
Heliotropium curassavicum	Seaside Heliotrope	1.2 - 1.6 ft				X	X			
Heliotropium curassavicum var. oculatum	Seaside Heliotrope	0.33 - 2 ft								
Heterotheca grandiflora [a]	Telegraph Weed	2.5 - 3.5 ft		X			X			D
Heterotheca sessiliflora [a]	False Goldenaster	2 - 4 ft		X			X	X		
Heterotheca sessiliflora ssp. echioides	Bristly Goldenaster	4 ft					X	X		
Hydrocotyle verticillata	Whorled Marsh Pennywort						X			
Iva axillaris	Poverty Weed									
Lasthenia fremontii [a]	Fremont's Goldfields	1.2 ft								
Lathyrus jepsonii	Jepson's Pea	6.6 ft					X	X	X	
Lathyrus jepsonii var. californicus	California Pea	8.2 ft					X	X		
Lemna gibba	Thallus									
Lepidium acutidens [a]	Alkali Pepperwort									

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Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Perennial Herbs (continued)										
Lithophragma cymbalaria	Mission Woodland Star	0.33 - 1.2 ft								
Lomatium utriculatum	Common Lomatium	1.6 ft					X	X		
Lupinus bicolor [a]	Miniature Lupine	0.26 - 1.3 ft			X		X			
Lupinus formosus	Summer Lupine	0.7 - 2.6 ft		X			X			
Lycopus americanus	American Water Horehound	0.7 - 1.8 ft						X		
Lomatium caruifolium	Caraway Leaved Lomatium	0.49 - 1.5 ft					X			
Lomatium caruifolium var. caruifolium	Alkali Desertparsley	1.5 ft					X			
Lupinus formosus var. robustus	Summer Lupine	0.7 - 2.6 ft								
Malvella leprosa	Alkali Mallow	0.33 - 1.3 ft			X		X			
Nitrophila occidentalis	Boraxweed	1 ft								
Oenothera deltoides [a]	Dune Primrose	0.33 - 3.3 ft	X	X			X			
Oenothera deltoides ssp. Cognata [a]	Birdcage Evening Primrose									
Oenothera elata	Hooker's Evening Primrose	5 ft			X		X	X		
Oenothera elata ssp. hirsutissima	Hairy Evening Primrose					X	X			
Persicaria amphibia	Swamp Knotweed	7.9 - 1.2 in						X		D
Persicaria hydropiperoides	Water Pepper	1 - 3.3 ft					X			D

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Table L-3. Stanislaus County Native Plant List (obtained from the California Native Plant Society)

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Perennial Herbs (continued)										
Persicaria punctata	Water Smartweed	0.49 - 3.3 ft					X			D
Phyla nodiflora	Common Lippia	2.4 - 6 in					X			
Pluchea odorata [a]	Marsh Fleabane	2 - 4 ft				X	X			
Pluchea odorata var. odorata [a]	Saltmarsh-fleabane	4.9 ft								
Potamogeton nodosus	Long-leaved Pondweed									
Primula clevelandii	Padre's Shootingstar	0.5 - 1 ft			X		X	X		D
Pseudognaphalium stramineum	Chilean Cudweed	2.3 ft						X		
Ranunculus californicus	California Buttercup	0.6 - 2.3 ft			X	X	X	X		D
Ranunculus canus	Sacramento Valley Buttercup	0.36 - 2.1 ft								
Rorippa curvisiliqua [a]	Curvepod Yellowcress	1 ft								
Rorippa palustris [a]	Bog Yellowcress	3.3 ft								
Sagittaria latifolia	Wappato	0.7 - 4.9 ft					X			
Sagittaria montevidensis										
Sagittaria montevidensis ssp. calycina										
Sagittaria sanfordii	Sanford's Arrowhead	4.3 ft								
Sanicula bipinnata	Poison Sanicle	2 ft					X			
Sesuvium verrucosum	Western Sea-purslane									
Solanum americanum [b]	American Black Nightshade	2.6 - 4.9 ft				X	X			
Solidago velutina ssp. californica	California Goldenrod	1.5 - 5 ft		X	X		X	X		E

