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CITY OF DAVIS

# Manual of Stormwater Quality Control Standards for New Development and Redevelopment

*prepared by*

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**Appendices**

# 1.0 Background, Goals, and Subject Projects

## 1.1 BACKGROUND

In 1972, the Federal Water Pollution Control Act (also referred to as the Clean Water Act (CWA)) was amended to provide that the discharge of pollutants to Waters of the United States from any point source be prohibited unless the discharge is in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. In 1987, further amendments to the CWA added Section 402(p), which established a framework for regulating municipal and industrial stormwater discharges under the NPDES program through a two-phase implementation plan. Phase I regulations promulgated in 1990 require metropolitan areas with a population greater than 100,000 (medium and large municipal separate storm sewer systems (MS4s)) and specific categories of industrial facilities to obtain an NPDES permit for stormwater discharges. Phase II regulations promulgated in 1999 require permits for stormwater discharges from small MS4s (population less than 100,000) and from construction sites disturbing between one and five acres of land.

The City of Davis (City) has a population of 64,401 (as of January 1, 2005), so it is subject to Phase II stormwater regulations under NPDES General Permit No. CAS000004, also known as the Phase II General Permit (Permit). The City's storm drain system serves the entire City – but not the unincorporated area of El Macero – and is divided into 11 basins. Rainfall runoff flows by gravity into the City's wet pond and five flood control facilities.[1] Pump stations lift water from these areas into main drainage channels: the Covell Drainage Channel, Channel A, Mace Ranch Park Drainage Channel, and the El Macero Drainage Channel. These channels ultimately drain to Willow Slough Bypass or the Yolo Basin Wetlands, Davis Site, east of the City.

Under provision D.2.e. of the Permit, the City is required to develop, implement, and enforce a Post-Construction Stormwater Management in New Development[2] and Redevelopment[3] Program to address stormwater runoff from new development and redevelopment projects by ensuring that controls are in place to prevent or minimize water quality impacts. The program emphasizes all aspects of pollution control including, but not limited to, regulatory mechanisms, public education, low impact design strategies, source controls, treatment controls, and adequate long-term operation and maintenance of these controls.

The program also requires the City to specify controls for post-construction runoff from new development and redeveloped areas. This Manual of Stormwater Quality Control Standards for New Development and Redevelopment (Manual) establishes standards for stormwater quality

[1] The City's flood control facilities do not currently meet the retention time specifications for Extended Detention Basins (T-5), but they provide some degree of pollutant removal.

[2] **New Development** – Land-disturbing activities; structural development, including construction or installation of a building or structure, creation of impervious surfaces; and land subdivision (as defined in Permit).

[3] **Redevelopment** – Under Attachment 4 and City of Davis policy, redevelopment is defined as a net increase in impervious area of 5,000 square feet or more on an already-developed site. Redevelopment includes, but is not limited to: the expansion of a building footprint or addition of a structure; structural development including an increase in gross floor area and/ or exterior construction or remodeling; and land disturbing activities related with structural or impervious surfaces. Where redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing development, and the existing development was not subject to these Design Standards, the Design Standards apply only to the addition, and not to the entire development (as defined in Permit).

control measures and provides guidance on their design and implementation. Control measures include general site design controls for low impact development (LID), source controls, and treatment controls. "General Site Design Control Measures for Low Impact Development (LID)," as used in this Manual, refer to site design strategies and features that primarily help to limit stormwater runoff volumes and peak flows from project sites but can also provide some degree of pollutant removal. These LID control measures are required for all Categorical new development and redevelopment projects. "Source Control Measures" and "Treatment Control Measures," as used in this Manual, refer to Best Management Practices (BMPs) and features incorporated in the design of a land development or redevelopment project that prevent and/or reduce pollutants in stormwater runoff from the project site. Source Control Measures prevent or limit the exposure of materials and activities to rainfall to prevent potential pollutants from being released into stormwater runoff. Treatment Control Measures are engineered systems that reduce pollutants in runoff to comply with the Permit requirements to prevent or minimize water quality impacts.

## 1.2 GOALS

This Manual has been prepared by the City of Davis to accomplish the following goals:

- Assist new developments in reducing urban runoff pollution to prevent or minimize water quality impacts;
- Ensure the implementation of measures in this Manual is compliant with the Permit and other State requirements;
- Provide standards for developers, design engineers, agency engineers, and planners to use in the selection, design, and implementation of General Site Design Control Measures for LID and appropriate Site-Specific Source and Treatment Control Measures; and
- Provide maintenance procedures to ensure that the selected control measures will be maintained to provide effective, long-term pollution control.

## 1.3 PROJECT CATEGORIES SUBJECT TO STANDARDS

Under Attachment 4 to the Permit and City of Davis policy, the types of new development and significant redevelopment projects that are required to implement the controls identified in this Manual include the following:

1. **Significant Redevelopment –** Under Attachment 4 and City of Davis policy, significant redevelopment is defined as a net increase in impervious area of 5,000 square feet or more on an already-developed site. Significant redevelopment includes, but is not limited to, expansion of a building footprint or addition or replacement of a structure; structural development including an increase in gross floor area and/or exterior construction or remodeling; replacement of impervious surface that is not part of a routine maintenance activity; and land disturbing activities related with structural or impervious surfaces. Where significant redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing development, and the existing development was not subject to development standards under this Manual, the numeric sizing criteria listed for items 2 through 8 below applies only to the addition, and not to the entire development. Conversely, if the redevelopment results in an increase of fifty percent or

more of the impervious surfaces of a previously existing development, then the entire development (new plus existing areas) are subject to development standards under this Manual.

2. **Single-family hillside residences –** "Hillside" refers to property located in an area with known erosive soil conditions where the development contemplates grading on any natural slope that is twenty-five percent or greater.

3. **Commercial development –** Under Attachment 4 and City of Davis policy, commercial development is defined as any development on undeveloped private land that is not for heavy industrial or residential use where the total impervious area created is greater than or equal to 5,000 square feet. The category includes, but is not limited to, hospitals, laboratories and other medical facilities; educational institutions; recreational facilities; commercial nurseries; multi-apartment buildings; car wash facilities; mini-malls and other business complexes; shopping malls; hotels; office buildings; public warehouses; and other light industrial facilities.

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

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

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

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

8. **Parking lots 5,000 square feet or more or with 25 or more parking spaces and potentially exposed to stormwater 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 for commerce.

The standards set forth in this Manual shall apply to all new development projects for which an application has not been deemed complete prior to the adoption of the Manual. Projects which have received approval, but for which construction drawings have not been approved, are strongly encouraged to incorporate these standards to the fullest extent practicable.

In addition to the Phase II General Permit requirements, as set forth in this Manual, owners/developers of some sites in the City may also be subject to the State of California's Industrial Storm Water General Permit, Order 97-03-DWQ (Industrial General Permit) and General Permit for Storm Water Discharges Associated with Construction Activity, Order 99-08-DWQ (Construction General Permit). The control measures provided in this Manual may assist the owner/developer in meeting the requirements of the State's permits.

# 2.0 Overview and Use of the Manual

## 2.1 INTRODUCTION

The stormwater pollution control measures detailed in this Manual include the following:

- General Site Design Control Measures for Low Impact Development (LID)
- Site-Specific Source Control Measures
- Treatment Control Measures

A summary of the above control measures is provided in **Section 2.2**. These control measures, for the purposes of this Manual, apply to infill and new development and redevelopment project categories listed in Attachment 4 of the Permit (see **Section 1.3**). Applicable new development and redevelopment project categories are listed in **Table 2-1** along with the categories of pollutants likely to be present in stormwater runoff from project areas.

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

| New Development and Redevelopment Project Category | Pollutant Category of Concern | | | | | | |
|---|---|---|---|---|---|---|---|
| | Sediment | Nutrients | Trash | Metals | Bacteria | Oil & Grease | Toxic Organics |
| Single-Family Hillside Residences | X | X | X | X | X | X | X |
| Commercial Developments | X | X | X | X | X | X | X |
| Automotive Repair Shops | X | | X | X | | X | X |
| Retail Gasoline Outlets | X | | X | X | | X | X |
| Restaurants | | X | X | | X | X | X |
| Home Subdivisions (≥ 10 units) | X | X | X | X | X | X | X |
| Parking Lots (≥ 5,000 SF or ≥ 25 spaces) | X | | X | X | | X | X |

X = Pollutant likely to be present in stormwater runoff from project area

## 2.2 SUMMARY OF STORMWATER POLLUTION CONTROL MEASURES

The categories of stormwater pollution control measures specified in this Manual are summarized in **Table 2-2** along with their associated Fact Sheets, primary objectives, and applicable projects. The General Site Design Control Measures for LID described in this Manual are intended primarily to limit stormwater runoff volumes and peak flows but can also provide some degree of pollutant removal. The Site-Specific Source Control Measures and Treatment Control Measures are intended to prevent and reduce pollutants in stormwater runoff and are often referred to as BMPs.

**Table 2-2. Summary of Required Stormwater Pollution Control Measures**

| Control Measure Category | Fact Sheets | Primary Objective | Applicable Projects |
|---|---|---|---|
| General Site Design Control Measures for LID | D-1 to D-4 (**Section 3**) | Minimize the volume and rate of stormwater runoff discharge from the project site | Categorical new development and redevelopment projects; Non-categorical projects as determined necessary by Public Works |
| Site-Specific Source Control Measures | S-1 to S-7 (**Section 4**) | ▪ Prevent potential pollutants from contacting rainwater or stormwater runoff<br>▪ Prevent discharge of contaminated runoff to the storm drain system or receiving water | Specific outdoor activities and development features:<br>1. Storm Drain Inlets<br>2. Outdoor Storage Areas<br>3. Trash Storage Areas<br>4. Loading/Unloading Dock Areas<br>5. Repair/Maintenance Bays<br>6. Vehicle/Equipment/ Accessory Wash Areas<br>7. Fueling Areas |
| Treatment Control Measures | T-1 to T-11 (**Section 5**) | Remove pollutants from stormwater runoff prior to discharge to the storm drain system or receiving water | Categorical new development and redevelopment projects<br>▪ Requires one or more approved treatment control measures |

General Site Design Control Measures for LID and Site-Specific Source Control Measures are generally the most effective means to control urban runoff pollution because they minimize the need for treatment and are required for all applicable projects. In addition, Treatment Control Measures are required to meet the NPDES Stormwater Permit requirement to prevent or minimize water quality impacts via discharge of pollutants to the stormwater conveyance system. Treatment Control Measures are required for all projects, except as noted in the paragraph below, and may be selected from a list of approved methods. Alternative or proprietary treatment controls not described in this Manual may be considered on a case-by-case basis under certain limited conditions that are specified and discussed in **Section 5.5**. Moreover, proof of adequate maintenance in the form of a Maintenance Agreement and Maintenance Plan must be provided for all Site-Specific Source Control Measures and Treatment Control Measures (see **Section 6**).

New Development and Redevelopment projects that discharge stormwater runoff to City-approved stormwater treatment control facilities that comply with the design requirements of this Manual are not required to provide separate Treatment Control Measures. However, such projects are required to provide General Site Design Control Measures for LID and Site-Specific Source Control Measures in accordance with this Manual.

## 2.3 CONTROL MEASURE REQUIREMENTS AND SELECTION

To aid the user of the Manual in determining what steps need to be completed in the design process to comply with stormwater control requirements, a design decision flowchart is provided as **Figure 2-1**. A key step in the process is project assessment to determine site conditions (e.g., soils, groundwater, and topography), hydraulic conditions, receiving water quality, and expected pollutants (see **Table 2-1**), as all these factors will influence the selection of appropriate Treatment Control Measures. The selection of appropriate control measures should be a collaborative effort between the project applicant and City stormwater staff. It is recommended that discussions between project planners, engineers, and City stormwater staff regarding selection of controls measures occur early in the design process.

If the project is determined by the City to be a Categorical new development and redevelopment project (see **Section 1.3** and **Table 2-1**), the project must be designed to include the control measures specified in this Manual. In addition:

- Projects that are non-Categorical new development and redevelopment projects are still subject to City stormwater staff review. Stormwater controls may be required by the City for non-Categorical projects depending on the potential for discharge of pollutants in stormwater runoff.
- City stormwater staff may accept alternative programs for stormwater pollution control provided that it can be demonstrated to the satisfaction of City stormwater staff that such programs provide a level of stormwater pollution control equivalent to that specified under this Manual.

A matrix of new development and redevelopment project categories and required stormwater pollution control measures is presented in **Table 2-3** to aid the Manual user in determining what controls are required for various project categories. Detailed descriptions, design criteria, and procedures for the three types of control measures are presented in fact sheet format in **Sections 3, 4,** and **5** of the Manual for General Site Design Control Measures for LID, Site-Specific Source Control Measures, and Treatment Control Measures, respectively.

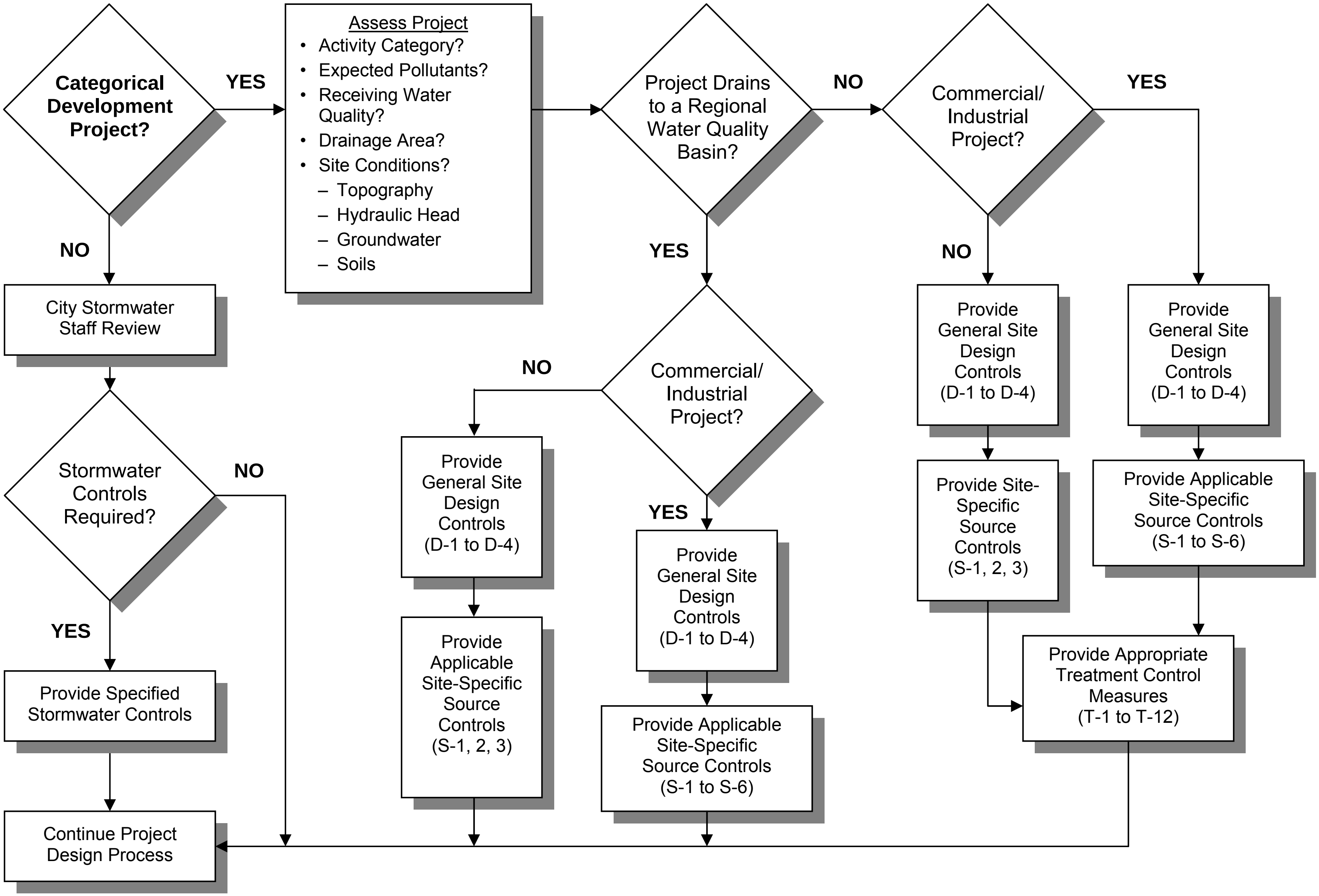



**Figure 2-1. Stormwater Control Measure Design Decision Flowchart**

## Table 2-3. Control Measure Selection Matrix for New Development and Redevelopment Project Categories

| New Development and Redevelopment Project Category | General Site Design Control Measures[a] | | | | Site-Specific Source Control Measures[b] | | | | | | Treatment Control Measures[c] | Other[d] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Conserve Natural Areas (D-1) | Protect Slopes and Channels (D-2) | Minimize Impervious Area (D-3)<br>D-3.1: Minimize Sidewalk and Street Widths<br>D-3.2: Minimize Impervious Footprint<br>D-3.3: Cluster Development<br>D-3.4: Use Porous Paving Materials | Minimize Effective Imperviousness (D-4)<br>D-4.1: LID Grass Channel/Swale<br>D-4.2: LID Grass Filter Strip<br>D-4.3: LID Stormwater Planter<br>D-4.4: LID Porous Pavement Filter<br>D-4.5: LID Vegetated Swale<br>D-4.6: LID Trench/Vault | Storm Drain Message and Signage (S-1) | Outdoor Storage Area Design (S-2) | Trash Storage Area Design (S-3) | Loading/Unloading Dock Area Design (S-4) | Vehicle/Equipment/Accessory Wash Area Design (S-5) | Fueling Area Design (S-6) | · Grass Swale (T-1)<br>· Grass Filter Strip (T-2)<br>· Wet Pond (T-3)<br>· Constructed Wetland Basin (T-4)<br>· Extended Detention Basin (T-5)<br>· Infiltration Trench/Vault (T-6)<br>· Infiltration Basin (T-7)<br>· Vegetated Swale (T-8)<br>· Stormwater Planter (T-9)<br>· Media Filter (T-10)<br>· Porous Pavement Filter (T-11)<br>· Alternative/Proprietary Treatment Control Measures[e] | Proof of Control Measure Maintenance |
| Single-Family Hillside Residences | R | R | R | R[f] | R | R[g] | – | – | – | – | S | R |
| Commercial Developments | R | R | R | R[f] | R | R[g] | R[g] | R[g] | R[g] | R[g] | S | R |
| Automotive Repair Shops | R | R | R | R[f] | R | R[g] | R[g] | – | R[g] | R[g] | S | R |
| Retail Gasoline Outlets | R | R | R | R[f] | R | R[g] | R[g] | – | R[g] | R | S | R |
| Restaurants | R | R | R | R[f] | R | R[g] | R[g] | R[g] | R[g] | – | S[h] | R |
| Home Subdivisions (≥ 10 units) | R | R | R | R[f] | R | R[g] | – | – | – | – | S | R |
| Parking Lots (≥ 5,000 SF or ≥ 25 spaces) | R | R | R | R[f] | R | R[g] | R[g] | – | – | – | S | R |

Notes:
(a) Refer to Fact Sheets in Section 3 for detailed information and design criteria
(b) Refer to Fact Sheets in Section 4 for detailed information and design criteria
(c) Refer to Fact Sheets in Section 5 for detailed information and design criteria
(d) Refer to Section 6 for detailed information on Control Measure Maintenance
(e) Use only on a case-by-case basis with City stormwater staff approval or in combination with other applicable treatment control measures
R Required if applicable to project
R[f] Required unless shown to be infeasible based on site conditions. Select one or more applicable control measures.
R[g] Required if outdoor activity area is included in the project
S Select one or more applicable treatment control measures from list above unless project drains to a regional basin
S[h] Restaurants with less than 5,000 SF impervious area are not required to provide treatment control measures

## 2.4 PROJECT STORMWATER QUALITY CONTROL PLAN AND PROJECT REVIEW PROCESS

Categorical new development and redevelopment projects (as defined in **Section 1.3**) subject to the requirements of the standards described in this Manual must submit a Project Stormwater Quality Control Plan (SWQCP) that adequately demonstrates that the proposed New Development or Redevelopment project will conform to all requirements of the standards. The SWQCP must be submitted in addition to the Stormwater Pollution Prevention Plan (SWPPP) required for all construction projects.

The Project SWQCP must be approved by the Public Works Department before building permits will be issued for the project. Project SWQCPs should conform to the content and format requirements indicated in **Appendix D-1** of this document and should be submitted to Public Works. Design calculations for all stormwater quality control features must be submitted along with the SWQCP to support the design(s). A flowchart depicting the City's project SWPPP and SWQCP review and approval process is provided as **Figure 2-2**.