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Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Perennial Herbs (continued)										
Spergularia macrotheca	Large Flowered Sand Spurry						X			
Spergularia macrotheca var. leucantha										
Stachys albens	White Hedge Nettle	1.6 - 8 ft				X		X	X	E
Suaeda nigra	Bush Seepweed	3 - 4.9 ft				X	X			E
Symphyotrichum subulatum var. parviflorum										
Triteleia laxa	Ithuriel's Spear	2 ft			X		X	X	X	D
Typha domingensis	Southern Cattail	13 ft				X	X			
Urtica dioica	Common Nettle									
Urtica dioica ssp. holosericea	Hoary Nettle									
Utricularia macrorhiza	Common Bladderwort						X			
Verbena bracteata	Bracted Vervain									
Shrubs										
Allenrolfea occidentalis	Iodine Bush	1 - 7 ft					X			
Baccharis pilularis	Coyote Bush	1.5 - 10 ft		X	X		X	X		E
Baccharis salicifolia	Mulefat	6 - 12 ft			X		X			E/D
Cephalanthus occidentalis	California Buttonbush	3 - 20 ft				X	X			D
Diplacus aurantiacus	Bush Monkey Flower	3.9 - 5 ft		X	X		X	X		E
Ericameria linearifolia	Linear Leaved Goldenbush	5 ft		X			X			
Erigeron foliosus var. foliosus [e]	Leafy Fleabane									
Eriogonum nudum	Nude Buckwheat	0.5 - 1 ft	X	X			X			D
Frangula californica ssp. tomentella	Hoary Coffeeberry	20 ft			X		X	X		

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Table L-3. Stanislaus County Native Plant List (obtained from the California Native Plant Society)

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Shrubs (continued)										
Gutierrezia californica [b]	California Matchweed	1 - 2 ft		X			X			D
Isocoma acradenia	Alkali Goldenbush	3.3 ft								
Isocoma acradenia var. bracteosa										
Lupinus albifrons	Silver Lupine	3.2 - 5 ft		X			X			E
Lupinus albifrons var. albifrons	Silver Lupine	3 - 5 ft					X			
Quercus wislizeni [f]	Interior Live Oak	15 - 50 ft		X	X		X	X		E
Rosa californica	California Wildrose	8 - 10 ft			X	X	X	X	X	D
Rubus ursinus [g]	Pacific Blackberry	2 - 6 ft				X	X	X	X	D
Salix exigua [f]	Sandbar Willow	10 - 23 ft				X	X			D
Salix exigua var. hindsiana [f]	Sandbar Willow	16.4 ft						X		D
Salix lasiandra var. lasiandra [f]	Yellow Willow	33 - 53 ft						X		D
Salix lasiolepis [f]	Arroyo Willow	7 - 35 ft				X	X			D
Sambucus nigra [f]	Black Elderberry	13.1 - 30 ft			X					D
Sambucus nigra ssp. Caerulea [f]	Blue Elderberry	20 - 30 ft			X		X	X	X	D
Senecio flaccidus	Threadleaf Ragwort	5 ft	X	X			X			
Senecio flaccidus var. douglasii	Douglas' Groundsel	5 ft					X			
Solanum americanum [b]	American Black Nightshade	2.6 - 4.9 ft				X	X			
Solanum umbelliferum	Bluewitch Nightshade	3.3 ft		X			X	X		D
Toxicodendron diversilobum [g]	Poisonoak	1.6 - 13 ft			X		X	X		D
Vitis californica [g]	California Grape	10 - 40 ft			X	X	X	X		D

Table L-3. Stanislaus County Native Plant List (obtained from the California Native Plant Society)