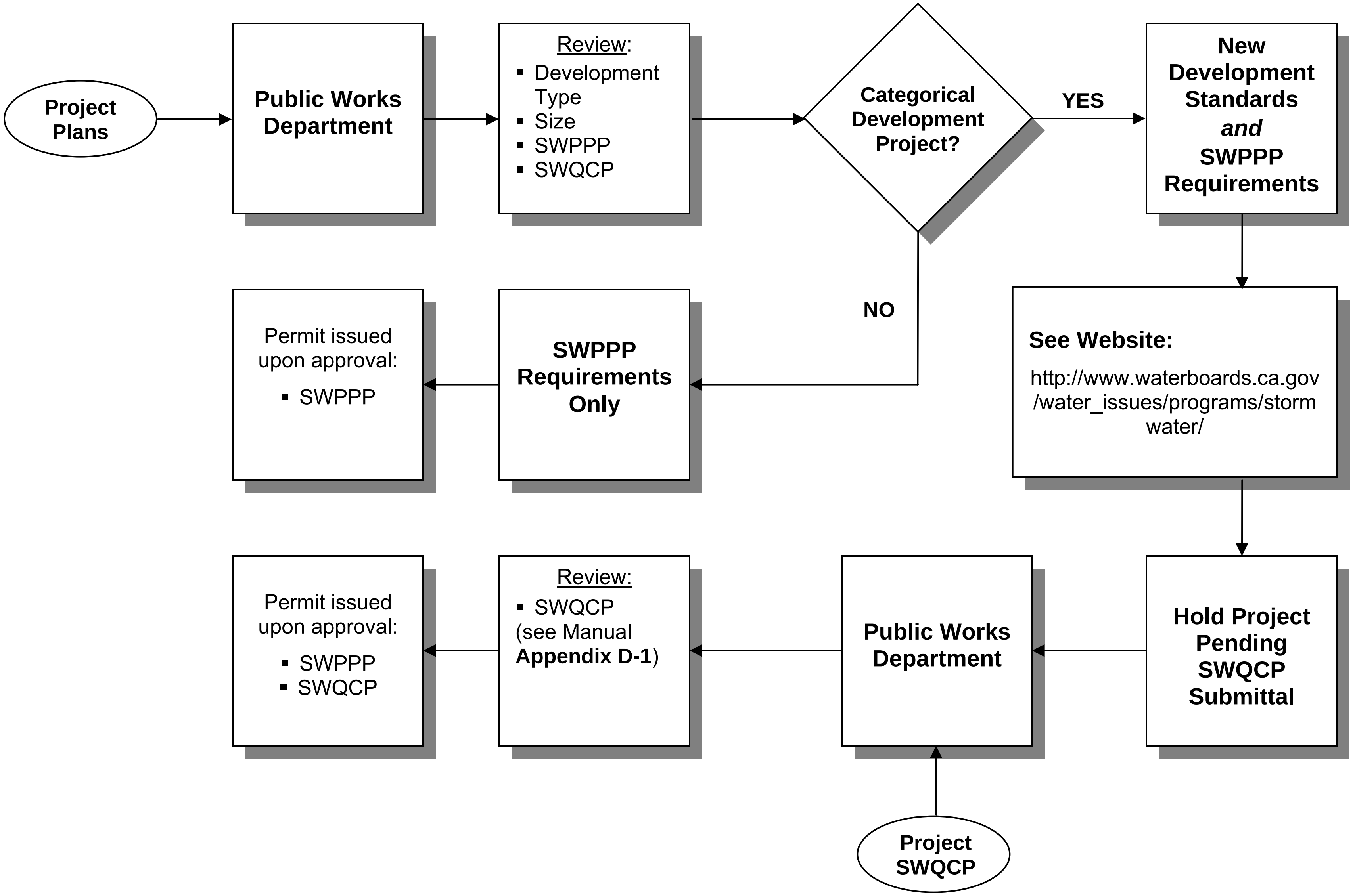



**Figure 2-2. Project Stormwater Pollution Prevention Plan (SWPPP) and Stormwater Quality Control Plan (SWQCP) Review Process Flowchart**

# 3.0 Site Design Control Measures

## 3.1 INTRODUCTION

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

- Reduced size of downstream Treatment Control Measures and conveyance systems;
- Reduced pollutant loading to downstream Treatment Control Measures;
- Reduced hydraulic impact on receiving streams; and
- Improved groundwater recharge.

Historically, site design techniques have focused on the efficient conveyance of stormwater away from a site, often resulting in disruption of the natural hydrology of the area. Such techniques can lead to the loss of natural water storage, increased impervious surface area, and increased runoff velocity. In this section, a more comprehensive approach to site design is presented which identifies techniques that prioritize not only water quality but also reduced impact on natural hydrology. Site Design Control Measures (also referred to as LID Control Measures) store, infiltrate, evaporate, and detain runoff and are incorporated throughout the site landscape rather than being applied at the point of discharge.

This section includes Fact Sheets on Control Measures for:

- Conserving natural areas (**Fact Sheet D-1**);
- Protecting slopes and channels (**Fact Sheet D-2**);
- Minimizing impervious area (**Fact Sheet D-3**); and
- Reducing effective imperviousness (**Fact Sheets D-4.1** through **D-4.6**).

Although the Site Design Control Measures for reducing effective imperviousness are similar to some Treatment Control Measures, they have distinct specifications. Site Design Control Measures generally do not provide sufficient retention or contact time to be considered Treatment Control Measures.

## 3.2 SITE DESIGN CONTROL MEASURES

Site Design Control Measures include the following design features and considerations designated D-1 through D-4; Control Measure D-4 includes specific design standards or features that are presented in Fact Sheets D-4.1 through D-4.6. Note that Fact Sheets D-4.1 through D-4.6 are designated "LID Treatment Control Measures" to distinguish them from similarly named Treatment Control Measures.

- D-1: Conserve Natural Areas
- D-2: Protect Slopes and Channels
- D-3: Minimize Impervious Area
- D-4: Reduce Effective Imperviousness
    - D-4.1: LID Grass Channel/Swale
    - D-4.2: LID Grass Filter Strip
    - D-4.3: LID Stormwater Planter
    - D-4.4: LID Porous Pavement Filter
    - D-4.5: LID Vegetated Swale
    - D-4.6: LID Trench/Vault

The Site Design Control Measures described in this section are required for all Categorical New Development and Redevelopment projects unless:

- The project proponent demonstrates to the satisfaction of the City that the particular measures are not applicable to the proposed project, or
- The project site conditions make it infeasible to implement the site design control measure in question.

In addition, the City may, at its discretion, require any non-categorical project to implement Site Design Control Measures as determined to be feasible for the project site.

Some of the non-proprietary LID Treatment Control Measures (D-4.3 through D-4.6) described in this section incorporate natural materials, such as gravel or sand, for which specifications are provided in the Fact Sheets. Recently, manufactured products have been developed as alternatives to such materials. Project applicants may submit such products for the City's consideration and approval as alternatives to the materials specified in the Fact Sheets. Such products must meet recognized standards for properties or performance, as applicable.

# D-1: Conserve Natural Areas

## 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 (May 2001) policies:

1. Concentrate or cluster development on least-sensitive portions of a site, while leaving the remaining land in a natural undisturbed state;
2. Limit clearing and grading of native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection;
3. Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought-tolerant plants;
4. Promote natural vegetation by using parking lot islands and other landscaped areas;
5. Preserve riparian areas and wetlands.

## Purpose

Erosion of unpaved 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 this Manual.

1. Unpaved slopes must be protected from erosion by properly conveying runoff across their surface.
2. Unpaved slopes must be landscaped (i.e., planted with full cover vegetation) 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 stormwater conveyance channels and waterways. Activities and structures must conform to applicable standards and specifications of agencies with jurisdiction over particular waterways (e.g., U.S. Army Corps of Engineers, California Department of Fish and Game).

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

## Purpose

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

## Design Strategies

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

1. Reduce the footprints of building and parking lots;
2. Cluster buildings and paved areas to maximize pervious area;
3. Use minimum allowable roadway and sidewalk cross sections, driveway lengths, and parking stall widths;
4. Include landscape islands in cul-de-sacs;
5. Maximize tree preservation or tree planting;
6. Preserve areas with high infiltration rates by avoiding compacting and paving over more pervious soils;
7. Where appropriate, use pervious pavement materials such as modular paving blocks, turf blocks, porous concrete and asphalt, brick, and gravel or cobbles.
8. Use grass-lined channels or surface swales to convey runoff instead of paved gutters (see **Fact Sheet D-4.1**).

## Purpose

The impacts of flow from impervious areas can be reduced by employing an LID design strategy termed “reducing effective imperviousness”. This approach involves routing runoff from impervious areas through engineered LID stormwater treatment control measures prior to discharge to a downstream Treatment Control Measure(s), storm drainage system, or receiving water (see **Figure 3-1**). The LID Treatment Control Measures serve to reduce peak flows, reduce total runoff volume, and provide a degree of treatment that is a function of the size of the control measure. In addition to the environmental and aesthetic benefits, minimizing effective imperviousness will typically allow reduction in the size of downstream conveyance and treatment systems, yielding savings in development costs.

The LID Treatment Control Measures are similar in all respects to the full Treatment Control Measures of the same names described in **Section 5**, with the exception that the LID Treatment Control Measures do not meet the sizing or loading criteria required to achieve full treatment and, consequently, provide only partial treatment. For projects that employ the LID Treatment Control Measures described in this fact sheet in accordance with the specified design criteria, credit is provided toward reduction of the effective impervious area used in **Section 5** of this Manual to determine the dimensions of full Treatment Control Measures. Procedures to calculate treatment credits for each type of LID Treatment Control Measure are presented in individual fact sheets within this section.

## LID Stormwater Treatment Control Measures

The six LID Stormwater Treatment Control Measures described in this Manual include the following:

- D.4-1: LID Grass Swale/Channel
- D.4-2: LID Grass Filter Strip
- D.4-3: LID Stormwater Planter
- D.4-4: LID Porous Pavement Filter
- D-4.5: LID Vegetated Swale
- D.4-6: LID Infiltration Trench/Vault

These LID Treatment Control Measures function in the same manner as the full Treatment Control Measures of the same name described in **Section 5** but typically provide less efficient treatment because they are loaded at higher rates or treat less volume than the full Treatment Control Measures. For example, a Grass Filter Strip may be applied as either a Treatment Control or as an LID Treatment Control. To be considered a Treatment Control, the Grass Filter Strip must be at least 15 feet long in the direction of flow and the linear unit application rate at the Stormwater Quality Design Flow (SQDF) must be less than 0.005 cfs/ft width. A Grass Filter Strip that is less than 15 feet long or that has a linear unit application rate greater than 0.005 cfs/ft of width would be considered an LID Treatment Control because the Strip would reduce effective imperviousness but would not provide a full degree of treatment.For each of these LID Treatment Control Measures, facts sheets are presented that provide procedures and examples for calculating credits to reduce the effective impervious area used to size downstream full Treatment Control Measures.

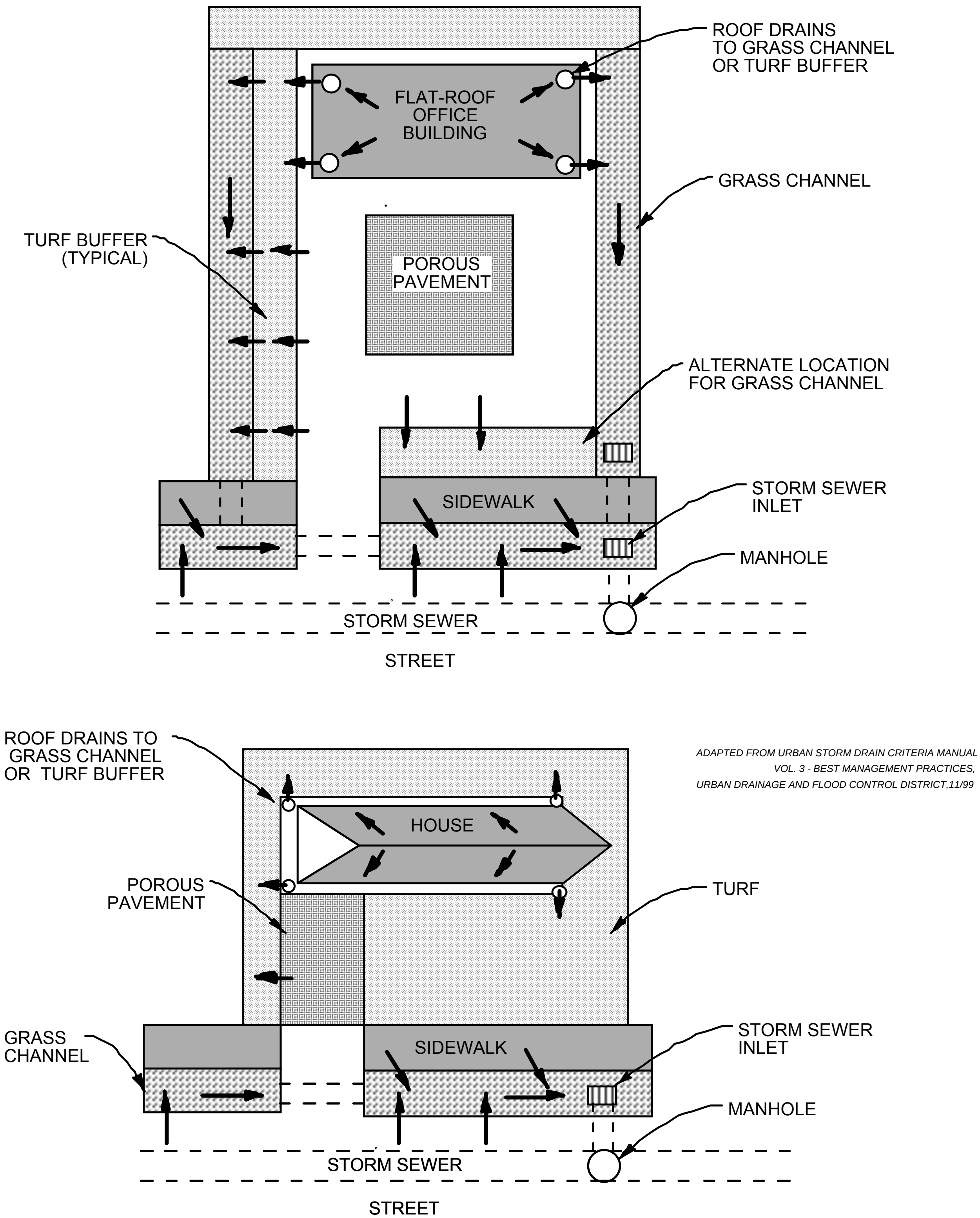



**Figure 3-1. Examples of Reducing Flow from Impervious Areas**

*Description*

Grass Swales/Channels are densely vegetated drainage ways with gentle side slopes and gradual longitudinal slopes in the direction of flow that receive runoff from impervious areas and slowly convey the runoff to downstream points of treatment and discharge. LID Grass Swales/Channels provide an opportunity for infiltration, reduce peak flows from impervious areas, and provide a degree of pollutant removal. LID Grass Swales/Channels have similar features and function in a manner similar to the full treatment Grass Swale described in **Fact Sheet T-1** in **Section 5.** Refer to **Fact Sheet T-1** for further description and discussion.

LID Grass Swales/Channels are appropriate for use in residential, commercial, industrial, and institutional settings, as illustrated in **Figure 3-1**. They are typically used in conjunction with LID Grass Filter Strips and are located adjacent to impervious areas to be mitigated. Their use should be incorporated into the site and master drainage planning, and their design should be performed in close coordination with the landscape architect. Tributary areas are typically less than 5 acres. Several LID Grass Swales/Channels may be used on a single site, each designed to receive flow from different impervious areas. Irrigation and regular mowing are required to maintain the turf grass cover.

*Design*

Design elements, construction considerations, and maintenance requirements of LID Grass Swales/Channels are similar in most respects to those of full treatment Grass Swales presented in **Fact Sheet T-1** in **Section 5**. LID Grass Swales/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 LID Grass Swales/Channels are listed in **Table 3-1** along with reference values for use in calculation of credits for reducing effective impervious area. The ratios of design values and reference values are used in the calculation of credits for reducing effective impervious area.

**Table 3-1. LID Grass Swale/Channel Design Criteria and Reference Values**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Longitudinal slope (flow direction) | 4%<br>0.5% | Maximum<br>Minimum |
| Maximum bottom width | 6 ft | |
| Maximum side slopes (H:V) | 4:1 | Side slopes to allow for ease of mowing. |
| Roughness coefficient (n) for treatment design | 0.2 | Reflects the roughness of swale when depth of flow is below the height of the grass. |
| Roughness coefficient (n) for conveyance design | 0.1 | Reflects the roughness of swale when depth of flow is above the height of the grass. Used to determine capacity of swale to convey peak hydraulic flows. |
| Vegetation | – | Turf grass (irrigated) |
| Vegetation height (typical) | 4 to 6 in. | Vegetation should be maintained at a height greater than the depth of flow at design flow rate but sufficiently low to prevent lodging or shading of the vegetation. |
| **Reference Values for Credit Calculation** | **Criteria** | **Notes** |
| Reference Design Flow ($SQDF_{ref}$) | SQDF | SQDF = 0.20 in/hr × C × A (see **Section 5**) |
| 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 |
| Treatment credit allowance factor | 40% | Percentage of calculated full treatment equivalence to account for reduced efficiency of Treatment Control Measures at higher hydraulic loading rates. |

## *Design and Credit Calculation Procedure*

### ***Step 1 – Calculate Stormwater Quality Design Flow (SQDF) for impervious area tributary to LID Grass Swale/Channel***

Using **Fact Sheet T-0** in **Section 5**, determine SQDF for area tributary to LID Grass Swale/Channel.

$SQDF_{ref} = i \times C \times A$

where

SQDF = Stormwater Quality Design Flow, cfs

i = Design storm intensity = 0.20 in/hr

C = Runoff coefficient for impervious area tributary to LID Grass Swale/Channel

$A_{imp}$ = impervious area tributary to LID Grass Swale/Channel, acres

**Example:**

C = 0.90

$A_{imp} = 40{,}000\ ft^2$

$SQDF_{ref} = 0.20 \times 0.90 \times 40{,}000/43{,}560 = 0.0149$ cfs

***Step 2 – Determine design width of Grass Swale/Channel ($W_{GS}$)***

Note: Design width of LID Grass Swale/Channel is not restricted to any value, but ease of mowing and maintenance should be considered.

**Example:**

$W_{GS}$ = 0.5 ft

***Step 3 – Determine design longitudinal slope of Grass Swale/Channel ($s_{GS}$) and side slope (H:V)***

$s_{GS}$ = 4% maximum; 0.5% minimum

H:V = 4:1

**Example:**

$s_{GS}$ = 1% = 0.01ft/ft

***Step 4 – Determine design length of Grass Swale/Channel ($L_{GS}$)***

Note: Design length of LID Grass Swale/Channel is not restricted to any minimum value

**Example:**

$L_{GS}$ = 40 ft

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

***Manning's Equation***

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

where

$Q = SQDF_{ref}$

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 velocity, and contact time at the SQDF and the design swale geometry

**Example:**

$D_{GS}$ = 0.347 ft = 4.17 in

$v_{GS}$ = 0.25 ft/sec

$t_{GS}$ = 2.65 min

***Step 6 – Calculate treatment credit for LID Grass Swale ($A_{credit}$)***

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

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

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

**Example:**

$A_{credit} = (3/4.17)^2 \times (1/0.25)^2 \times (2.65/7) \times 40{,}000$

$A_{credit} = (0.72)^2 \times (1)^2 \times 0.38 \times 40{,}000\ ft^2$

$A_{credit} = 0.20 \times 40{,}000\ ft^2 = 8{,}000\ ft^2$

***Step 7 – Calculate effective impervious area ($A_{eff}$)***

$A_{eff} = A_{imp} – A_{credit}$

**Example:**

$A_{eff} = 40{,}000 – 8{,}000 = 32{,}000\ ft^2$

*Construction Considerations*

See **Fact Sheet T-2** in **Section 5**.

*Long-Term Maintenance*

See **Fact Sheet T-2** in **Section 5**.

*Description*

An LID Grass Filter Strip is a uniformly graded and densely vegetated strip of turf grass onto which runoff flow from impervious areas is distributed uniformly across the top width of the strip to achieve sheet flow down the length of the strip. An LID Grass Filter Strip has similar features and functions in a similar manner to the full treatment Grass Filter Strip described in **Fact Sheet T-2** in **Section 5**. Refer to **Fact Sheet T-2** for further description and discussion.

LID Grass Filter Strips are appropriate for use in residential, commercial, industrial, and institutional settings as illustrated in **Figure 3-1**. They are typically located adjacent to impervious areas to be mitigated. Their use should be incorporated into the site and master drainage planning, and their design should be performed in close coordination with the landscape architect. Tributary areas are typically less than 5 acres. Several LID Grass Filter Strips may be used on a single site, each designed to receive flow from different impervious areas. Irrigation and regular mowing are required to maintain the turf grass cover. Grass Filter Strips should be located away from, or protected from, excessive pedestrian or vehicular traffic that can damage the grass cover and adversely affect achievement of sheet flow over the surface.

*Design*

Design elements, construction considerations, and maintenance requirements of LID Grass Filter Strips are similar in most respects to those of full treatment Grass Filter Strips presented in **Fact Sheet T-2** in **Section 5**. LID Grass Filter Strips differ in terms of the values used for the two principal design parameters that govern treatment performance:

- Linear application rate across the top width of the filter strip, cfs/ft width
- Down-slope length in flow direction, ft

Key design criteria and reference values for LID Grass Filter Strips are listed in **Table 3-2**. The ratios of design values and reference values are used in the calculation of credits for reducing effective impervious area.

**Table 3-2. LID Grass Filter Strips Design Criteria and Reference Values**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Minimum design length ($L_{GFS}$) | 3 ft | In flow direction |
| Slope (flow direction) | 4% | Maximum |
| | 0.5% | Minimum |
| Vegetation | – | Turf grass (irrigated) |
| Vegetation height (typical) | 2 – 4 in. | |
| **Reference Values for Credit Calculation** | **Criteria** | **Notes** |
| Reference Design Flow ($SQDF_{ref}$) | SQDF | SQDF = 0.20 in/hr × C × A (see **Section 5**) |
| Reference linear application rate ($q_{a,ref}$) | 0.005 cfs/ft width | |
| Reference length ($L_{ref}$) | 15 ft | In flow direction |
| Treatment credit allowance factor | 40% | Percentage of calculated full treatment equivalence to account for reduced efficiency of Treatment Control Measures at higher hydraulic loading rates |

## *Design and Credit Calculation Procedure*

### *Step 1 – Calculate Stormwater Quality Design Flow (SQDF) for impervious area tributary to LID Grass Filter Strip*

Using **Fact Sheet T-0** in **Section 5**, determine SQDF for area tributary to LID Grass Filter Strip.

$SQDF_{ref}$ = i × C × A

where

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

i = Design storm intensity = 0.20 in/hr

C = Runoff coefficient for impervious area tributary to LID Grass Filter Strip

$A_{imp}$ = impervious area tributary to LID Grass Filter Strip, acres

**Example:**

C = 0.90

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

$SQDF_{ref}$ = 0.20 x 0.90 x 3,600/43,560 = 0.0149 cfs

### *Step 2 – Determine design width of Grass Filter Strip ($W_{GFS}$)*

Note: Design width of LID Grass Filter Strip is not restricted to any value but runoff flow must be distributed uniformly across the width of the strip.

**Example:**

$W_{GFS}$ = 2.0 ft

***Step 3 – Calculate design linear application rate ($q_a$)***

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

**Example:**

$q_a = 0.0149 \text{ cfs}/2.0 \text{ ft} = .0075 \text{ cfs/ft}$

***Step 4 – Determine design length of Grass Filter Strip ($L_{GFS}$)***

Note: Design length of LID Grass Filter Strip is not restricted to any minimum value

**Example:**

$L_{GFS} = 6.0 \text{ ft}$

***Step 5 – Calculate treatment credit for LID Grass Filter Strip ($A_{credit}$)***

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

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

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

**Example:**

$A_{credit} = (0.005/0.0075)^2 \times (6/15) \times 3{,}600 \text{ ft}^2$

$A_{credit} = (0.67)^2 \times (6/15) \times 3{,}600 \text{ ft}^2$

$A_{credit} = 0.12 \times 3{,}600 \text{ ft}^2 = 433 \text{ ft}^2$

***Step 6 – Calculate effective impervious area ($A_{eff}$)***

$A_{eff} = A_{imp} – A_{credit}$

**Example:**

$A_{eff} = 3{,}600 – 433 = 3{,}167 \text{ ft}^2$

*Construction Considerations*

See **Fact Sheet T-2** in **Section 5**.

*Long-Term Maintenance*

See **Fact Sheet T-2** in **Section 5**.

*Description*

A Stormwater Planter is a vegetated planter containing layers of topsoil, a sand/peat mixture, and gravel that receives runoff from downspouts or piped inlets or sheet flow from adjoining impervious areas. A shallow surcharge zone is provided above the vegetated surface for temporary storage of the runoff. During stormwater events, runoff accumulates in the surcharge zone and gradually infiltrates into the underlying sand/peat bed, filling the void spaces of the bed. Treatment of the runoff occurs through a variety of natural mechanisms as the runoff infiltrates through the root zone of the vegetation and during detention of the runoff in the underlying sand/peat bed. An LID Stormwater Planter has similar features and functions in a similar manner to the full treatment Stormwater Planter described in **Fact Sheet T-9** in **Section 5**. Refer to **Fact Sheet T-9** for further description and discussion.

LID Stormwater Planters are appropriate for use in residential, commercial, industrial, and institutional settings and are ideally suited for small areas such as parking lot islands, perimeter building planters, street medians, and site entrance or buffer features. They are typically located adjacent to impervious areas to be mitigated. Their use should be incorporated into the site and master drainage planning, and their design should be performed in close coordination with the landscape architect. Tributary areas are typically less than 0.5 acres. Several LID Stormwater Planters may be used on a single site, each designed to receive flow from different impervious areas. Irrigation and regular vegetation care are required to maintain the planter vegetation.

*Design*

Design elements, construction considerations, and maintenance requirements of LID Stormwater Planters are similar in most respects to those of full treatment Stormwater Planters presented in **Fact Sheet T-9** in **Section 5**. LID Stormwater Planters differ in terms of the surcharge storage and soil/gravel media volume provided. LID treatment Stormwater Planters provide a surcharge storage volume less than the SQDV, which is the design criteria volume for full treatment Stormwater Planters (see **Fact Sheet T-0**, **Section 5**).

Key design criteria and reference values for LID Stormwater Planters are listed in **Table 3-3**. The ratios of design values and reference values are used in the calculation of credits for reducing effective impervious area.

**Table 3-3. LID Stormwater Planter Design Criteria and Reference Values**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Drainage area | ≤ 0.5 acre | |
| Design average surcharge depth ($d_s$) | 6-12 in. | |
| 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 |
| Gravel layer | 9 in. | ASSHTO #8 Coarse Aggregate |
| **Reference Values for Credit Calculation** | **Criteria** | **Notes** |
| Reference volume | $SQDV_{ref}$ | Based 12-hr drawdown. See **Fact Sheet T-0**, **Section 5** |

*Design and Credit Calculation Procedure*

***Step 1 – Calculate Reference Stormwater Quality Design Volume ($SQDV_{ref}$) for impervious area tributary to LID Stormwater Planter***

Using **Fact Sheet T-0** in **Section 5**, determine the SQDV for impervious area tributary to the LID Stormwater Planter based on for 12-hr drawdown period and imperviousness (**I**) of tributary area **.**

$SQDV_{ref}$ = $V_u \times$ (1 ft/12 in) $\times A_{imp}$

where

$SQDV_{ref}$ = Stormwater Quality Design Volume, $ft^3$

$V_u$ = Unit basin storage volume, in (from **Figure 5-1** for Imperviousness = **I** and 12-hr drawdown)

$A_{imp}$ = impervious area tributary to LID Stormwater Planter, $ft^2$

**Example:**

I = 0.90 (tributary area @ 90% imperviousness)

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

$V_u$ = 0.32 in

$SQDV_{ref}$ = 0.32 x (1/12) x 3,600 = 96 $ft^3$

***Step 2 – Determine design surcharge storage depth ($D_s$) and surface area ($A_{planter}$) of LID Stormwater Planter***

**Example:**

$D_S$ = 0.75 ft

$A_{planter}$ = 36 $ft^2$

***Step 3 – Calculate design surcharge storage volume for LID Stormwater Planter ($V_{ss}$)***

$V_{ss}$ = $D_S$ x $A_{planter}$

**Example:**

$V_{ss}$ = 0.75 ft x 36 $ft^2$ = 27 $ft^3$

***Step 5 – Calculate treatment volume credit for LID Stormwater Planter ($V_{credit}$)***

$V_{credit} = V_{ss} / SQDV_{ref}$

Note: If calculated value of ($V_{ss} / SQDV_{ref}$) is > 1.0, the value is set to 1.0

**Example:**

$V_{credit} = 27\ ft^3 / 96\ ft^3 = 0.28$

***Step 6 – Calculate effective impervious area ($A_{eff}$)***

$A_{eff} = A_{imp}\ (1 - V_{credit})$

**Example:**

$A_{eff} = 3{,}600 \times (1 - 0.28)$

$A_{eff} = 3{,}600 \times 0.72 = 2{,}592\ ft^2$

*Construction Considerations*

See **Fact Sheet T-9** in **Section 5**.

*Long-Term Maintenance*

See **Fact Sheet T-9** in **Section 5**.

*Description*

An LID Porous Pavement Filter consists of an installation of level modular block porous pavement that is provided with a surcharge zone above the pavement to temporarily store runoff draining from the tributary impervious area. During stormwater events, runoff accumulates in the surcharge zone and infiltrates into the porous pavement and its sublayers of sand and gravel and slowly exits through an underdrain connected to downstream drainage. Treatment of the runoff occurs through a variety of natural mechanisms as the runoff infiltrates through the filter bed. An LID Porous Pavement Filter has similar features and functions in a similar manner to the full treatment Porous Pavement Filter described in **Fact Sheet T-11** in **Section 5**. Refer to **Fact Sheet T-11** for further description and discussion.

LID Porous Pavement Filters are appropriate for use in residential, commercial, industrial, and institutional settings and are ideally suited for small areas such as parking lots and driveways with low traffic volume. They are typically located adjacent to impervious areas to be mitigated. Their use should be incorporated into the site and master drainage planning, and their design should be performed in close coordination with the landscape architect. Tributary areas are typically less than 0.5 acre. Several LID Porous Pavement Filters may be used on a single site, each designed to receive flow from different impervious areas.

*Design*

Design elements, construction considerations, and maintenance requirements of LID Porous Pavement Filters are similar in most respects to those of full treatment Porous Pavement Filters presented in **Fact Sheet T-11** in **Section 5**. LID Porous Pavement Filters differ in terms of the surcharge storage and sand/gravel media volume provided. LID treatment Porous Pavement Filters provide a surcharge storage volume less than the SQDV, which is the design criteria volume for full treatment Porous Pavement Filters (see **Fact Sheet T-0**, **Section 5**).

Key design criteria and reference values for LID Porous Pavement Filters are listed in **Table 3-4**. The ratios of design values and reference values are used in the calculation of credits for reducing effective impervious area.

**Table 3-4. LID Porous Pavement Filter Design Criteria and Reference Values**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Drainage area | ≤ 0.5 acre | |
| Design average surcharge depth ($d_s$) | 2 in. | Above porous pavement |
| Modular Porous Block Type | 40% | Open surface area |
| Sand layer depth | 1 in. | Minimum. ASTM C-33 Sand |
| Gravel layer | 9 in. | ASSHTO #8 Coarse Aggregate |
| **Reference Values for Credit Calculation** | **Criteria** | **Notes** |
| Reference volume | $SQDV_{ref}$ | Based 12-hr drawdown. See **Section 5**, **Fact Sheet T-0**. |

*Design and Credit Calculation Procedure*

***Step 1 – Calculate Reference Stormwater Quality Design Volume ($SQDV_{ref}$) for impervious area tributary to LID Porous Pavement Filter***

Using **Fact Sheet T-0** in **Section 5**, determine the SQDV for impervious area tributary to the LID Porous Pavement Filter based on for 12-hr drawdown period and imperviousness (I) of tributary area.

$SQDV_{ref} = V_u \times (1\ ft/12\ in) \times A_{imp}$

where

$SQDV_{ref}$ = Stormwater Quality Design Volume, $ft^3$

$V_u$ = Unit basin storage volume, in (from **Figure 5-1** for Imperviousness = I and 12-hr drawdown)

$A_{imp}$ = impervious area tributary to LID Porous Pavement Filter, $ft^2$

**Example:**

I = 0.90 (tributary area @ 90% imperviousness)

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

$V_u$ = 0.32 in

$SQDV_{ref}$ = 0.32 x (1/12) x 3,600 = 96 $ft^3$

***Step 2 – Determine design surcharge storage depth ($D_s$) and surface area ($A_{PPF}$) of LID Porous Pavement Filter***

**Example:**

$D_S$ = 2 in = 0.17 ft

$A_{PPF}$ = 300 $ft^2$

***Step 3 – Calculate design surcharge storage volume for LID Porous Pavement Filter ($V_{ss}$)***

$V_{ss} = D_S \times A_{PPF}$

**Example:**

$V_{ss}$ = 0.17 ft x 300 $ft^2$ = 50 $ft^3$

***Step 5 – Calculate treatment volume credit for LID Porous Pavement Filter ($V_{credit}$)***

$V_{credit} = V_{ss} / SQDV_{ref}$

Note: If calculated value of ($V_{ss} / SQDV_{ref}$) is > 1.0, the value is set to 1.0

**Example:**

$V_{credit}$ = 50 $ft^3$/96 $ft^3$ = 0.52

***Step 6 – Calculate effective impervious area ($A_{eff}$)***

$A_{eff} = A_{imp} (1 – V_{credit})$

**Example:**

$A_{eff}$ = 3,600 x (1 – 0.52)

$A_{eff}$ = 3,600 x 0.48 = 1,725 $ft^2$

*Construction Considerations*

See **Fact Sheet T-11** in **Section 5**.

*Long-Term Maintenance*

See **Fact Sheet T-11** in **Section 5**.

*Description*

An LID Vegetated Swale is a landscaped depression with mixed vegetation, including shrubs and trees, that is used to collect and convey runoff. Pollutants are removed by settling and filtration as the runoff flows over the surface of the swale or infiltrates into the ground. Other names commonly used for Vegetated Swales include Rain Gardens and Bioretention Areas. An LID Vegetated Swale has similar features and functions in a similar manner to the full treatment Vegetated Swale described in **Fact Sheet T-8** in **Section 5**. Refer to **Fact Sheet T-8** for further description and discussion.

LID Vegetated Swales are appropriate for use in residential, commercial, industrial, and institutional settings and are ideally suited for small areas such as parking lots and driveways with low traffic volume. They are typically located adjacent to impervious areas to be mitigated. Their use should be incorporated into the site and master drainage planning, and their design should be performed in close coordination with the landscape architect. Tributary areas are typically less than 0.5 acre. Several LID Vegetated Swales may be used on a single site, each designed to receive flow from different impervious areas.

*Design*

Design elements, construction considerations, and maintenance requirements of LID Vegetated Swale are similar in most respects to those of full treatment Vegetated Swales presented in **Fact Sheet T-8** in **Section 5**. Vegetated Swales differ in terms of the surcharge storage and sand/gravel media volume provided. LID treatment Vegetated Swales provide a surcharge storage volume less than the SQDV, which is the design criteria volume for full Vegetated Swales (see **Fact Sheet T-0**, **Section 5**).

Key design criteria and reference values for LID Vegetated Swales are listed in **Table 3-5**. The ratios of design values and reference values are used in the calculation of credits for reducing effective impervious area.

**Table 3-5. LID Vegetated Swale Design Criteria and Reference Values**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Drainage area | ≤ 0.5 acre | |
| Design average surcharge depth ($d_s$) | 6 - 12 in. | |
| Top soil layer | 12 in. | Minimum |
| **Reference Values for Credit Calculation** | **Criteria** | **Notes** |
| Reference volume | $SQDV_{ref}$ | Based 12-hr drawdown. See **Section 5**, **Fact Sheet T-0**. |

*Design and Credit Calculation Procedure*

***Step 1 – Calculate Reference Stormwater Quality Design Volume ($SQDV_{ref}$) for impervious area tributary to LID Vegetated Swale***

Using **Fact Sheet T-0** in **Section 5**, determine the SQDV for impervious area tributary to the LID Vegetated Swale based on for 12-hr drawdown period and imperviousness (I) of tributary area.

$SQDV_{ref} = V_u \times (1 \text{ ft}/12 \text{ in}) \times A_{imp}$

where

$SQDV_{ref}$ = Stormwater Quality Design Volume, $ft^3$

$V_u$ = Unit basin storage volume, in (from **Figure 5-1** for Imperviousness = I and 12-hr drawdown)

$A_{imp}$ = impervious area tributary to LID Vegetated Swale, $ft^2$

**Example:**

I = 1.0 (tributary area @ 100% imperviousness)

$A_{imp}$ = 1,000 $ft^2$

$V_u$ = 0.34 in

$SQDV_{ref}$ = 0.34 x (1/12) x 1,000 = 28 $ft^3$

***Step 2 – Determine design surcharge storage depth ($D_s$) design surcharge storage volume of Vegetated Swale***

**Example:**

| | |
|---|---|
| Swale depth of storage ($D_S$) | = 6 in = 0.5 ft |
| Swale bottom width ($b_s$) | = 2.0 ft |
| Swale side slope (H:V) | = 3:1 |
| Swale length ($L_s$) | = 10.0 ft |
| Swale storage area ($A_{VS}$) | = 1.75 $ft^2$ |
| Swale storage volume ($V_{VS}$) | = $L_S$ x $A_{VS}$ = 17.5 $ft^3$ |

***Step 3 – Calculate treatment volume credit for LID Vegetated Swale ($V_{credit}$)***

$V_{credit} = V_{vs} / SQDV_{ref}$

Note: If calculated value of ($V_{ss}$ /$SQDV_{ref}$) is > 1.0, the value is set to 1.0

**Example:**

$V_{credit}$ = 17.5 $ft^3$/28 $ft^3$ = 0.62

***Step 4 – Calculate effective impervious area ($A_{eff}$)***

$A_{eff} = A_{imp} (1 - V_{credit})$

**Example:**

$A_{eff}$ = 1,000 x (1 – 0.62)

$A_{eff}$ = 1,000 x 0.38 = 380 $ft^2$

*Construction Considerations*

See **Fact Sheet T-8** in **Section 5**.

*Long-Term Maintenance*

See **Fact Sheet T-8** in **Section 5**.

*Description*

An LID Infiltration Trench or Vault is a narrow trench constructed in naturally pervious soils (types A or B) and typically filled with gravel and sand, although use of alternative products may be considered in place of gravel fill (see **Section 3-2**) . Runoff is stored in the trench until it infiltrates into the soil profile over a specified drawdown period. Overflow drains are often provided to allow drainage if the Infiltration Trench becomes clogged. Infiltration Vaults and Infiltration Leach Fields are subsurface variations of the Infiltration Trench concept in which runoff is distributed to the upper zone of the subsurface gravel bed by means of perforated pipes. An LID Infiltration Trench/Vault has similar features and functions in a similar manner to the full treatment Infiltration Trench/Vault described in **Fact Sheet T-6** in **Section 5**. Refer to **Fact Sheet T-6** for further description and discussion.

LID Infiltration Trenches/Vaults are appropriate for use in residential, commercial, industrial, and institutional settings. They are typically used in conjunction with LID Grass Filter Strips and are located adjacent to impervious areas to be mitigated. Their use should be incorporated into the site and master drainage planning, and their design should be performed in close coordination with the landscape architect. Tributary areas are typically less than one (1) acre. Several LID Infiltration Trenches/Vaults may be used on a single site, each designed to receive flow from different impervious areas.

*Design*

Design elements, construction considerations, and maintenance requirements of LID Infiltration Trenches/Vaults are similar in most respects to those of full treatment Infiltration Trenches/Vaults presented in **Fact Sheet T-6** in **Section 5**. LID Infiltration Trenches/Vaults differ in terms of the surcharge storage volume provided. LID treatment Infiltration Trenches/Vaults provide a surcharge storage volume less than the SQDV, which is the design criteria volume for full treatment Infiltration Trenches/Vaults (see **Fact Sheet T-0**, **Section 5**).

Key design criteria and reference values for LID Infiltration Trenches/Vaults are listed in **Table 3-5**. The ratios of design values and reference values are used in the calculation of credits for reducing effective impervious area.

**Table 3-5. LID Infiltration Trench/Vault Design Criteria and Reference Values**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Drainage area | ≤ 1.0 acre | |
| Soil permeability range | 0.6-2 in./hr | Saturated vertical permeability |
| Minimum groundwater separation | 10 ft | Between trench bottom and seasonally high groundwater table |
| Minimum trench width | 1 ft | |
| Maximum trench surcharge depth ($D_{max}$) | 10 ft | |
| Setbacks | 100 ft<br>10 ft<br>100 ft<br>– | From wells, tanks, fields, springs<br>Downslope from foundations<br>Upslope from foundations<br>Do not locate under tree drip-lines |
| Trench media material size/type | 1-3 in. | Washed gravel. |
| **Reference Values for Credit Calculation** | **Criteria** | **Notes** |
| Reference volume | $SQDV_{ref}$ | Based 40-hr drawdown. See **Section 5, Fact Sheet T-0** |

## *Design and Credit Calculation Procedure*

***Step 1 – Calculate Reference Stormwater Quality Design Volume ($SQDV_{ref}$) for impervious area tributary to LID Infiltration Trench/Vault***

Using **Fact Sheet T-0** in **Section 5**, determine the SQDV for impervious area tributary to the LID Infiltration Trench/Vault based on for 40-hr drawdown period and imperviousness (I) of tributary area .