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Succulents										
Crassula aquatica [c]	Water Pygmyweed									
Crassula connata [c]	Pygmy-weed	0.8 - 4 in								
Leptosyne stillmanii [c]	Stillman's Coreopsis	0.16 - 1 ft					X			
Trees [6] - ***Consult with Public Works Department – Trees and Forestry Services prior to the selection of trees***										
Acer negundo	Box Elder	35 - 66 ft				X	X	X		D
Aesculus californica	California Buckeye	13.1 - 39.4 ft		X	X		X	X		D
Alnus rhombifolia	White Alder	49.2 - 82 ft				X	X	X		D
Fraxinus latifolia	Oregon Ash	35 - 82 ft			X	X	X	X		D
Juglans hindsii	Northern California Black Walnut	60 ft			X	X	X			
Populus fremontii	Fremont Cottonwood	39.4 - 114.8 ft				X	X			D
Populus fremontii ssp. fremontii	Fremont Cottonwood	66 ft					X			
Quercus douglasii	Blue Oak	16 - 82 ft			X		X	X		D
Quercus lobata	Valley Oak	60 - 100 ft			X		X			D
Sambucus nigra [f]	Black Elderberry	13.1 - 30 ft			X					D
Sambucus nigra ssp. Caerulea [f]	Blue Elderberry	20 - 30 ft			X		X	X	X	D
Salix exigua [f]	Sandbar Willow	10 - 23 ft				X	X			D
Salix exigua var. hindsiana [f]	Sandbar Willow	16.4 ft						X		D

[6] Consult with the City Trees and Forestry Services to identify which trees are appropriate for a given location and desired outcome/use [209-342-2253].

Table L-3. Stanislaus County Native Plant List (obtained from the California Native Plant Society)

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Salix gooddingii	Goodding's Black Willow	15 - 40 ft				X	X			D
Trees (continued)										
Salix laevigata	Red Willow	30 - 50 ft				X	X	X		D
Salix lasiandra [f]	Shining Willow	3 - 30 ft				X		X		D
Salix lasiolepis [f]	Arroyo Willow	7 - 35 ft				X	X			D
Quercus wislizeni [f]	Interior Live Oak	15 - 50 ft		X	X		X	X		E
Vines										
Clematis ligusticifolia [h]	Virgin's Bower	1 - 30 ft			X			X	X	D
Cuscuta californica [d]	Chaparral Dodder									
Cuscuta campestris [d]	Field Dodder									
Cuscuta subinclusa [d]	Canyon Dodder									
Rubus ursinus [g]	Pacific Blackberry	2 - 6 ft				X	X	X	X	D
Toxicodendron diversilobum [g]	Poisonoak	1.6 - 13 ft			X		X	X		D
Vicia hassei [d]	Slender Vetch	0.7 - 2.3 ft								
Vitis californica [g]	California Grape	10 - 40 ft			X	X	X	X		D

Reference: California Native Plant Society website https://calscape.org/

Notes:

[a] Annual herb, Perennial herb

[b] Annual herb, Perennial herb, Shrub

[c] Annual herb, Succulent

[d] Annual herb, Vine

[e] Perennial herb, Shrub

[f] Shrub, Tree

[g] Shrub, Vine

[h] Vine, Perennial herb

APPENDIX M

STANDARD CALCULATIONS FOR DIVERSION STRUCTURE DESIGN

APPENDIX M. STANDARD CALCULATIONS FOR DIVERSION STRUCTURE DESIGN

Introduction

Stormwater runoff in excess of the water quality flow (WQF) or volume (WQV) is to be diverted around or through the treatment control measure. This appendix provides equations and design criteria necessary to design diversion structures to divert stormwater runoff in excess of the WQV or WQF around or through the treatment control measures.

Diversion Structure Design

Capture or isolation of the WQV is typically achieved by employing one of the following techniques:

- Divert the WQV 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 WQV 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 WQF or WQV is treated and retained and stormwater runoff that exceeds the WQV or WQF is diverted or bypassed, untreated, directly to the downstream storm drain system or rockwells.

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 WQF or WQV. 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 M-1** illustrates the more commonly used diversion structures. The height of the weir to divert the flow is determined as follows:

<u>Treatment Control Measures Designed Based on the WQV</u>

1. Determine the WQV (**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 WQV is being stored.

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

$$Q_d = C \times L \times h^{1.5}$$ *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 M-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 M-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)

Treatment Control Measures Designed Based on the WQF

1. Establish the size of the on-site drainage system (pipe diameter or dimensions) based on the drainage design storm

2. Determine the WQF (**Section 6**)

3. Determine the depth of flow in the on-site drainage system when carrying the WQF using Manning's equation (eqn H-2)

eqn H-2

Where

WQF = 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 WQF. 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 WQV 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.

Bypassing Flows through Infiltration and Sedimentation/Filtration Treatment Control Measures

Weirs, orifices or pipes in treatment control measures are used to bypass runoff in excessive of the WQV and WQF. 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 WQV. To design the weir, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the WQV.

Orifices

Orifices can be considered in place of weirs or pipes. To avoid drawing floatables into the bypass, a hooded orifice (**Figure M-2**) should be designed using the equation H-3:

Q_d = C xA x $(2gh)^{0.5}$ *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 WQV. Use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the WQV 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 WQV. To do this, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the WQV 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 (**Figure M-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 (**Figure M-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 (eqn H-4) using the peak flow of the drainage design storm and assuming they are flowing full. Under these conditions, Manning's equation reduces to:

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.

Routing Excess Runoff Through a Vegetated Swale

The depth of flow in a Vegetated Swale at WQF is determined using a roughness coefficient of 0.2. If additional flows beyond the WQF 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 WQF 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:

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”);

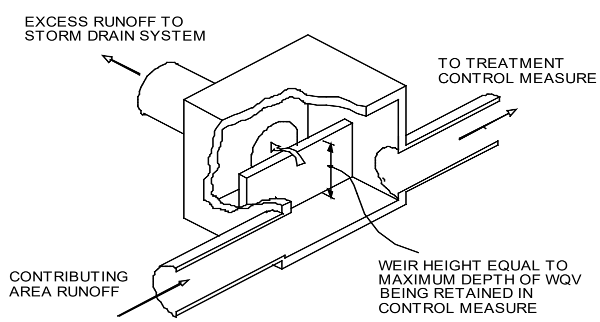
2. Use the estimated roughness coefficient to determine the depth of flow using trial and error solution of Equation H-2 substituting the peak flow of the drainage design storm for the WQF;

3. Use the calculated depth to determine the wetted perimeter for the drainage system;

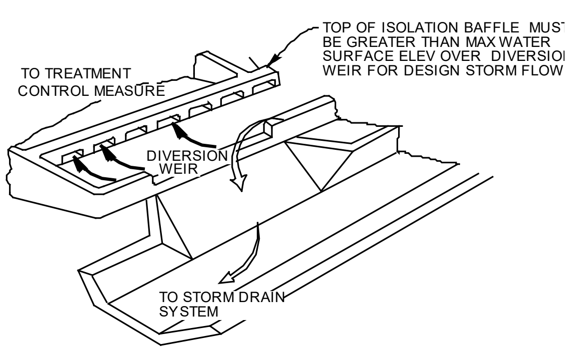
4. Use the wetted perimeter associated with each “n” for the drainage system and using Equation H-5 to calculate the equivalent roughness coefficient (calculated “n_e”), and compare to the estimated “n_e”; and

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 M-1. Common Diversion Structures at Inlets

North Tennessee Water Quality BMP Manual Design and Maintenance of Structural BMPs. (2008). (tech.).