$SQDV_{ref}$ = $V_u \times (1\ ft/12\ in) \times A_{imp}$

where

$SQDV_{ref}$ = Stormwater Quality Design Volume, $ft^3$

$V_u$ = Unit basin storage volume, in (from **Figure 5-1** for Imperviousness = I and 40-hr drawdown)

$A_{imp}$ = impervious area tributary to LID Infiltration Trench/Vault , $ft^2$

**Example:**

I = 1.0 (tributary area @ 100% imperviousness)

$A_{imp}$ = 20,000 $ft^2$

$V_u$ = 0.60 in

$SQDV_{ref}$ = 0.60 x (1/12) x 20,000 = 1,000 $ft^3$

***Step 2 – Determine design surcharge storage depth ($D_s$) and surface area ($A_{IT}$) of LID Infiltration Trench/Vault***

**Example:**

$D_S$ = 6.0 ft

$L_{IT}$ = 30 ft

$W_{IT}$ = 2 ft

$A_{IT}$ = 60 ft$^2$

***Step 3 – Calculate design surcharge storage volume for LID Infiltration Trench/Vault ($V_{ss}$)***

$V_{ss}$ = $D_S$ x $A_{IT}$ x porosity (0.30)

**Example:**

$V_{ss}$ = 6.0 ft x 60 ft$^2$ x 0.30 = 108 ft$^3$

***Step 5 – Calculate treatment volume credit for LID Infiltration Trench/Vault ($V_{credit}$)***

$V_{credit}$ = $V_{ss}$ /$SQDV_{ref}$

Note: If calculated value of ($V_{ss}$ /$SQDV_{ref}$) is > 1.0, the value is set to 1.0

**Example:**

$V_{credit}$ = 108 ft$^3$ /1,000 ft$^3$ = 0.11

***Step 6 – Calculate effective impervious area ($A_{eff}$)***

$A_{eff}$ = $A_{imp}$ (1– $V_{credit}$)

**Example:**

$A_{eff}$ = 20,000 x (1 – 0.11)

$A_{eff}$ = 20,000 x 0.89 = 17,840 ft$^2$

*Construction Considerations*

See **Fact Sheet T-6** in **Section 5**.

*Long-Term Maintenance*

See **Fact Sheet T-6** in **Section 5**.

# 4.0 Site-Specific Source Control Measures

## 4.1 INTRODUCTION

The principal objective of the Site-Specific Source Control Measures specified in this Manual is to prevent potential pollutants from contacting rainwater or stormwater runoff and prevent the discharge of contaminated runoff to the storm drain system or receiving water.

## 4.2 SOURCE CONTROL MEASURES

Site-Specific Source Control Measures are designated S-1 through S-6 and include the design features and considerations summarized in **Table 4-1**.

**Table 4-1. Summary of Site-Specific Source Control Design Features**

| Site-Specific Source Control Measure[1, 2] | Design Feature or Element | | | | | | |
|---|---|---|---|---|---|---|---|
| | Signs, placards, stencils | Surfacing, pavement | Covers, screens | Hydraulic isolation | Spill containment | Sanitary sewer connection | Emergency shut-off valve |
| S-1: Storm Drain Stenciling and Signage | X | | | | | | |
| S-2: Outdoor Material Storage Area Design | | X | X | X | | X[3] | |
| S-3: Outdoor Trash Storage Area Design | X | X | X | X | | X | |
| S-4: Loading/Unloading Area Design | | X | X | X | | X | X[3] |
| S-5: Outdoor Vehicle/Equipment/Accessory Wash Area Design | | X | X | X | | X | |
| S-6: Fuel Dispensing and Maintenance Area Design | | X | X | X | X | X | X |

1. Refer to Fact Sheets in Section 4 for detailed information and design criteria
2. The control measures described in this Section are required for all Categorical New Development and Redevelopment projects as follows: S-1 is required if applicable to the project; and S-2 through S-6 are required if the specific outdoor activity area is included the project.
3. Based on type of material being stored or transferred.


## Description

Waste materials dumped into storm drain inlets can have severe impacts on surface and ground waters. Posting notices regarding discharge prohibitions at storm drain inlets can prevent waste dumping. Typically, storm drain stenciling, markers, and/or signage is placed at storm drain inlets located in new or redeveloped commercial, industrial, and residential sites. The message simply informs the public that dumping of wastes into storm drain inlets is prohibited and/or the drain discharges to our wetlands, sloughs and creeks.

## Design Criteria

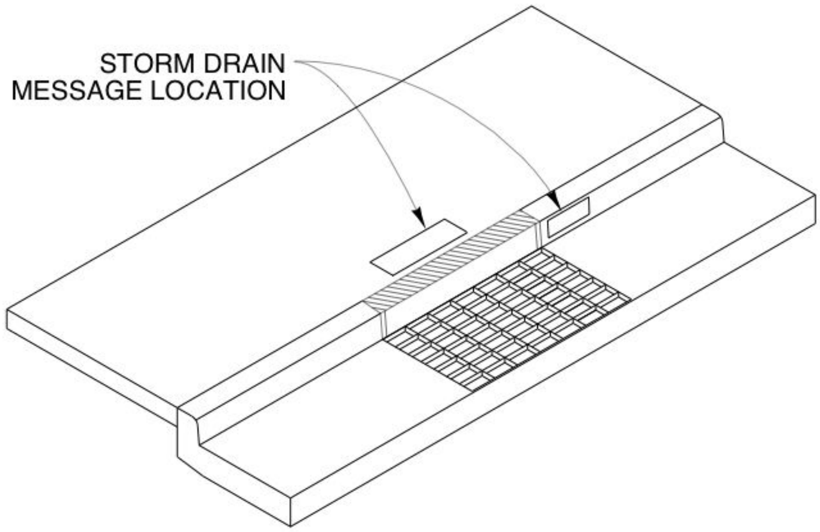
The storm drain marker for the City of Davis is depicted here and is available upon request. If the City's markers aren't suitable for the development, consult the City stormwater staff to determine specific requirements for storm drain messages.

## Design Procedure

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

## Long-Term Maintenance

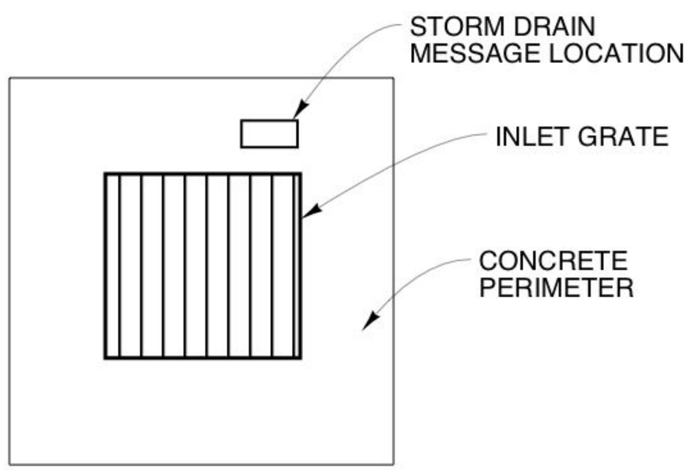
Legibility of markers and signs shall be maintained. Missing or damaged markers shall be replaced. If required by the City, the owner/operator or homeowner's association shall enter into a maintenance agreement with the City or record a deed restriction upon the property title to maintain the presence and legibility of storm drain markers and signs.




CURB TYPE INLET

NOTES:

1. STORM DRAIN MESSAGE SHALL BE APPLIED IN SUCH A WAY AS TO PROVIDE A CLEAR, LEGIBLE IMAGE.
2. STORM DRAIN MESSAGE SHALL BE PERMANENTLY APPLIED DURING THE CONSTRUCTION OF THE CURB AND GUTTER USING A METHOD APPROVED BY THE CITY.




AREA TYPE INLET

**Figure 4-1. Storm Drain Message Location**


Photo Credit: Sacramento Stormwater Quality Partnership

## Description

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

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

## Applicability

Materials are placed into three categories based on potential risk for pollutant release associated with stormwater contact – high risk, low risk, and exempt. General types of materials under each category are listed below. City stormwater staff will make final determinations regarding category listings, if necessary.

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

## Design Criteria

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

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

### Accumulated Stormwater and Non-Stormwater

Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permission. Contact the City's Wastewater Division at 530-757-5686 regarding discharge of contaminated accumulated water.

### Long-Term Maintenance

The integrity of stormwater controls for outdoor storage areas shall be maintained in accordance with maintenance agreements between the City and owner/operator of the facility. Maintenance plans and maintenance agreements between the City and the owner/operator may be required and must be executed by the owner/operator before improvement plans are approved. Refer to **Section 6** for further guidance regarding maintenance agreements and plans.

## Description

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

## Design Criteria

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

Wastes from commercial and industrial sites are typically hauled away for disposal by commercial carriers that may have design or access requirements for waste storage areas. The design criteria listed below are recommendations and are not intended to be in conflict with requirements established by the waste hauler. The waste hauler should be contacted prior to the design of your site trash collection area. Conflicts or issues should be discussed with the City staff.

The following trash storage area design controls were developed to enhance the local agency codes and ordinances and should be implemented considering the type of waste and the type of containment. The criteria apply to commercial and industrial facilities and multi-family residential developments that provide shared trash storage areas. Separate requirements are provided for commercial and industrial facilities that handle food wastes, liquid wastes, or other potentially dangerous wastes.

| Design Feature | Design Criteria |
|---|---|
| Surfacing | Construct the storage area base with a material impervious to leaks and spills. |
| Screens | Install a screen or wall around trash storage area to prevent off-site transport of loose trash. |
| Covers | • For commercial and industrial facilities and multi-family developments that handle food wastes (e.g., restaurants, grocery and convenience stores, movie theaters, catering operations), liquid wastes, or potentially dangerous wastes:<br>o Provide a permanent canopy, roof, or awning that completely covers the waste storage area to prevent rainfall from contacting the waste containers or wastes being stored<br>o Direct runoff from the cover away from the hydraulically isolated waste storage area to a stormwater disposal point that meets all applicable requirements of this manual and codes<br>• For all other facilities:<br>o Provide waste storage bins with water proof lids |
| Hydraulic Isolation and Drainage | • For commercial and industrial facilities that handle food wastes liquid wastes, or potentially dangerous wastes:<br>o Hydraulically isolate the waste storage area by means of grading, berms, or drains to prevent run-on of stormwater from surrounding areas or roof drains<br>o Direct runoff from surrounding areas away from the hydraulically isolated waste storage area to a stormwater disposal point that meets all applicable requirements of this manual and codes<br>o Direct drainage from the hydraulically isolated waste storage area to an approved City sanitary sewer or approved collection point<br>• For all other facilities:<br>o Locate storm drains at least 35 feet from the perimeter of the waste storage area if feasible. |
| Signs | Post signs near all bins and dumpsters informing users that hazardous materials are not to be disposed of therein and that lids should always be closed. |

## Long-Term Maintenance

The integrity of structural elements that are subject to damage (e.g., screens, covers, and signs) must be maintained by the owner/operator in accordance with maintenance agreements between the City and owner/operator of the facility. Maintenance plans and maintenance agreements between the City and the owner/operator may be required and must be executed by the owner/operator before improvement plans are approved. Refer to **Section 6** for further guidance regarding maintenance agreements and maintenance plans.

Photo Credit: Sacramento Stormwater Quality Partnership

## Description

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

## Design Criteria

Design requirements for outdoor loading/unloading areas are governed by Building and Fire Codes and City ordinances and zoning requirements. Source controls described in this fact sheet are meant to enhance and be consistent with these code and ordinance requirements. Companies may have their own design or access requirements for loading areas. The design criteria listed below are not intended to be in conflict with requirements established by individual companies. Conflicts or issues should be discussed with the City staff.

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

| Design Feature | Design Criteria |
|---|---|
| Surfacing | Construct floor surfaces with paving material that is impervious and chemically resistant to materials being handled in the loading/unloading area. |
| Covers | • Cover outdoor loading/unloading areas to a distance of at least 10 feet beyond the loading dock or building face if there is no raised dock.<br>• For interior transfer bays, provide a 10-ft minimum “no obstruction zone” to allow trucks or trailers to extendat least 5 feet inside the building. Identify “no obstruction zone” clearly on building plans and paint zone with high visibility floor paint.<br>• 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 the building. |
| Hydraulic Isolation and Drainage | • For outdoor loading/unloading areas, hydraulically isolate the first 6 feet of paved area measured from the building or dock face by means of grading, berms, or drains to prevent run-on of stormwater from surrounding areas or roof drains. Direct runoff and drainage from surrounding areas away from hydraulically isolated area to a stormwater discharge point that meets all applicable requirements of this manual.<br>• 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.<br>• Direct drainage from the hydraulically isolated loading/unloading area to an approved City sanitary sewer or other approved collection point. Discharges shall be appropriately pretreated as necessary. |

## Long-Term Maintenance

The integrity of stormwater controls for loading/unloading areas shall be maintained in accordance with maintenance agreements between the City and owner/operator of the facility. Maintenance plans and maintenance agreements between the City and the owner/operator may be required and must be executed by the owner/operator before improvement plans are approved. Refer to **Section 6** for further guidance regarding maintenance agreements and plans.

## Description


Photo Credit: Rachel Terpstra, Larry Walker Associates

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

## Design Criteria

Design requirements for vehicle and equipment washing areas are governed by Building and Fire Codes and current local agency ordinances and zoning requirements. The design criteria described in this fact sheet are meant to enhance and be consistent with these code requirements. The following design criteria are required for vehicle and equipment washing areas. All hazardous and toxic wastes must be prevented from entering the storm drain system.

| Design Feature | Design Criteria |
|---|---|
| Surfacing | Construct the vehicle/equipment wash area floors with Portland cement concrete (PCC). |
| Covers | • Cover the wash area with a permanent canopy, roof, or awning to prevent precipitation from directly contacting the washing area. Direct runoff from the cover away from the washing area to a stormwater disposal point that meets all applicable code requirements and applicable requirements of this manual.<br>o Covers 10 feet high or less shall have a minimum overhang of 3 feet measured from the perimeter of the hydraulically isolated washing area.<br>o Cover higher than 10 feet shall have a minimum overhang of 5 feet measured from the perimeter of the hydraulically isolated washing area. |
| Hydraulic Isolation and Drainage | • Hydraulically isolate the paved wash area by means of grading, berms, or perimeter drains to prevent run-on of stormwater from surrounding areas or roof drains.<br>• 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 35 feet from the hydraulically isolated wash area if feasible.<br>• Direct drainage from the hydraulically isolated wash area to one of the following:<br>o An approved pretreatment and recycle system.<br>o An approved pretreatment system with a connection to the City sanitary sewer. |

## Accumulated Stormwater and Non-Stormwater

Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged to the storm drain or sanitary sewer system without the appropriate approval. Contact the City's Wastewater Division at 530-757-5686 regarding discharge of contaminated accumulated water.

## Long-Term Maintenance

The integrity of structural elements (e.g., manholes, pretreatment facilities) must be maintained by the owner/operator in accordance with maintenance agreements between the City and owner/operator of the facility. Maintenance plans and maintenance agreements between the City and the owner/operator may be required and must be executed by the owner/operator before improvement plans are approved. Refer to **Section 6** for further guidance regarding maintenance agreements and maintenance plans.


Photo Credit: Rachel Terpstra, Larry Walker Associates

## Description

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

## Design Criteria

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

| Design Feature | Design Criteria |
|---|---|
| Surfacing | • Pave fuel dispensing and maintenance area with PCC. The fuel dispensing area is defined as extending 6.5 feet from the corner of each fuel dispenser or the length at which the hose and nozzle assemble may be operated plus 1 foot, whichever is less. The paving around the fuel dispensing area may exceed the minimum dimensions of the “fuel dispensing area” stated above.<br>• Use asphalt sealant to protect asphalt paved areas surrounding the fuel dispensing or maintenance area. |
| Covers | • Cover the fuel dispensing or maintenance area with a permanent canopy, roof, or awning to prevent precipitation from directly contacting the fuel dispensing area. Direct runoff from the cover away from the fuel dispensing area to a stormwater disposal point that meets all applicable code requirements and applicable requirements of this manual.<br>o Covers 10 feet high or less shall have a minimum overhang of 3 feet measured from the perimeter of the hydraulically isolated fuel dispensing area.<br>o Cover higher than 10 feet shall have a minimum overhang of 5 feet measured from the perimeter of the hydraulically isolated fuel dispensing area.<br>• 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. |

| Design Feature | Design Criteria |
|---|---|
| Hydraulic Isolation and Drainage | • Hydraulically isolate the paved fuel dispensing or maintenance area by means of grading, berms, or perimeter drains to prevent run-on of stormwater from surrounding areas or roof drains.<br>o Design the fuel dispensing or maintenance area pad with zero slope (flat) to keep minor spills and leaks on the pad and encourage use of proper cleanup methods. Proper cleanup methods shall consist of dry cleanup methods, such as sweeping for removal of litter and debris and use of absorbents for liquid spills and leaks.<br>o If berms are used, design the berm height four inches above the surface of the fuel dispensing or maintenance area pad.<br>• Direct drainage from the hydraulically isolated fueling or maintenance area to an approved City sanitary sewer or other approved collection point. Discharges shall be appropriately pretreated as necessary.<br>• 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

Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged to the storm drain or sanitary sewer system without the appropriate approval. Contact the City's Wastewater Division at 530-757-5686 regarding discharge of contaminated accumulated water.

## Long-Term Maintenance

The integrity of structural elements (e.g., manholes) must be maintained by the owner/operator in accordance with maintenance agreements between the City and owner/operator of the facility. Maintenance plans and maintenance agreements between the City and the owner/operator may be required and must be executed by the owner/operator before improvement plans are approved. Refer to **Section 6** for further guidance regarding maintenance agreements and maintenance plans.

# 5.0 Treatment Control Measures

## 5.1 INTRODUCTION

Treatment Control Measures, also known as best management practices (BMPs), are required in addition to Site-Specific Source Control Measures to prevent or minimize water quality impacts from stormwater. Treatment Control Measures are engineered technologies designed to remove pollutants from stormwater runoff. The type of Treatment Control Measure(s) to be implemented at a site depends on a number of factors including: type of pollutants in the stormwater runoff; quantity of stormwater runoff to be treated; project site conditions (e.g., soil type and permeability, slope); receiving water conditions; and State Industrial Storm Water General Permit requirements, where applicable. Land area requirements and costs to design, construct, and maintain Treatment Control Measures vary.

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

The Treatment Control Measures presented in this Manual are designed based on flow rates or runoff volume. Those designed based on flow rates are to be designed for the SQDF, and those designed based on volume are to be designed for the SQDV. Definitions and calculation procedures to determine SQDF and SQDV are presented in **Fact Sheet T-0**. The Treatment Control Measures specified in this Manual are to be sized for the SQDF or SQDV only. Flow rates in excess of SQDF or SQDV are to be diverted around or through the Treatment Control Measure. The Treatment Control Measures specified in this section are listed in **Table 5-1** along with the basis of design, SQDF or SQDV, to be used for the particular control measures.

**Table 5-1. Sizing Criteria for Treatment Control Measures**

| Treatment Control Measure | Design Basis |
|---|---|
| T-1: Grass Swale | SQDF |
| T-2: Grass Filter Strip | SQDF |
| T-3: Wet Pond | SQDV |
| T-4: Constructed Wetland Basin | SQDV |
| T-5: Extended Detention Basin | SQDV |
| T-6: Infiltration Trench/Vault | SQDV |
| T-7: Infiltration Basin | SQDV |
| T-8: Vegetated Swale | SQDV |
| T-9: Stormwater Planter | SQDV |
| T-10: Media Filter | SQDV |
| T-11: Porous Pavement Filter | SQDV |
| Proprietary Treatment Control Measures | SQDF or SQDV |

The stormwater Treatment Control Measures specified in Fact Sheets T-1 through T-11 are the more common non-proprietary measures being implemented nationwide. Studies have shown these measures to be reasonably effective if properly installed and maintained. The relative effectiveness of treatment controls specified in this section for removal of pollutants of concern is shown in **Table 5-2**. Pollutants of concern listed are those that have been identified as causing or contributing to impairment of beneficial uses of water bodies in California. As discussed in **Section 2**, the measures presented in this section are pre-approved and will ensure timely plan check review. A limited number of proprietary treatment control measures also have been approved for general or conditional use by the City. The effectiveness of these devices varies depending on the manufacturer and type of device (see **Section 5.4**).

**Table 5-2. Effectiveness of Treatment Control Measures for Removal of Pollutants of Concern**

| Treatment Control Measure | Pollutant of Concern[1] | | | | | | |
|---|---|---|---|---|---|---|---|
| | Sediment | Nutrients | Trash | Metals | Bacteria | Oil & Grease | Toxic Organics |
| T-1: Grass Swale | M | L | L | M | L | M | M |
| T-2: Grass Filter Strip | M | L | L | M | L | M | M |
| T-3: Wet Pond | H | H | H | H | M | H | M |
| T-4: Constructed Wetland Basin | H | M | H | H | M | H | M |
| T-5: Extended Detention Basin | H | M | H | H | M | H | M |
| T-6: Infiltration Trench/Vault | H | H | H | H | H | H | H |
| T-7: Infiltration Basin | H | H | H | H | H | H | H |
| T-8: Vegetated Swale | M | L | L | M | L | M | M |
| T-9: Stormwater Planter | H | L | H | H | M | H | H |
| T-10: Media Filter | H | L | H | H | M | H | M |
| T-11: Porous Pavement Filter | H | L | H | H | M | H | M |
| Proprietary Treatment Control Measures[2] | – | – | – | – | – | – | – |

Notes:
1. H: ≥75% expected removal efficiency for typical urban stormwater runoff
M:75% to 25% expected removal efficiency for typical urban stormwater runoff
L: ≤25% expected removal efficiency for typical urban stormwater runoff
2. Effectiveness of proprietary devices varies depending on the manufacturer and type of device. Limited performance data are available.