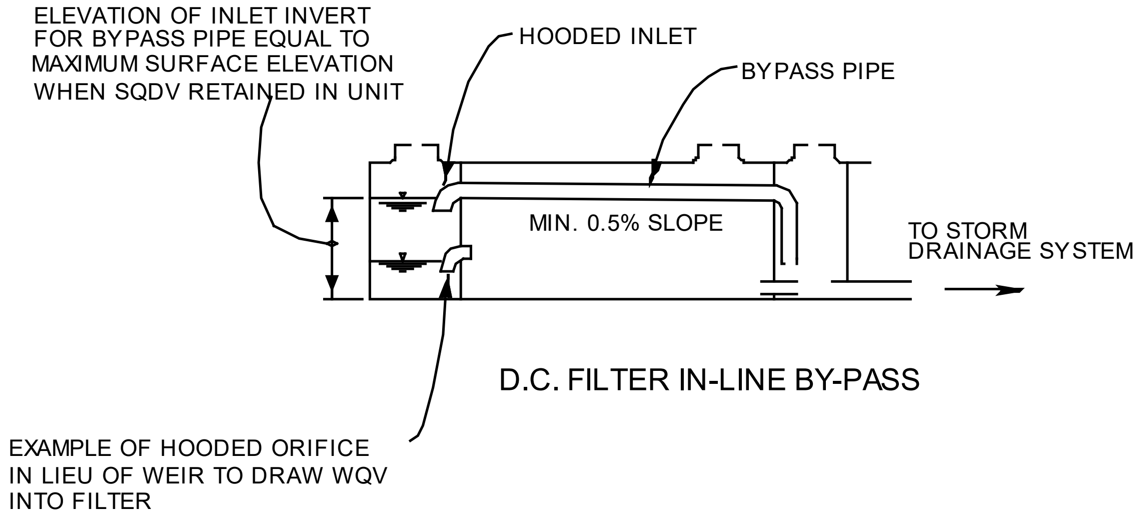


Figure M-2. Illustration of Pipe Bypass in Infiltration Trench
North Tennessee Water Quality BMP Manual Design and Maintenance of Structural BMPs. (2008). (tech).

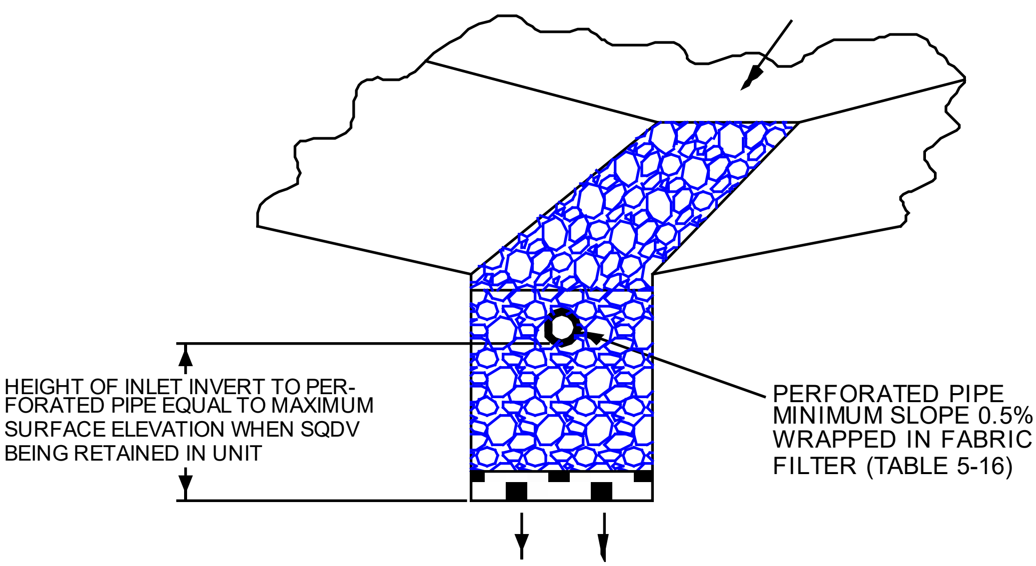


Figure M-3. Ilustration of Pipe Bypass in a Filtration Device
North Tennessee Water Quality BMP Manual Design and Maintenance of Structural BMPs. (2008). (tech.).

APPENDIX N

APPROVED PROPRIETARY CONTROL MEASURES

APPENDIX N. APPROVED PROPRIETARY CONTROL MEASURES

This appendix lists proprietary stormwater treatment devices that have been approved by the City for general use in new development and significant redevelopment projects. As noted within the Guidance Manual (**Section 5**), projects must first show that the volume retention requirement (VRR) is met through the use of volume retention measures (VRMs) prior to the utilization of conventional treatment controls.

*It should be noted that **Appendix I** does not include devices approved for trash control. For a list of certified and/or agency-approved devices contact the City. In addition, vector breeding considerations must be addressed when considering what types of trash treatment controls to implement due to the potential nuisance and human health effects. Those devices that have been reviewed and approved by Vector Control are identified within the State's certified list of trash treatment control devices and should be confirmed with the City.*

To provide a rational basis for approval of proprietary devices, the City has elected to recognize as approved for general and pilot use those proprietary devices that have been approved for general, conditional, or pilot use by other selected major stormwater programs that have established and are actively conducting a comprehensive testing protocol and approval process. Currently, the City recognizes the lists of proprietary devices approved for general, conditional, and pilot use as well as trash capture systems from the following stormwater programs:

- Sacramento Stormwater Quality Partnership (website: http://www.sacstormwater.org/)
- State of Washington Department of Ecology Stormwater Program (website: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html)
- State Water Board Certified Full Capture System List of Trash Treatment Control Devices (website: www.waterboards.ca.gov/water_issues/programs/stormwater/trash_implementation.html)

The City may recognize lists from other programs in the future and will update **Appendix I** accordingly.

APPENDIX O

EXAMPLE CALCULATION

APPENDIX O. EXAMPLE CALCULATION

This Appendix provides an example calculation to illustrate the application of the volume retention requirements (VRR), volume retention measures (VRMs), tributary impervious area credit and low impact development (LID)-based Treatment Control Measures. The calculation begins at Step 5, Apply VRMs. Real world development applications should also adhere to Steps 1 – 4 as described in **Section 2**.

SITE CONDITIONS

A commercial site design (**Figure O-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 retention Measures

The sub steps for Step 5 as described in **Section 5** are as follows:

- Calculate the VRR (post - pre)
- Select VRMs
- Determine volume retention
- Determine remaining VRR
- Determine tributary impervious area credits

Calculate Volume retention 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 *(0.51/12))
Disturbed soils	76,750	0.91	0.25	0.228	
Undisturbed open space /trees	7,250	0.09	0.05	0.004	
Total	**84,000**			**0.233**	**831**

Post-Project Volume

Site Element	Element Area ft²	Fraction of Total Area	Runoff Coefficient	Weighted Runoff Coefficient (Fraction of Total Area * Runoff Coefficient)	0.51-inch Storm Volume, ft³ (Total Project Area * Total Weighted Runoff Coefficient * (0.51/12))
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
VRR (post – pre)					**1,816**

Select Volume retention Measures & Determine Volume retention

Thirty-four evergreen, Interception Trees were selected as the VRMs for this site. Additional details on Interception Trees can be found in Fact Sheet V-3.

Parameter	Unit	Value
No. of trees	ea	34
Avg. canopy diameter	ft	20
Unit projected canopy area (area of tree projected over impervious area)	ft²	314
Total canopy area (unit projected canopy area * no. of trees)	ft²	10,676
Percent interception	%	40%
Volume retention (0.51” * Total canopy area * Percent interception / 12 in/ft)	ft³	**181**

Determine Remaining Volume retention Requirement

Remaining VRR (VRR – Interception Tree Volume retention):

1,816 ft³ – 181 ft³ = 1,635 ft³

Determine Tributary Impervious Area Credits

Each VRM fact sheet describes how impervious area credits are calculated. See Fact Sheet V-3 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