Unless otherwise agreed to by the City, the landowner, site operator, or homeowners' association is responsible for the operation and maintenance of the Treatment Control Measures. Project developers/property owners are responsible for the maintenance of structural stormwater control measures implemented pursuant to the requirements of this Manual until the property ownership is legally transferred or the City assumes responsibility through annexation (see **Appendix C-2** for sample owner/developer certification of responsibility). Failure to properly operate and maintain the measures could result in reduced treatment of stormwater runoff or a concentrated loading of pollutants to the storm drain system. To protect against failure, a Maintenance Plan must be developed and implemented for all Treatment Control Measures. Guidelines for maintenance plans are provided in **Section 6** of this Manual. The maintenance plan must be made available at the City's request. In addition, a maintenance agreement with the City is required for system under private ownership. Example maintenance agreements are included in **Appendix C-1**.

In addition to maintenance, the City may require water quality monitoring agreements for any of the Treatment Control Measures recommended in this Manual. Monitoring may be conducted by the site operator, the City, or both. Monitoring may be required for a period of time to help the City evaluate the effectiveness of Treatment Control Measures in reducing pollutants in stormwater runoff.

## 5.2 SELECTION OF TREATMENT CONTROLS

Various factors must be considered when selecting a Treatment Control Measure. In addition to removing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the control measure, soil type and permeability, slope, hydraulic head, size of the control measure, and need for vegetation irrigation are important factors in selecting the proper Treatment Control Measure. Vector breeding considerations must also be addressed in determining Treatment Control Measures because of nuisance and potential human health effects. The site constraints that are used to select Treatment Control Measures are presented in **Table 5-3**.

## 5.3 DESIGN AND IMPLEMENTATION OF TREATMENT CONTROLS

Fact sheets containing siting and design criteria, calculation procedures and examples, and maintenance requirements for the approved treatment controls are presented in this subsection.

Several of the non-proprietary treatment control measures (T-1 through T-11) described in this section involve the use of natural materials, such as gravel or sand, for which specifications are provided in the Fact Sheets. Recently, manufactured products have been developed as alternatives to such materials. Project applicants may submit such products for the City's consideration and approval as alternatives to the materials specified in the Fact Sheets. Such products must meet recognized standards for properties or performance, as applicable.

**Table 5-3. Site Constraints for Treatment Control Measures[1]**

| Treatment Control Measure[4] | Drainage Area (acres) | Depth to Water Table (ft) | | Soil Type[2] | | Slope (%) | | Hydraulic Head | | Vegetation Irrigation | | Vector Control Frequency | | Maintenance Frequency[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <10 | >10 | A/B | C/D | Min | Max | High | Low | Yes | No | High | Low | |
| T-1: Grass Swale | ≤10 | X | X | X | X | 1 | 4 | | X | X | | | X | L |
| T-2: Grass Filter Strip | ≤5 | X | X | X | X | 1 | 4 | | X | X | | | X | L |
| T-3: Wet Pond | ≥10 | X | X | | X | ~0 | ~0 | | X | X | X | X | | M |
| T-4: Constructed Wetland Basin | Up to 100+ | X | X | X | X | ~0 | ~0 | | X | X | X | X | | H |
| T-5: Extended Detention Basin | ≥5 | X | X | X | X | ~0 | ~0 | | X | X | X | X | | M |
| T-6: Infiltration Trench/Vault | ≤5 | | X | X | | ~0 | ~0 | | X | X | X | | X | L |
| T-7: Infiltration Basin | ≤50 | | X | X | | ~0 | ~0 | | X | X | X | | X | H |
| T-8: Vegetated Swale | ≤1 | X | X | X | X | 0.5 | 6 | | X | X | | | X | M |
| T-9: Stormwater Planter | ≤1 | | X | X | X | ~0 | ~0 | | X | X | | | X | M |
| T-10: Media Filter | 1.5 to 50 | X | X | X | X | ~0 | ~0 | X | | | X | | X | H |
| T-11: Porous Pavement Filter | ≤1 | X | X | X | X | ~0 | ~0 | | X | | X | | X | L |

1. X indicates control measure is suitable for listed site condition.
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. The maintenance frequency is how often maintenance activities need to be conducted to preserve Treatment Control Measure effectiveness. H = high; M = medium; L = low.
4. Suitability of alternative/proprietary treatment control measures varies depending on the manufacturer and type of device. See Section 5-5.

## Description

The primary control strategy for all of the Treatment Control Measures specified in this section is to treat the SQDF or SQDV of the stormwater runoff. The SQDF and SQDV are functions of the effective imperviousness ($I_{WQ}$) of a specified project site and the runoff coefficient (C) for the tributary surfaces in question. This Fact Sheet presents the following calculation procedures, with examples, necessary to determine the SQDF and SQDV:

- Determination of Tributary Area Imperviousness
- Stormwater Quality Design Volume (SQDV) Calculation
- Stormwater Quality Design Flow (SQDF) Calculation

## Determination of Tributary Area Imperviousness

Projects typically comprise a variety of land uses or site elements that have variable values of imperviousness. Impervious or relatively impervious areas include sidewalks, roadways, parking areas, staging areas, storage areas, slabs, roofs, and other non-vegetated areas, including compacted soil areas. Typical pervious areas include parks, open space, lawns, and landscaped areas. The design imperviousness ($I_{WQ}$) of a project site is the weighted average imperviousness of the various site elements. Off-site areas that could run-on to a site and contribute drainage to the Treatment Control Measure should be included in the determination of design imperviousness.

The effective imperviousness of a site can be reduced through implementation of Low Impact Development (LID) Treatment Control Measures, as described in **Section 3**. Procedures for calculating effective impervious areas following implementation of such LID Treatment Control Measures are presented in **Fact Sheets D-4.1** through **D-4.5**. The procedure for determining the design imperviousness ($I_{WQ}$) of the tributary area for a Treatment Control Measure is described below.

### Design Imperviousness Calculation Procedure

#### Step 1 – Estimate Imperviousness of Site Elements in Tributary Area

Estimate the imperviousness or percent imperviousness of individual site elements. **Table 5-4** may be used as guide for estimating imperviousness of typical site elements.

**Table 5-4. Recommended Percent Imperviousness and "C" Values for Typical Site Elements**

| Site Element | Percent Imperviousness | Runoff Coefficient, C[b] |
|---|---|---|
| Asphalt/concrete pavement | 100 | 0.90 |
| Gravel pavement (compacted) | 40 | 0.35 |
| Roofs | 90 | 0.75 |
| Porous pavement | 35[a] | 0.15[a] |
| Lawn/turf | 0 | 0.10 |
| Open space | 0 | 0.10 |

a. Variable with product type; assumes porous subsoil and use of underdrains.
b. Appropriate only for design of Treatment Control Measures, not for flood control sizing.

### Step 2 – Calculate Design Imperviousness ($I_{WQ}$) of Tributary Area

Calculate the weighted average imperviousness of the tributary site elements. **Table 5-5** may be used as a guide in calculating $I_{WQ}$. Note that the actual site element areas, not the effective area ($A_{eff}$) resulting from application of LID treatment controls discussed in Fact Sheet D-4, should be used in this calculation.

**Table 5-5. Calculation Table for Determination of Design Imperviousness ($I_{WQ}$)**

| Site Element | Unit Area ($ft^2$) | Percent Imperviousness | Weighting Factor[b] | Weighted % Imperviousness[c,d] |
|---|---|---|---|---|
| Asphalt/concrete pavement | | 100 | | |
| Gravel pavement | | 40 | | |
| Roofs | | 90 | | |
| Porous pavement | | 35[e] | | |
| Lawn/turf | | 0 | | |
| Open space | | 0 | | |
| Total Contributing Area[a] | | – | – | |

a. Total contributing area = sum of unit areas
b. Weighting factor = unit area / total tributary area
c. Weighted imperviousness = weighting factor x percent imperviousness
d. Design imperviousness = sum of weighted imperviousness
e. Variable with product type; assumes porous subsoil and use of underdrains

### Example Calculation ($I_{WQ}$)

For a project site, determine weighted averages of individual site elements. Using **Table 5-5**, determine the design imperviousness ($I_{WQ}$). The results are presented in **Table 5-6**.

**Table 5-6. Example Calculation Sheet for Determination of Design Imperviousness, $I_{WQ}$**

| Site Element | Unit Area ($ft^2$) | Percent Imperviousness | Weighting Factor[b] | Weighted % Imperviousness[c,d] |
|---|---|---|---|---|
| Asphalt/concrete pavement | 32,200 | 100 | 0.51 | 51 |
| Gravel pavement | 4,800 | 40 | 0.08 | 3 |
| Roofs | 15,000 | 90 | 0.24 | 21 |
| Porous pavement | 0 | 35[e] | 0 | 0 |
| Lawn/turf | 11,500 | 0 | 0.18 | 0 |
| Open space | 0 | 0 | 0 | 0 |
| Total Contributing Area[a] | 63,500 | – | – | 75 |

a. Total contributing area = sum of unit areas
b. Weighting factor = unit area / total tributary area
c. Weighted imperviousness = weighting factor x percent imperviousness
d. Design imperviousness = sum of weighted imperviousness
e. Variable with product type; assumes porous subsoil and use of underdrains

### Solution:

$I_{WQ}$ = 75%

## Calculation of Stormwater Quality Design Volume (SQDV)

Hydrologic calculations for design of volume-based stormwater treatment controls in the Davis area shall be in accordance with the procedures set forth in this Fact Sheet.

The SQDV is defined as the volume necessary to capture and treat 80 percent or more of the average annual runoff volume from the site at the design drawdown period specified in the Fact Sheet for the proposed Treatment Control Measure.

### Calculation Procedure

#### Step 1 – Determine Unit Basin Storage Volume

- Enter the horizontal axis of **Figure 5-1** with the appropriate $I_{WQ}$ value determined above. (**Figure 5-1** provides a direct reading of Unit Basin Storage Volume required for 80% capture of annual runoff for values of $I_{WQ}$ and is based on rain gauge data from Sacramento International Airport).
- Move vertically up **Figure 5-1** until the appropriate drawdown period line is intercepted. (The design drawdown period specified in the respective Fact Sheet for the proposed Treatment Control Measure.)
- Move horizontally across **Figure 5-1** from this point until the vertical axis is intercepted.
- Read the Unit Basin Storage Volume along the vertical axis.

#### Step 2 – Calculate SQDV

The SQDV for the proposed Treatment Control Measure is calculated by multiplying the Unit Basin Storage Volume by the effective contributing drainage area. The effective area ($A_{eff}$) is the contributing area determined after applying credits for application of LID treatment controls (see Fact Sheet D.4). 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.

### Example Calculation (SQDV)

#### Step 2 – Determine Unit Basin Storage Volume

- Determine design drawdown period for proposed control measure.

  *Example:* T-5: Extended Detention Basin → Drawdown period = 40 hrs

- Determine the Unit Basin Storage Volume for 80% Annual Capture, $V_u$ using **Figure 5-1**.

  *Example:* For $I_{WQ}$/100 = 0..75 and drawdown = 40 hrs, $V_u$ = 0.47 in

#### Step 3 – Calculate SQDV

- Calculate the SQDV for the basin, where SQDV = $V_u \times A_{eff}$.

  *Example:* For $A_{eff}$ = 10 acres

  SQDV = (0.47 in) × (10 ac) × (ft/12 in) × (43,560 ft$^2$/ac) = 17,061 ft$^3$

**Solution:**

Size the proposed control measure for SQDV = 17,061 ft$^3$ and 40-hr drawdown.

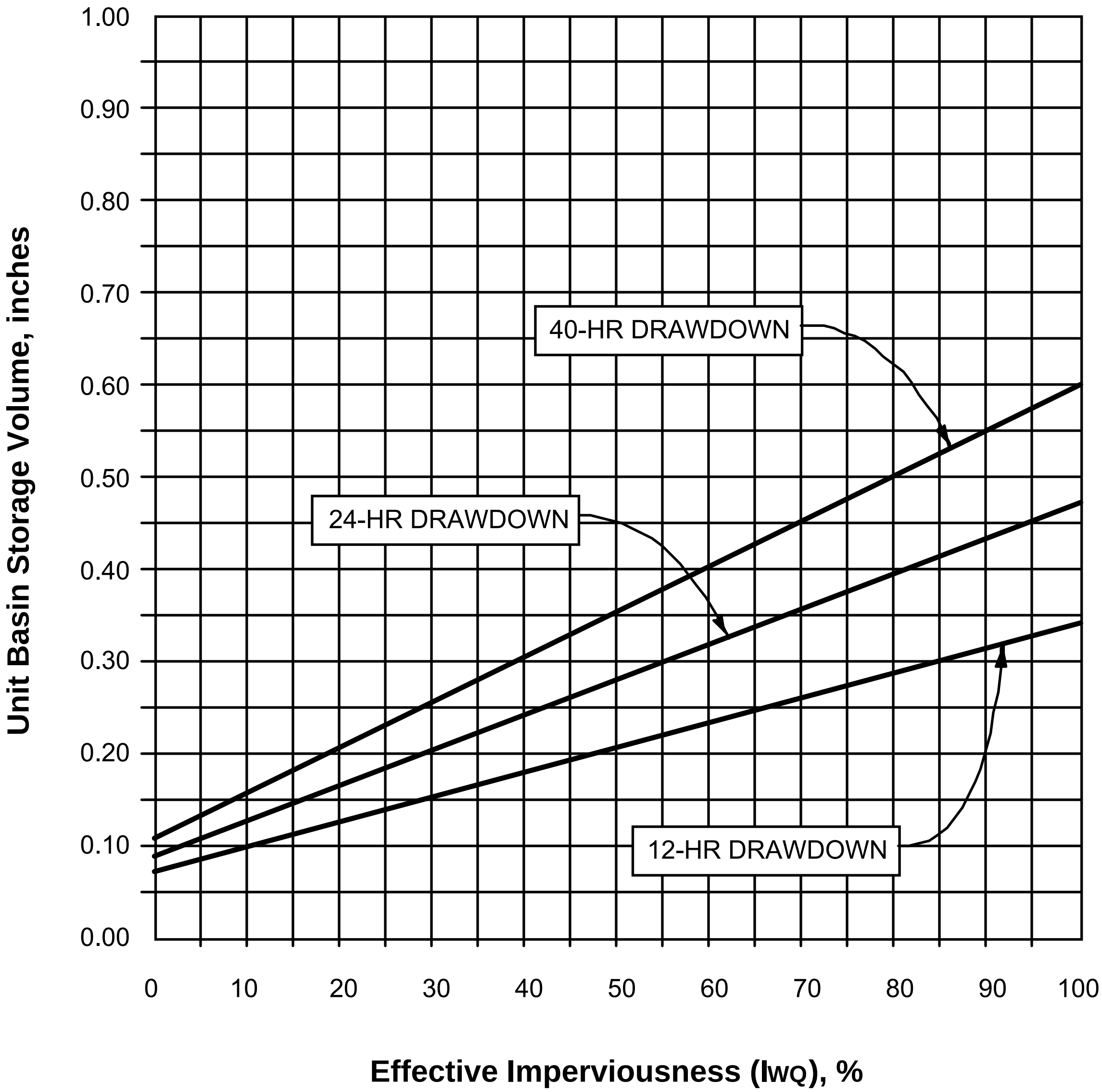



**Figure 5-1. Unit Basin Storage Volume vs. Effective Imperviousness**

## Stormwater Quality Design Flow (SQDF) Calculation

The Stormwater Quality Design Flow (SQDF) is defined to be equal to the maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two. The 85th percentile hourly rainfall intensity for the Davis area is estimated to be approximately 0.10 inches/hour, based on the cumulative frequency curve for Sacramento presented in the *California Stormwater Quality Association (CASQA) Stormwater Best Management Practice Handbook – New Development and Redevelopment* (2003) for representative rainfall gauges throughout California. The curve for Sacramento is considered to be a conservative representation of rainfall intensities in the Davis area.

### Calculation Procedure (SQDF)

**Step 1 – Determine the 85$^{th}$ percentile rainfall intensity**

Determine the 85$^{th}$ percentile hourly rainfall intensity for the Davis area.

Use 0.10 in/hr.

**Step 2 – Calculate design rainfall intensity (i)**

Multiply the 85$^{th}$ percentile hourly rainfall intensity by a factor of two to obtain design rainfall intensity.

Use $i = 0.10 \times 2 = 0.20$ in/hr.

**Step 3 – Determine project drainage area and runoff coefficient ("C")**

Determine the project drainage area and the weighted average runoff coefficient "C" for the project drainage area using values listed in **Table 5-4** or the following equation:

$$C = 0.858\,(I_{WQ})^3 - 0.78\,(I_{WQ})^2 + 0.774\,(I_{WQ}) + 0.04$$

where

$C$ = runoff coefficient

$I_{WQ}$ = design imperviousness

Note: C values obtained from standard hydrology reference manuals for small storms may also be used, if referenced.

**Step 4 – Calculate the SQDF**

$$SQDF = i \times C \times A_{eff}$$

where

SQDF = Stormwater Quality Design Flow, cfs

$i$ = Design storm intensity = 0.20 in/hr

$C$ = Runoff coefficient for project drainage area

$A_{eff}$ = effective project drainage area after adjustment for LID credits, acres

### Calculation Example (SQDF)

- Using the $I_{WQ}$ value determined in the example calculation, 75% (see **Table 5-6**), calculate C using the equation in Step 3:

  $$C = 0.858(0.75)^3 - 0.78(0.75)^2 + 0.774(0.75) + 0.04$$

  $$C = 0.54$$

- Calculate SQDF

  SQDF = 0.20 × C × $A_{eff}$

  $A_{eff}$ = effective project drainage area, acres = 56,000 $ft^2$/(43,560 $ft^2$/acre) = 1.30 acres

  SQDF = 0.20 x 0.54 x 1.30 = 0.14 cfs

**Solution:**

SQDF = 0.14 cfs


## Description

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

A Grass Swale differs from a conventional drainage channel or roadside ditch due to the incorporation of specific features that enhance stormwater pollutant removal effectiveness. A Grass 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 5-2** for a typical Grass Swale configuration.

***Other Names:*** Vegetated Swale, Bioswale

> Do not confuse a Grass Swale with a *Grass Filter Strip* (T-2), Vegetated Swale (T-8) or an *LID Channel/Swale* (D-4.2), which is used as an LID strategy or for pretreatment. The latter provides only limited pollutant removal because of higher application rates, and it requires downstream treatment controls.

### Advantages

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

### Limitations

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

## Planning and Siting Considerations

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

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

## Design Criteria

Design criteria for the Grass Swale are listed in **Table 5-7**. A Design Data Summary Sheet is provided at the end of this fact sheet.

**Table 5-7. Grass Swale Design Criteria**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Tributary drainage area | ≤ 10 acres | For larger areas, break up into sub-watersheds of 10 acres or less, with a swale for each sub-watershed. |
| Design flow | SQDF | See *Standard Calculations Fact Sheet* |
| Roughness coefficient (n) for treatment design | 0.2 | Reflects the roughness associated with shallow flow through dense vegetation. |
| Roughness coefficient (n) for conveyance design | 0.1 | Reflects the roughness of swale when depth of flow is above the height of the grass. Used to determine capacity of swale to convey peak hydraulic flows |
| Minimum contact time for treatment of the SQDF | 7 minutes | Provide sufficient length to yield minimum contact time for the WQF |
| Minimum bottom width | 2 ft | |
| Maximum bottom width | 10 ft | Swales wider than 10 feet can be divided by internal berms to conform to maximum width criteria. |
| Maximum side slopes | 3:1 | Side slopes to allow for ease of mowing. Steeper slopes may be allowed with adequate slope stabilization. |
| Longitudinal slope | 1-4% | |
| Check dams | As required | For longitudinal slope > 4% and as a means of promoting more infiltration. Space dams as required to maintain maximum longitudinal bottom slope ≤ 4%. |
| Underdrains | As required | For longitudinal slope < 1% |
| Maximum depth of flow at SQDF | 3-5 in. | 1 inch below top of vegetation |
| Maximum flow velocity (treatment) | 1 ft/sec | Based on Manning's n = 0.20. Concentrated inlet flow must be spread |
| Inlet Design/Curb cuts | ≥ 12 in. wide | To prevent clogging and promote flow spreading. Pavement should be slightly higher than swale. Include energy dissipaters. |

## Design Procedure

### Step 1 – Determine the Grass Swale's Function

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

### Step 2 – Calculate Stormwater Quality Design Flow (SQDF)

Using the *Standard Calculations Fact Sheet*, determine the contributing area and stormwater quality design flow, SQDF.

### Step 3 – Provide for peak hydraulic design flows

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

### Step 4 – Design the Grass Swale Using Manning's Equation

Swales can be trapezoidal (as illustrated in **Figure 5-2**) or parabolic in shape. While trapezoidal channels are the most efficient channel for conveying flows, parabolic configurations provide good water quality treatment and may be easier to mow since they don't have sharp breaks in slope.

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

**Manning's Equation**

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

where

Q = SQDF

A = Cross-sectional area of flow

P = Wetted perimeter of flow

s = Bottom slope in flow direction

n = Manning's n (roughness coefficient)

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

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

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

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 the minimum contact time of 7 minutes.

For swales that receive direct concentrated runoff at the upstream end, provide an energy dissipater, as appropriate, and a flow spreader such as a pea gravel diaphragm flow spreader at the upstream end of the swale. (See **Figure 5-3** in T-2: Grass Filter Strip for schematic of pea gravel flow spreader.)

**Step 6 – Select Vegetation**

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

Select vegetation that:

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

See **Appendix F** for recommended grasses for Grass 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 Grass Swale vegetation.

## Construction Considerations

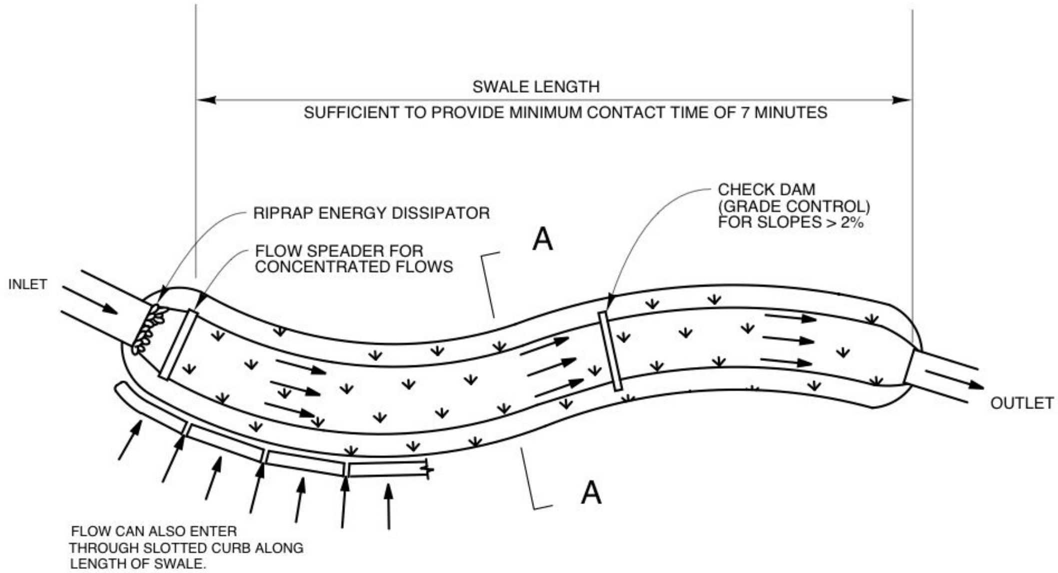
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the swale to prevent high sediment 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 may require 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 Grass Filter Strips. Such agreements will typically include requirements such as those outlined in **Table 5-8**. The property owner or his/her designee is responsible for compliance with the agreement. A sample maintenance agreement is presented in **Appendix C-1**.

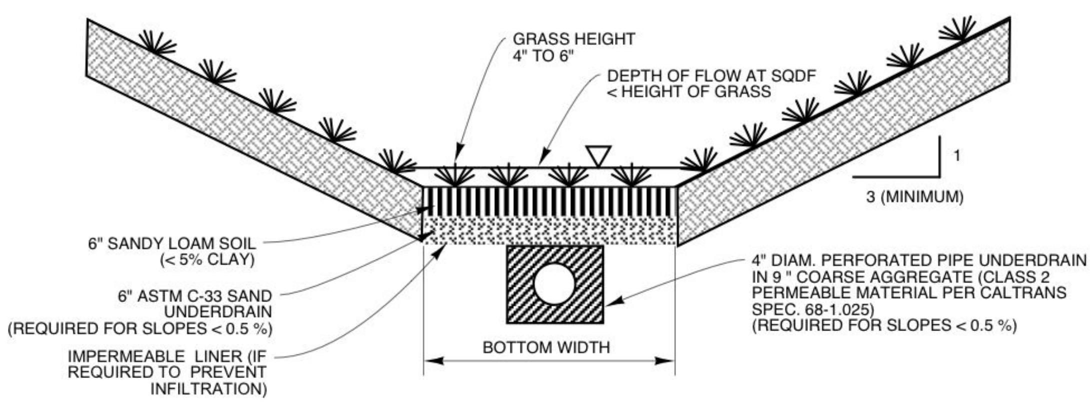
**Table 5-8. Inspection and Maintenance Requirements for Grass Swales**

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




TRAPEZOIDAL GRASS SWALE PLAN

NOT TO SCALE




TRAPEZOIDAL GRASS SWALE SECTION

NOT TO SCALE

*ADAPTED FROM URBAN STORM DRAIN CRITERIA MANUAL VOL. 3 - BEST MANAGEMENT PRACTICES, URBAN DRAINAGE AND FLOOD CONTROL DISTRICT,11/99*

**Figure 5-2. Grass Swale**

## Design Data Summary Sheet for Grass Swale (Page 1 of 1)

**Designer:** ____________________

**Company:** ____________________

**Date:** ____________________

**Project:** ____________________

**Location/Swale I.D. No.:** ____________________

| | |
|---|---|
| 1. Design Flow: SQDF = I x C x A<br>a. I = Design Intensity = 0.20 in/hr<br>b. C = Runoff Coefficient<br>c. $A_{eff}$ = Effective Tributary Area | <br>I = ______ in/hr<br>C = ______<br>$A_{eff}$ = ______ acres<br>SQDF = ______ cfs |
| 2. Swale Geometry (trapezoidal)<br>a. Swale Bottom Width (b)<br>b. Side slope (Z) | <br>b = ______ ft<br>Z = ______ |
| 3. Depth of flow (d) at SQDF (3"-5" with Manning's n= 0.20) | d = ______ in |
| 4. Design Slope<br>a. s = 1% minimum without underdrains; 4% maximum without grade controls<br>b. Number of grade controls required | <br>s = ______ %<br>______ (number) |
| 5. Design flow velocity (Manning's n= 0.20) | V = ______ ft/sec |
| 6. Contact Time ($t_c$ = 7 minutes minimum) | $t_c$ = ______ minutes |
| 7. Design Length<br>L = ($t_c$) x (flow velocity) x 60 | <br>L = ______ ft |
| 8. Vegetation (describe) | ______<br>______<br>______ |
| 9. Outflow Collection (Check type used or describe "Other") | ____ Grated Inlet<br>____ Infiltration Trench<br>____ Underdrain Used<br>____ Other ______<br>______ |

Notes ____________________

____________________

## Description

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

Greater surface area and contact time promote greater runoff treatment efficiencies. The volume of runoff can be reduced through infiltration into underlying soils. See **Figure 5-3** for a typical Grass Filter Strip configuration.

***Other Names:*** Vegetated Filter Strips, Biofilter

### 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
- Attractive
- Easy to maintain

### Limitations

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

> Do not confuse a Grass Filter Strip with a *Grass Swale* (T-1) or an *LID Buffer Strip* (D-4.3), which is used as an LID strategy or for pretreatment. The latter provides only limited pollutant removal because of higher application rates, and, consequently, requires downstream treatment controls.

## Planning and Siting Considerations

- Select location where site topography allows for the design of filter strips with proper slopes in flow direction
- Integrate Grass Filter Strips into open space buffers, undisturbed natural areas, and other landscape areas when possible
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the filter strip and cars are allowed to overhang the filter strip.
- Irrigation is typically required to maintain viability of the filter strip vegetation. Coordinate design of general landscape irrigation system with that of the Grass 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 Grass Filter Strips are listed in **Table 5-9**. A Design Data Summary Sheet is provided at the end of this fact sheet.

**Table 5-9. Grass Filter Strip Design Criteria**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Drainage area | ≤ 5 acres | For larger areas, break up into sub-watersheds of 5 acres or less with a filter strip for each. |
| Design flow | SQDF | See *Standard Calculations Fact Sheet* |
| 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 | 15 ft | Most treatment occurs in the first 15 feet of flow. Longer lengths will typically provide somewhat higher levels of treatment |
| Vegetation height (typical) | 2 – 4 in. | Vegetation should be maintained at a height greater than the depth of flow at design flow rate but sufficiently low to prevent lodging or shading of the vegetation. |

## Design Procedure

### Step 1 – Calculate Water Quality Flow (SQDF)

Using the *Standard Calculations Fact Sheet*, determine the contributing area and stormwater quality design flow, WQF.

### Step 2 – Calculate minimum width of Grass Filter Strip ($W_{GFS}$)

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

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

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

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

The length of the filter strip in the flow direction must be a minimum of 15 feet. Greater lengths are desirable, as somewhat better treatment performance can typically be expected.

### Step 4 – Determine design slope

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

**Step 5 – Design inlet flow distribution**

Incorporate a device such as slotted curbing, modular block porous pavement, or other spreader devices at the upstream end of the filter strip to evenly distribute flow along the top width. Concentrated flow delivered to the filter strip must be distributed evenly by means of a level spreader as shown in **Figure 5-2.**

**Step 6 – Select vegetation**

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

Select vegetation that:

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

See **Appendix F** for recommended grasses for Grass 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., grass channel/swale, storm drain, gutter).

**Step 8 – Design irrigation system**

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

## Construction Considerations

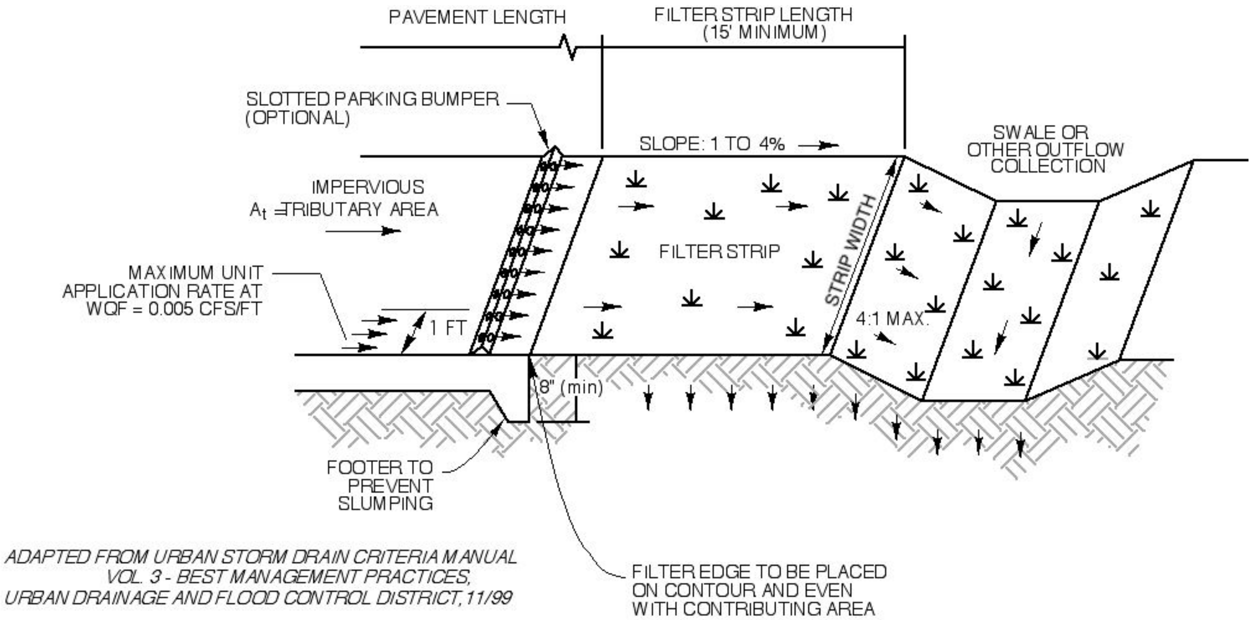
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the filter strip to prevent high 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 final acceptance of a private development project, which includes treatment control measures such as Grass Filter Strips. Such agreements will typically include requirements such as those outlined in **Table 5-10**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix C-1**.

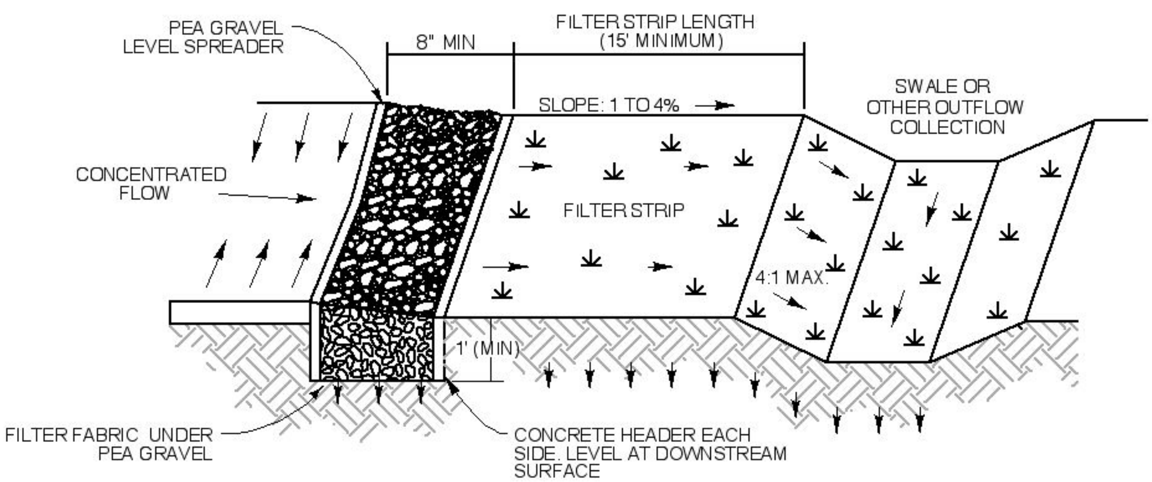
**Table 5-10. Inspection and Maintenance Requirements for Grass Filter Strips**

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




SHEET FLOW CONTROL

NOT TO SCALE




CONCENTRATED FLOW CONTROL

NOT TO SCALE

**Figure 5-3. Grass Filter Strip**

## Design Data Summary Sheet for Grass Filter Strips (Page 1 of 1)

**Designer:**________________________________________

**Company:**________________________________________

**Date:**________________________________________

**Project:**________________________________________

**Location/Filter Strip I.D. No.:**________________________________________

| | |
|---|---|
| 1. Design Flow: SQDF = I x C x A<br>a. I = Design Intensity = 0.18 in/hr<br>b. C = Runoff Coefficient<br>c. $A_{eff}$ = Effective tributary area | <br>I = __________ in/hr<br>C = __________<br>$A_{eff}$ = __________ acres<br>SQDF = __________ cfs |
| 2. Design Width<br>$W_{GFS}$ = (SQDF)/0.005 cfs/ft | <br>$W_{GFS}$ = __________ ft |
| 3. Design Length (15 ft minimum) | $L_{GFS}$ = __________ ft |
| 4. Design Slope (1% minimum; 4% maximum) | $S_{GFS}$ = __________ % |
| 5. Flow Distribution (Check type used or describe "Other") | _____ Slotted Curbing<br>_____ Modular Block Porous Pavement<br>_____ Level Spreader<br>_____ Other ____________________<br>____________________________ |
| 6. Vegetation (describe ) | ____________________________<br>____________________________ |
| 7. Outflow Collection (Check type used or describe "Other") | _____ Grass Swale<br>_____ Street Gutter<br>_____ Storm Sewer<br>_____ Underdrain Used<br>_____ Other ____________________<br>____________________________ |

Notes ________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________


## Description

Wet Ponds are open earthen basins that feature a permanent pool of water that is displaced by stormwater flow, in part or total, during runoff events. Like Extended Detention Basins, Wet Ponds are designed to temporarily retain the SQDV of stormwater runoff and to slowly release this volume over a specified period (12 hours). Wet Ponds differ from Extended Detention Basins in that the influent runoff flow water mixes with and displaces the permanent pool as it enters the basin. The design drawdown time for Wet Ponds (12 hours) is shorter than for Extended Detention Basins (40 hours) because enhanced treatment is provided in the permanent pool. Wet Ponds differ from Constructed Wetland Basins in having a greater average depth, and therefore less vegetation. A dry-weather base flow is required to maintain a permanent pool. The primary pollutant removal mechanism is settling, but pollutant removal, particularly of nutrients, also occurs through biological activity in the pond. The basic elements of a Wet Pond are shown in **Figure 5-4**.

### Advantages

- Wet ponds can be designed to provide other benefits such as recreation, wildlife habitat, and open space. Safety issues must be addressed.
- 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.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to stormwater flow.
- Can serve essentially any size tributary area.

### Disadvantages

- Public safety must be considered with respect to access.
- 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.
- Ponds require a relatively large footprint.
- Depending on volume and depth, pond designs may require approval from the State Division of Safety of Dams.

## Planning and Siting Considerations

- Wet Ponds are appropriate for use in the following settings:

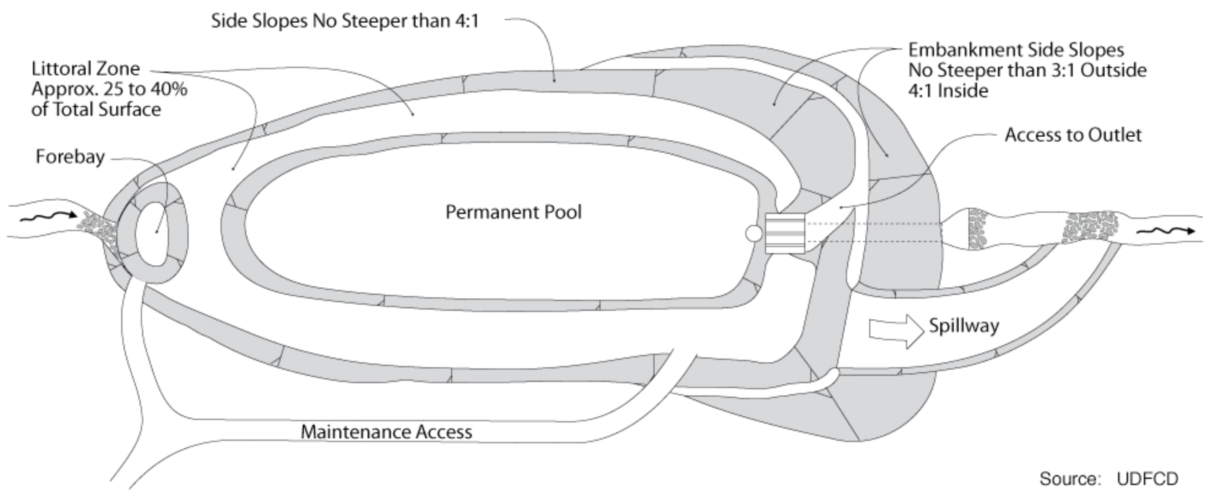
  - Where there is a need to achieve a reasonably high level of dissolved contaminant removal and/or sediment capture;
  - Where base flow rates or other channel flow sources are relatively consistent year-round; or
  - In residential settings where aesthetic and wildlife habitat benefits can be appreciated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

## Design Criteria

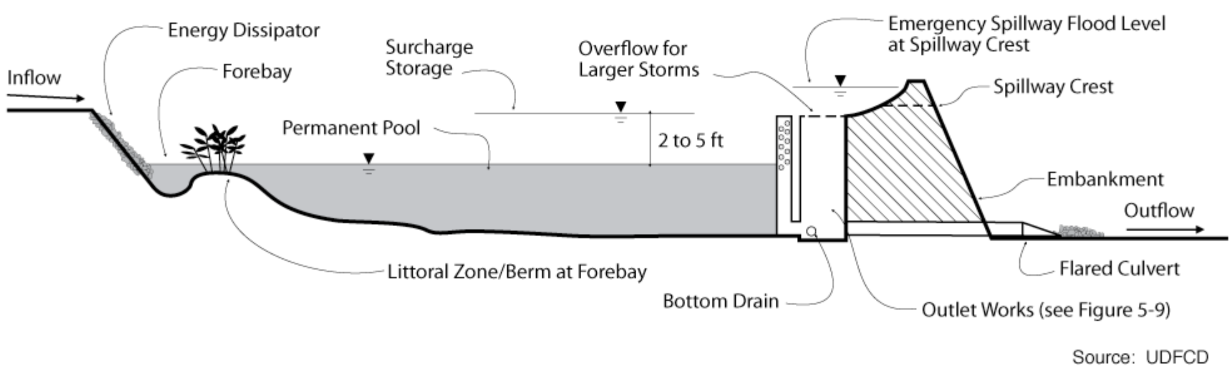
Principal design criteria for Wet Ponds are listed in **Table 5-11**. A Design Data Summary Sheet is provided at the end of this fact sheet.