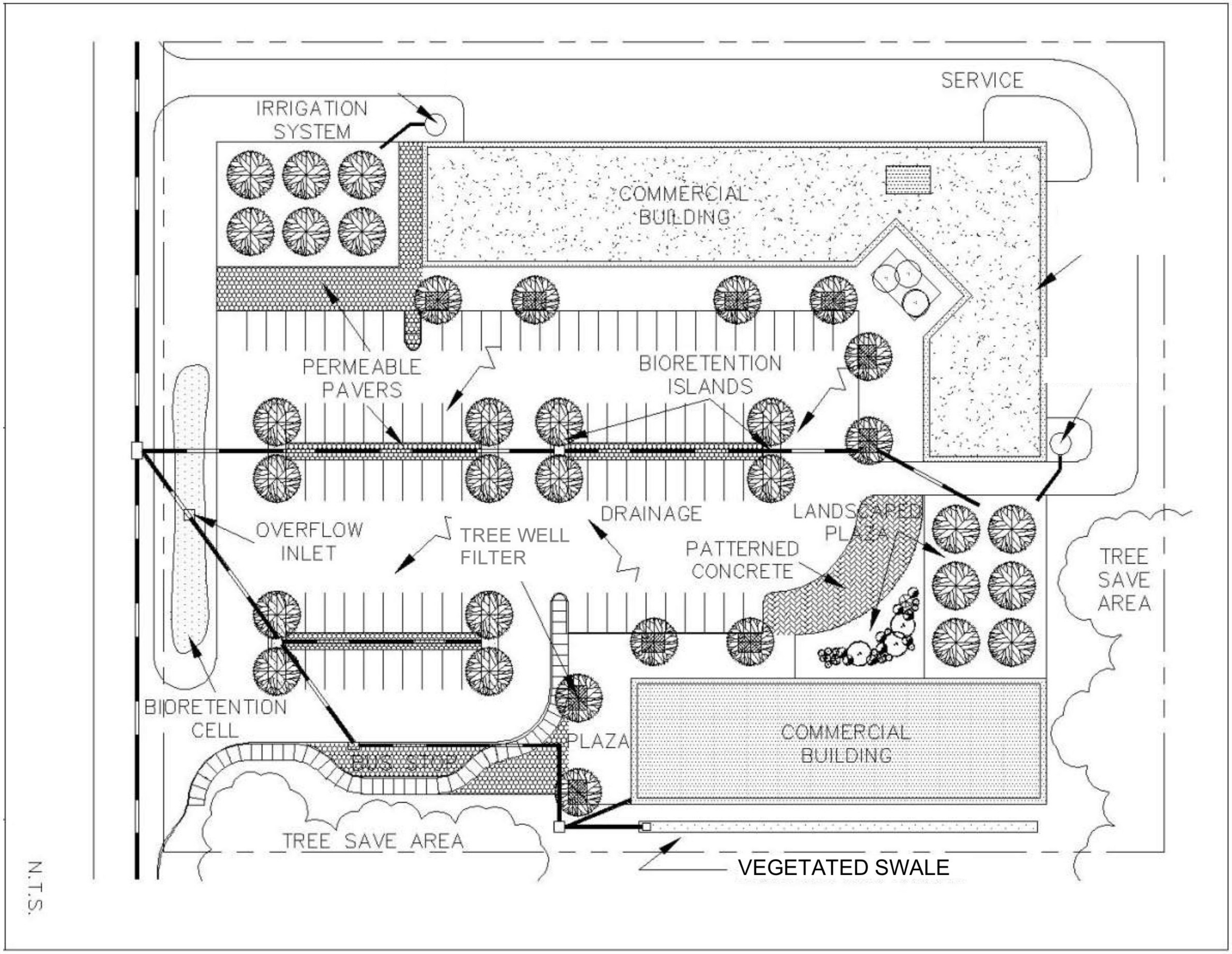


Figure O-1. Example Commercial Site Design. Modified from LID Center. *Source: Guillette, A. (n.d.). Anne Guillette, LEED Accredited Professional Low Impact Design Studio (formerly with the Low Impact Development Center). Low Impact Development: An Alternative Site Design Strategy. https://doi.org/2016*

STEP 6: APPLY LID TREATMENT CONTROLS

If VRR was not met through use of VRMs (Step 5), LID-based Treatment Control Measures must be used to further reduce volume. Treatment control measures must be designed to treat the WQF or WQV.

In this example calculation, the VRR was not fully met through the use of Interception Trees, as a result, the development will also apply the following LID-based Treatment Controls:

- Parking Lot Bioretention
- Vegetated Swale
- Bioretention Cell
- Tree-well Filter

Calculations for each of the LID-based Treatment Control Measures 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
WQV[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 retention (Depth of ponding zone * Bioretention area * 0.25) + (Depth of planting zone * Bioretention area * 0.1)	ft^3	430

1: WQV 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
WQV[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 retention (Depth of ponding zone * Swale area * 0.25) + (Depth of planting zone * Swale area * 0.1)	ft^3	253

1: WQV is treatment volume required; Treatment volume provided is the amount of treatment actually provided by vegetated swale

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
WQV[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 retention (Depth of ponding zone * Total filter area * 0.25) + (Depth of planting zone * Total filter area * 0.1)	ft^3	65

1: WQV 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 RETENTION

Control Measure	Units	Volume retention
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 retention	ft^3	**1,838**
VRR	ft^3	1,816

APPENDIX P

REFERENCES

APPENDIX P. REFERENCES

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