**Table 5-11. Wet Pond Design Criteria**

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




Plan View




Section View

**Figure 5-4. Conceptual Layout of Wet Pond**

## Design Procedure

### Step 1 – Calculate Water Quality Design Volume (SQDV)

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

### Step 2 – Determine Minimum Volume for Permanent Pool

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

$V_{pp}$ = 1.0 to 1.5 x SQDV

### Step 3 – Determine Depth Zones

Distribution of the permanent pool area is needed to achieve desired biodiversity. In addition to the forebay, two depth zones are required (see **Figure 5-5**). The Littoral Zone provides for aquatic plant growth along the perimeter of the pool. The Deeper Zone covers the remaining pond area and promotes sedimentation and nutrient uptake by phytoplankton. Distribute component areas as follows:

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

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

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

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

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

### Step 4 – Determine inflow requirement

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

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

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

**Step 6 – Design Outlet Works**

The outlet works are to be designed to release the SQDV over a 12-hour period. Protect the outlet from clogging with a trash rack and a skimmer shield that extends below the outlet and above the maximum SQDV depth. An outlet works for a Wet Pond is depicted in **Figure 5-6**.

a. For single orifice outlet control or single row of orifices at the permanent pool elevation (WS $Elev_{pp}$) (see **Figure 5-6**), use the orifice equation based on the SQDV ($ft^3$) and depth of water above orifice centerline D (ft) to determine orifice area ($in^2$):

***Orifice Equation***

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

where

Q = Flow rate
C = Orifice coefficient (use 0.61)
A = Area of orifice
g = Acceleration due to gravity (32.2 $ft/sec^2$)
D = Depth of water above orifice centerline ($D_{SQDV}$)

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

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

where

t = drawdown period (hrs) = 12 hrs

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

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

where

$K_{12} = 0.008D^2 + 0.056D – 0.012$

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

nr = 1 + (D x 3)

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

Total Orifice Area = area/row x nr

**Step 7 – Design Basin Shape**

Whenever possible, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. The length to width ratio should be between 2:1 to 4:1, with 3:1

recommended. Internal baffling with berms or modification of inlet and outlet points may be necessary to achieve this ratio.

**Step 8 – Design Embankment Side Slopes**

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

- Side slopes above the permanent pool should be no steeper than 4:1, preferably 5:1 or flatter.
- The littoral zone should be very flat (40:1 or flatter) with the depth ranging from 6 inches near the shore and extending to no more than 12 inches at the furthest point from the shore.
- The side slope below the littoral zone shall be 3:1 or flatter.

**Step 9 – Inlet/Outlet Design**

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

**Step 10 – Design Maintenance Access**

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

**Step 11 – Provide Bypass**

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

**Step 12 – Provide Underdrains**

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

**Step 13 – Select Vegetation**

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

**Step 14 – Design Security Fencing**

Provide aesthetic security fencing around basin to protect habitat except when specifically waived by the stormwater agency. Fencing design shall be approved by the stormwater agency.

## Construction Considerations

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

## Long-Term Maintenance

The City may require 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 Wet Ponds. Such agreements will typically include requirements such as those outlined in **Table 5-12**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix C-1**.

**Table 5-12. Inspection and Maintenance Requirements for Wet Ponds**

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

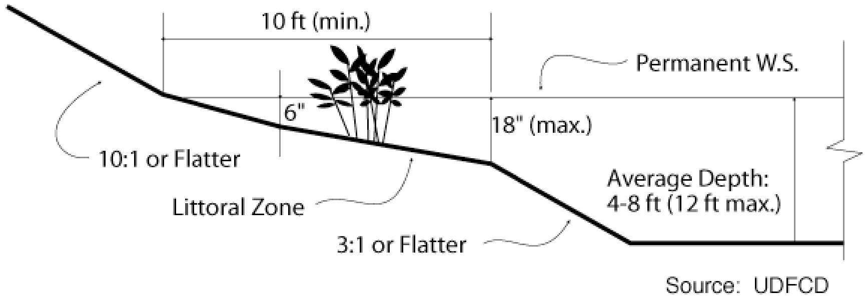



**Figure 5-5. Depth Zones for Wet Pond**

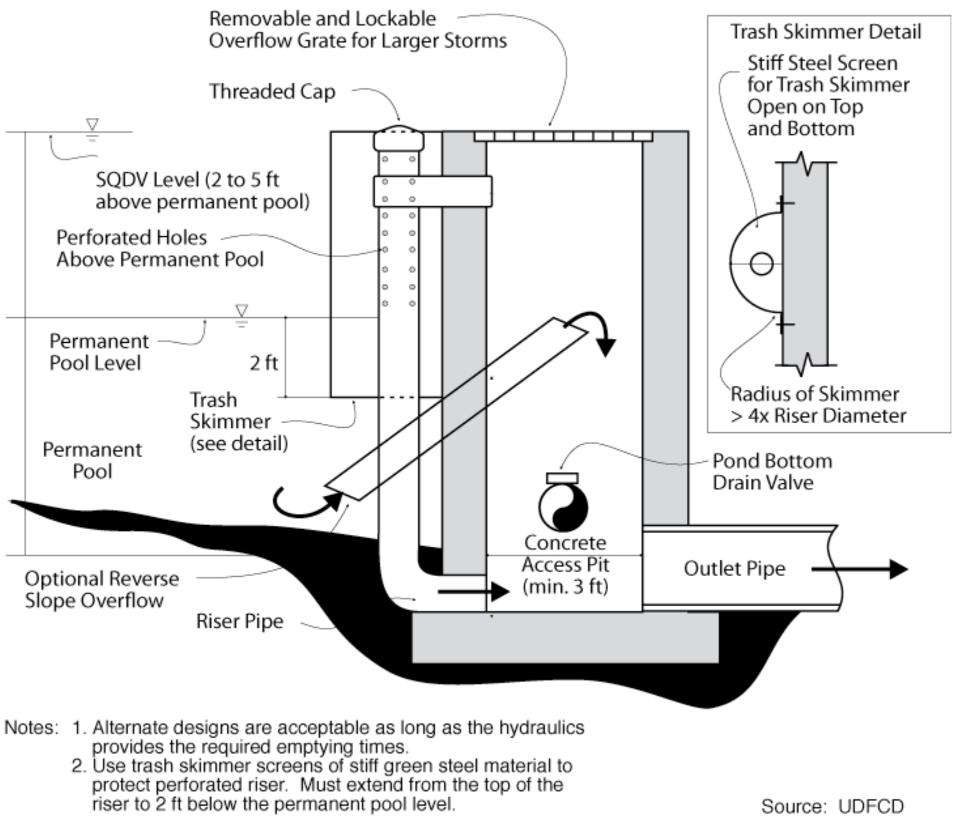



**Figure 5-6. Outlet Works for Wet Pond**

## Design Data Summary Sheet for Wet Pond (Page 1 of 2)

**Designer:**______________________________

**Company:**______________________________

**Date:**______________________________

**Project:**______________________________

**Location:**______________________________

| | | | |
|---|---|---|---|
| 1. Water Quality Design Volume | | | |
| a. Effective tributary drainage area | $A_{eff}$ = | ________ | $ft^2$ |
| b. Stormwater Quality Design Volume | SQDV = | ________ | $ft^3$ |
| a. Minimum Permanent Pool Volume | | | |
| ($V_{pp}$ = 1.0 to 1.5 x SQDV) | $V_{pp}$ = | ________ | acre-ft |
| b. Depth Zones | | | |
| a. Forebay | | | |
| Volume range = 5-10 % of SQDV | Volume = | ________ | $ft^3$ |
| Drain time (<45 min) | $t_{drain}$ = | ________ | min |
| a. Littoral Zone | | | |
| Depth Range = 6-12 in | Depth = | ________ | in |
| Area = 25-40% of $A_{pp}$ | Area = | ________ | $ft^2$ |
| b. Deeper Zone | | | |
| Depth Range = 4 to 8 ft average, 12 ft maximum | Depth = | ________ | ft |
| | $Depth_{max}$ = | ________ | ft |
| Water surface area range = 55-65% of $A_{pp}$ | Area = | ________ | $ft^2$ |
| 4. Determine Maximum Month Inflow Requirement | $Q_{E-P}$ = | ________ | acre-ft/mo. |
| $Q_{inflow} = - Q_{E-P} + Q_{seepage} + Q_{ET}$ | $Q_{seepage}$ = | ________ | acre-ft/mo. |
| | $Q_{ET}$ = | ________ | acre-ft/mo. |
| | $Q_{inflow}$ = | ________ | acre-ft/mo. |
| 5. Trash Rack present? | Yes/No | ________ | |
| 6. Outlet Works | | | |
| a. Outlet Type (check one) | Single Orifice | ________ | |
| | Multi-orifice Plate | ________ | |
| | Perforated Pipe | ________ | |
| | Other | ________ | |
| b. Depth of water above bottom orifice ($D_{SQDV}$) | Depth = | ________ | ft |
| c. Single Orifice Outlet | | | |
| 1) Total Area | A = | ________ | $in^2$ |
| 2) Diameter (or L x W) | D = | ________ | in |

## Design Data Summary Sheet for Wet Pond (Page 2 of 2)

**Project:**_______________________________________________

| | | | |
|---|---|---|---|
| 6. Outlet Works (cont.) | | | |
| d. Multiple Orifice Outlet | | | |
| 1) Area per Row of Perforations | A = | ________ | $in^2$ |
| 2) Perforation Diameter (2-inch max.) | Diam = | ________ | in |
| 3) No. of Perforations (columns) per Row | Perforations = | ________ | |
| 4) No. of Rows (4-inch spacing) | Rows = | ________ | |
| 5) Total Orifice Area | | | |
| (Area per Row) x (Number of Rows) | Area = | ________ | $in^2$ |
| 7. Basin Shape | | | |
| a. Length-Width Ratio (2:1 min.) | Ratio = | ________ | L:W |
| 8. Embankment Side Slope (H:V) | | | |
| a. Interior Side Slope (no steeper than 4:1) | Int. Side Slope = | ________ | H:V |
| b. Exterior Side Slope (no steeper than 3:1) | Ext. Side Slope = | ________ | H:V |
| c. Littoral Zone Slope (40:1 or flatter) | Littoral Zone = | ________ | H:V |
| d. Side slope below Littoral Zone (3:1 or flatter) | Below Litt. Zone = | ________ | H:V |
| 9. Inlet and outlet points (select one or both) | Energy dissipation | ________ | |
| | Erosion protection | ________ | |
| 10. Maintenance Access Ramp | | | |
| a. Slope (10% maximum) | Slope = | ________ | % |
| b. Width (16 ft minimum) | Width = | ________ | ft |
| 11. Bypass provided? | Yes/No | ________ | |
| 12. Underdrains provided? | Yes/No | ________ | |
| 13. Vegetation (describe) | Native Grasses | ________ | |
| | | ________ | |
| | Irrigated Turf | ________ | |
| | | ________ | |
| | Emergent Aquatic Plants (specify type/density) | ________ | |
| | | ________ | |
| | | ________ | |
| | | ________ | |
| | Other | ________ | |

Notes: ____________________________________________

____________________________________________


Photo Credit: Rachel Terpstra, Larry Walker Associates

## Description

A Constructed Wetland Basin is an earthen basin treatment system having a permanent pool of water that includes a forebay, an open-water zone, a wetland zone with aquatic plants, and an outlet zone. Influent flow to a Constructed Wetland Basin mixes with and displaces the permanent pool. The surcharge volume above the permanent pool is slowly released over a specified drawdown period (24 hours for SQDV). A supplemental water source is required to maintain the permanent water pool. The aquatic plants provide energy dissipation and enhance pollutant removal by sedimentation and biological uptake.

A Constructed Wetland Basin is designed to retain the stormwater quality volume in a wetland basin and discharge that volume to downstream drainage over the design drawdown period. Treatment of the runoff occurs through a variety of natural mechanisms that occur in the wetland, including sedimentation, filtration, adsorption, and biological uptake. Much of the water discharged from the wetland basin during and following a storm event is water displaced from the permanent pool. Constructed Wetland Basins differ from Wet Ponds in having shallower depth and more aquatic vegetation.

### Advantages

- Reduces stormwater discharge to surface waters during most storm events.
- Reduces peak flows during small storm events.
- Can provide wildlife habitat and passive recreational opportunities.

### Limitations

- Supplemental water supply required to maintain the permanent pool.
- Public safety related to access must be considered. Security fencing generally required.

## Planning and Siting Considerations

- **Tributary Drainage Area:** Up to 100+ acres.
- **Soil Type:** Most appropriate for Type C and D soils. Type A and B soils could be used with the addition of a clay liner.
- **Topography:** Not appropriate on fill or steep slopes.
- Integrate Constructed Wetland Basins into open space buffers, undisturbed natural areas, and other landscaped areas when possible.
- Provide aesthetic security fencing approved by the agency unless specifically waived by agency.
- Vector considerations: Potential for mosquitoes exists due to permanent water pool. However, proper design of permanent pool zones and introduction of mosquito fish will minimize the risk.

## Design Criteria

Design criteria for Constructed Wetland Basins are listed in **Table 5-13**. A Design Data Summary Sheet is provided at the end of this fact sheet.

**Table 5-13. Constructed Wetland Basin Design Criteria**

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

## Design Procedure

**Step 1 – Calculate Water Quality Volume (SQDV)**

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

**Step 2 – Determine Basin Minimum Volume for Permanent Pool**

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

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

**Step 3 – Determine Basin Depths and Surface Areas**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\text{WS Elev}_{SQDV} = \text{WS Elev}_{pp} + \text{Final } D_{SQDV}$

**Step 5 – Determine inflow requirement**

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

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

where

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

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

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

**Step 6 – Design Basin Forebay**

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

**Step 7 – Design Outlet Works**

Provide outlet works that limit the maximum water surface elevation to WS $Elev_{SQDV}$. The Outlet Works are to be designed to release the SQDV over a 24 hour period. Protect the outlet from clogging with a trash rack and a skimmer shield that extends below the outlet and above the maximum SQDV depth. A single orifice outlet control is depicted in **Figure 5-7**.

a. For single orifice outlet control or single row of orifices at the permanent pool elevation (WS $Elev_{pp}$) (see **Figure 5-7**), use the orifice equation based on the SQDV ($ft^3$) and depth of water above orifice centerline D (ft) to determine orifice area ($in^2$):

   ***Orifice Equation***

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

   where

   Q = Flow rate
   C = Orifice coefficient (use 0.61)
   A = Area of orifice
   g = Acceleration due to gravity (32.2 ft/$sec^2$)
   D = Depth of water above orifice centerline ($D_{SQDV}$)

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

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

   where

   t = drawdown period (hrs) = 24 hrs

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

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

where

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

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

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

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

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

**Step 8 – Design basin shape**

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

**Step 9 – Design basin side slopes**

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

**Step 10 – Design Maintenance Access**

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

**Step 11 – Design Security Fencing**

Provide aesthetic security fencing around basin to protect habitat except when specifically waived by the stormwater agency. Fencing design shall be approved by the stormwater agency.

**Step 12 – Select Vegetation**

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

## Construction Considerations

- An impermeable liner may be required to maintain permanent pool level in areas with porous soils.

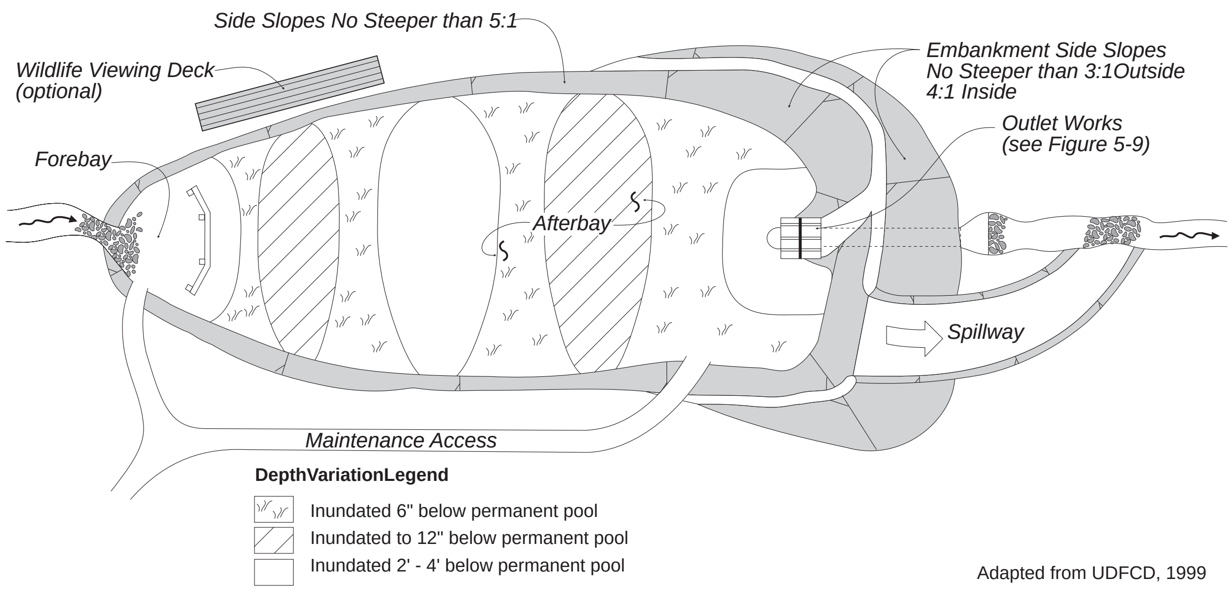
- Install seepage collars on outlet piping to prevent seepage through embankments.

## Long-Term Maintenance

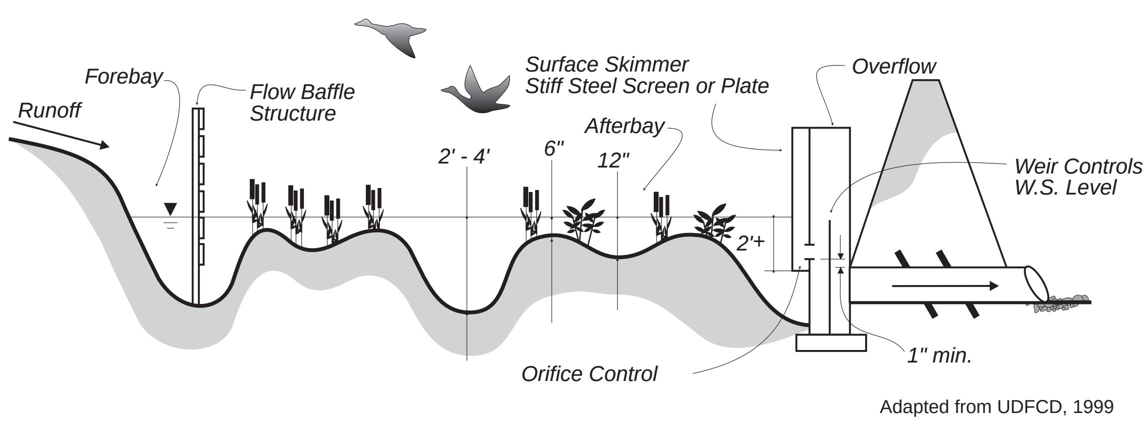
The City may require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as Constructed Wetland Basins. Such agreements will typically include requirements such as those outlined in **Table 5-14**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix C-1**.

**Table 5-14. Inspection and Maintenance Requirements for Constructed Wetland Basins**

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




Plan View




Section View

**Figure 5-7. Constructed Wetland Basin**

## Design Data Summary Sheet for Constructed Wetland Basin (Page 1 of 2)

**Designer:**______________________________

**Company:**______________________________

**Date:**______________________________

**Project:**______________________________

**Location:**______________________________

| | | | |
|---|---|---|---|
| 1. Design Water Quality Volume | | | |
| a. Effective tributary drainage area | $A_{eff}$ = | ________ | $ft^2$ |
| b. Stormwater Quality Design Volume | SQDV = | ________ | $ft^3$ |
| 2. Minimum Permanent Pool Volume (Vpp ≥ 0.75 x SQDV) | $V_{pp}$ = | ________ | acre-ft |
| 3. Wetland Basin Depths and Water Surface Areas | | | |
| a. Permanent pool volume ($V_{pp}$) | $V_{pp}$ = | ________ | acre-ft |
| b. Average depth of permanent pool ($D_{avg}$) | $D_{avg}$ = | ________ | ft |
| c. Water surface area of permanent pool ($A_{pp}$) | $A_{pp}$ = | ________ | $ft^2$ |
| d. Water surface elevation of permanent pool | | | |
| (WS $Elev_{pp}$) | WS $Elev_{pp}$ = | ________ | ft |
| e. Forebay | | | |
| Depth range = 2-4 ft | Depth = | ________ | ft |
| Volume range = 5-10 % of SQDV | Volume = | ________ | acre-ft |
| Water surface area range = 5-10 % of $A_{pp}$ | WS Area = | ________ | $ft^2$ |
| f. Open Water Zone | | | |
| Depth Range = 2-4 ft | Depth = | ________ | ft |
| Water surface area range = 30-50% of $A_{pp}$ | WS Area = | ________ | $ft^2$ |
| g. Wetland Zones with Emergent Vegetation | | | |
| Depth Range = 6-12 inches | Depth = | ________ | ft |
| Water surface area range = 50-70% of $A_{pp}$ | WS Area = | ________ | $ft^2$ |
| h. Outlet Pool | | | |
| Depth Range = 3 ft minimum | Depth = | ________ | ft |
| Water surface area range = 5-10% of $A_{pp}$ | WS Area = | ________ | $ft^2$ |
| 4. Surcharge Depth of SQDV and Max WS Elevation | | | |
| a. Maximum water surface area with SQDV ($A_{SQDV}$) | $A_{SQDV}$ = | ________ | $ft^2$ |
| b. Surcharge depth of SQDV ($D_{SQDV}$ ≤ 2.0 ft) | $D_{SQDV}$ = | ________ | ft |
| Final $D_{SQDV} = SQDV/((A_{SQDV} + A_{pp})/2)$ | | | |
| c. Maximum water surface elevation with SQDV | | | |
| (WS $Elev_{SQDV}$) | WS $Elev_{SQDV}$ = | ________ | ft |
| 5. Determine Maximum Month Inflow Requirement | $Q_{E-P}$ = | ________ | acre-ft/mo. |
| $Q_{inflow} = - Q_{E-P} + Q_{seepage} + Q_{ET}$ | $Q_{seepage}$ = | ________ | acre-ft/mo. |
| | $Q_{ET}$ = | ________ | acre-ft/mo. |
| | $Q_{inflow}$ = | ________ | acre-ft/mo. |

## Design Data Summary Sheet for Constructed Wetland Basin (Page 2 of 2)

**Project:**________________________________

| | | | |
|---|---|---|---|
| 6. Outlet Works | Single Orifice | ________ | |
| a. Outlet Type (check one) | Multi-orifice Plate | ________ | |
| | Perforated Pipe | ________ | |
| | Other | ________ | |
| b. Depth of water above bottom orifice ($D_{SQDV}$) | Depth = | ________ | ft |
| c. Single Orifice Outlet | | | |
| 1) Total Area | A = | ________ | $in^2$ |
| 2) Diameter (or L x W) | D = | ________ | in |
| d. Multiple Orifice Outlet | | | |
| 1) Area per Row of Perforations | A = | ________ | $in^2$ |
| 2) Perforation Diameter (2-inch max.) | Diam = | ________ | in |
| 3) No. of Perforations (columns) per Row | Perforations = | ________ | |
| 4) No. of Rows (4-inch spacing) | Rows = | ________ | |
| 5) Total Orifice Area | | | |
| (Area per Row) x (Number of Rows) | Area = | ________ | $in^2$ |
| 7. Basin Shape | | | |
| a. Length-Width Ratio (2:1 min.) | Ratio = | ________ | L:W |
| 8. Embankment Side Slope | | | |
| a. Interior Side Slope (no steeper than 4:1) | Int. Side Slope = | ________ | L:W |
| b. Exterior Side Slope (no steeper than 3:1) | Ext. Side Slope = | ________ | L:W |
| 11. Maintenance Access Ramp | | | |
| c. Slope (10% maximum) | Slope = | ________ | % |
| d. Width (10 ft minimum) | Width = | ________ | ft. |
| 11. Vegetation (describe) | Native Grasses | ________ | |
| | Irrigated Turf | ________ | |
| | Emergent Aquatic Plants (specify type/density) | ________ | |
| | Other | ________ | |

Notes: ________________________________


## Description

Extended Detention Basins are permanent basins formed by excavation and/or construction of embankments to temporarily detain the SQDV of stormwater runoff to allow for the sedimentation of particulates to occur before the runoff is discharged. An extended detention basin serves to reduce peak stormwater runoff rates, as well as provide treatment. Extended Detention Basins are typically dry between storms, although a shallow pool, one to three feet deep, can be included in the design for aesthetic purposes and to promote biological uptake and conversion of pollutants. A bottom outlet provides a controlled slow release of the detained runoff over a specified time period. Extended Detention Basins can also be used to provide flood control by including additional detention storage. The basic elements of an extended detention basin are shown in **Figure 5-8**. This configuration is most appropriate for large sites.

### Advantages

- May be designed to provide other benefits such as recreation, wildlife habitat, and open space. Safety issues must be addressed.
- Relatively easy and inexpensive to build and operate due to its simple design.
- Can provide substantial capture of sediment and pollutants associated with particulates.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to stormwater flow.
- Useful in retrofit situations where their low hydraulic head requirements allow them to be sited within the constraints of the existing storm drain system. Can be designed into flood control basins or sometimes retrofitted into existing flood control basins.

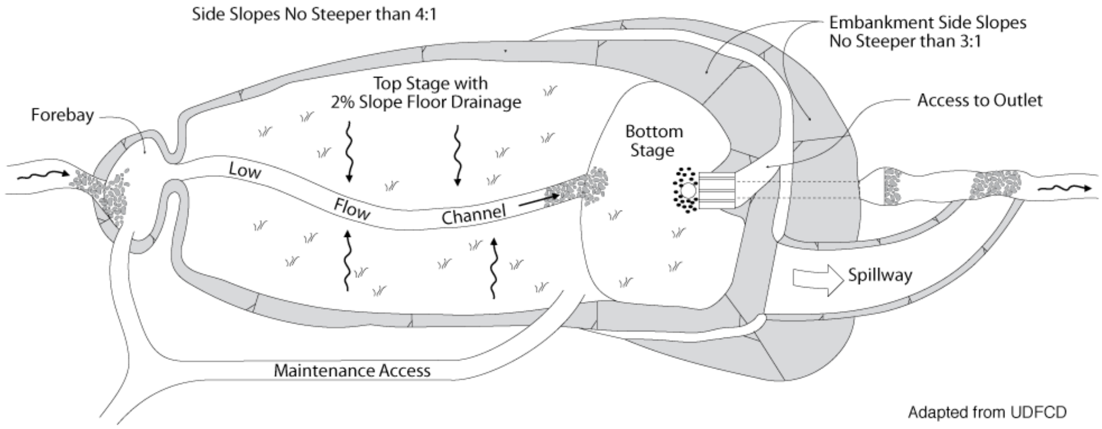
### Disadvantages

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

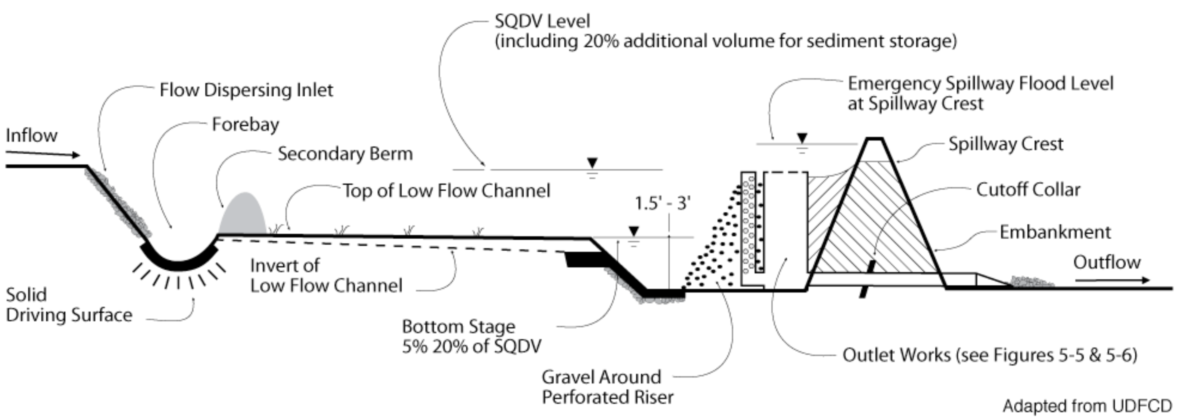
## Planning and Siting Considerations

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

- **Land area requirements:** Approximately 0.5 to 2 percent of the tributary development area.
- **Soil Type:** Can be used with almost all soils and geology, with minor adjustments for regions with rapidly percolating soils. In these areas, impermeable liners can be installed to prevent groundwater contamination. The base of the basin should not intersect the groundwater table because a permanently wet bottom can become a vector breeding ground.




Plan View




Section View

**Figure 5-8. Extended Detention Basin Conceptual Layout**

## Design Criteria

Principal design criteria for Wet Ponds are listed in **Table 5-15**. A Design Data Summary Sheet is provided at the end of this fact sheet.

**Table 5-15. Extended Detention Basin Design Criteria**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Design volume | SQDV | 80% annual capture. Use **Figure 5-1** @ 40-hr drawdown |
| Maximum drawdown time for SQDV | 40 h | Based on SQDV |
| | 12 h | Minimum time for release of 50% SQDV |
| Basin design volume | 120% | Percentage of SQDV. Provide 20% sediment storage volume. |
| Inlet/outlet erosion control | – | Provide energy dissipaters to reduce velocity |
| Forebay | | |
| a. Volume | 5-10% | Percentage of SQDV |
| b. Drain time | < 45 min | |
| Low-flow channel | | |
| a. Depth | 9 in. | |
| b. Flow capacity | 200% | Percentage of forebay outlet release capacity |
| Upper stage | | |
| a. Bottom slope | 2% | |
| b. Depth | 2 ft | Minimum |
| c. Width | 30 ft | Minimum |
| Length to width ratio | 2:1 | Minimum (larger preferred) |
| Bottom stage | | |
| a. Volume | 5-20% | Percentage of SQDV |
| b. Depth | 1.5-3 ft | Deeper than Upper Stage |
| Freeboard | 1 ft | Minimum |
| Embankment side slope (H:V) | ≥ 4:1 | Inside |
| | ≥ 3:1 | Outside (without retaining walls) |
| Maintenance access ramp slope (H:V) | 10:1 | or flatter |
| Maintenance access ramp width | 16 ft | Minimum – approach paved with asphalt concrete |

## Design Procedure

### Step 1 – Calculate Water Quality Volume (SQDV)

Using the *Calculation of Stormwater Quality Design Flow and Volume Fact Sheet*, determine the tributary drainage area and stormwater quality design volume (SQDV) for 40-hour drawdown.

### Step 2 – Determine Minimum Basin Storage Design Volume

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

$$V_{BS} = 1.2 \times SQDV$$

**Step 3 – Design Outlet Works**

The outlet works are to be designed to release the SQDV over a 40-hour period, with no more than 50% released in 12 hours. Protect the outlet from clogging with a trash rack and a skimmer shield that extends below the outlet and above the maximum SQDV depth. Refer to **Figures 5-9** and **5-10** for schematics pertaining to structure geometry; grates, trash racks, and screens; outlet type: perforated riser pipe or orifice plate.

a. For single orifice outlet control or single row of orifices at the basin bottom surface elevation (see **Figure 5-10**), use the orifice equation based on the SQDV ($ft^3$) and depth of water above orifice centerline D (ft) to determine orifice area ($in^2$):

***Orifice Equation***

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

where

Q = Flow rate
C = Orifice coefficient (use 0.61)
A = Area of orifice
g = Acceleration due to gravity (32.2 ft/$sec^2$)
D = Depth of water above orifice centerline ($D_{SQDV}$)

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

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

where

t = drawdown period (hrs) = 40 hrs

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

Area/row ($in^2$) = SQDV/$K_{40}$

where

$K_{40} = 0.013D^2 + 0.22D – 0.10$

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

nr = 1 + (D x 3)

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

Total Orifice Area = area/row x nr

**Step 4 – Provide Trash Rack/Gravel Pack**

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

**Step 5 – Design Basin Shape**

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

**Step 6 – Two-Stage Design**

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

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

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

**Step 7 – Design Pond Forebay**

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

**Step 8 – Low-Flow Channel**

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

**Step 9 – Select Vegetation**

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

**Step 10 – Design Embankment Side Slopes**

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

**Step 11 – Inlet/Outlet Design**

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

**Step 12 – Design Maintenance Access**

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

**Step 13 – Provide Bypass**

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

**Step 14 – Geotextile Fabric**

Non-woven geotextile fabric used in conjunction with gravel packs around perforated risers shall conform to the specifications listed in **Table 5-16**.

**Table 5-16. Non-woven Geotextile Fabric Specifications**

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

Adapted from SSPWC, 1997.

**Step 15 – Design Security Fencing**

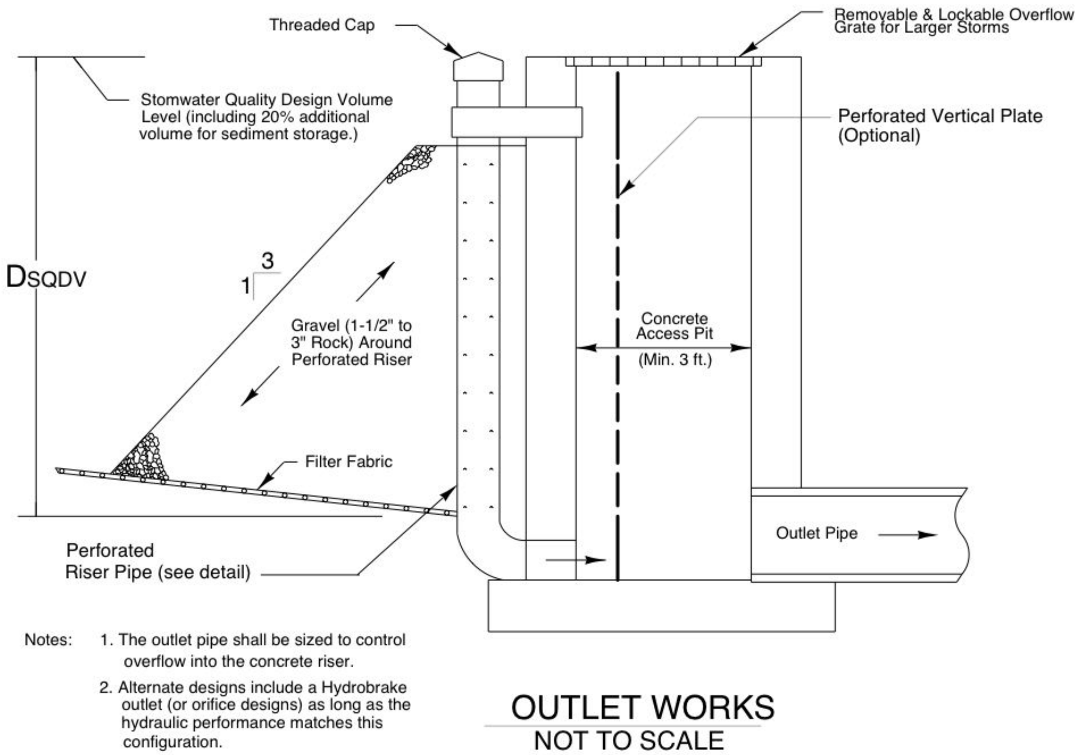
Provide aesthetic security fencing around basin to protect habitat except when specifically waived by the stormwater agency. Fencing design shall be approved by the stormwater agency.

## Long-Term Maintenance

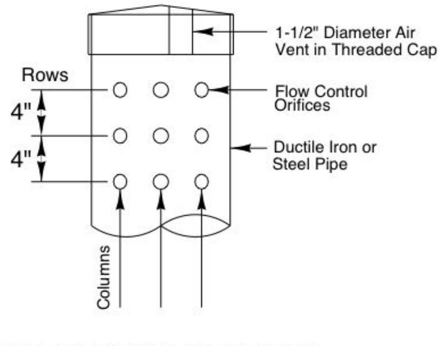
The City require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as Extended Detention Basins. Such agreements will typically include requirements such as those outlined in **Table 5-17**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix C-1**.

**Table 5-17. Inspection and Maintenance Requirements for Extended Detention Basins**

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




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




PERFORATED VERTICAL RISER PIPE
NOT TO SCALE

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

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

*ADAPTED FROM UDFCD, 1999*

OUTLET CONFIGURATIONS USING MULTIPLE ORIFICE FLOW CONTROL

**Figure 5-9. Perforated Pipe Outlet Structure**

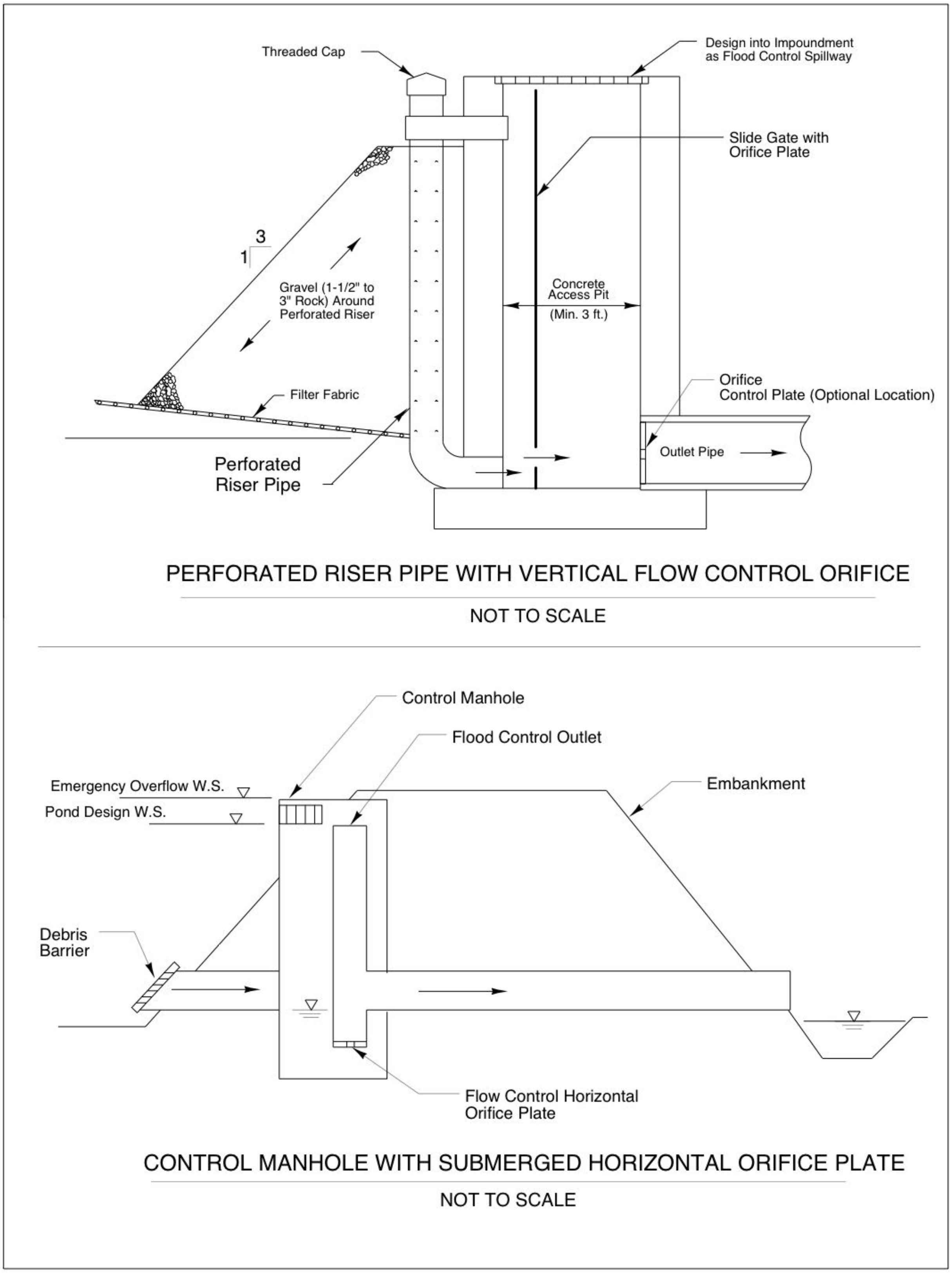



**Figure 5-10. Orifice Plate Outlet Type**

## Design Data Summary Sheet for Extended Detention Basin (Page 1 of 2)

**Designer:**______________________________

**Company:**______________________________

**Date:**______________________________

**Project:**______________________________

**Location:**______________________________

| | | | |
|---|---|---|---|
| 1. Water Quality Design Volume | | | |
| a. Effective tributary drainage area | $A_{eff}$ = | ______ | $ft^2$ |
| b. Stormwater Quality Design Volume | SQDV = | ______ | $ft^3$ |
| 2. Minimum Basin Storage Design Volume | | | |
| ($V_{BS}$ = 1.2 x SQDV) | $V_{BS}$ = | ______ | acre-ft |
| 3. Outlet Works | | | |
| a. Outlet Type (check one) | Single Orifice | ______ | |
| | Multi-orifice Plate | ______ | |
| | Perforated Pipe | ______ | |
| | Other | ______ | |
| b. Depth of water above bottom orifice ($D_{SQDV}$) | Depth = | ______ | ft |
| c. Single Orifice Outlet | | | |
| 1) Total Area | A = | ______ | $in^2$ |
| 2) Diameter (or L x W) | D = | ______ | in |
| d. Multiple Orifice Outlet | | | |
| 1) Area per Row of Perforations | A = | ______ | $in^2$ |
| 2) Perforation Diameter (2-inch max.) | Diam = | ______ | in |
| 3) No. of Perforations (columns) per Row | Perforations = | ______ | |
| 4) No. of Rows (4-inch spacing) | Rows = | ______ | |
| 5) Total Orifice Area | | | |
| (Area per Row) x (Number of Rows) | Area = | ______ | $in^2$ |
| 4. Trash Rack or Gravel Pack present? | Yes/No | ______ | |
| 5. Basin Shape | | | |
| a. Length-Width Ratio (2:1 min.) | Ratio = | ______ | L:W |
| 6. Two-Stage Design | | | |
| a. Upper Stage | | | |
| Bottom slope (2%) | Bottom slope = | 2 | % |
| Depth (2 ft min) | Depth = | ______ | ft |
| Width (30 ft min) | Width = | ______ | ft |
| a. Bottom Stage | | | |
| Volume (5-20%) | Volume = | ______ | in |
| Depth (1.5 – 3 ft) | Depth = | ______ | ft |

## Design Data Summary Sheet for Extended Detention Basin (Page 2 of 2)

**Project:**________________________________

| | |
|---|---|
| 7. Forebay<br>a. Volume (5-10% SQDV)<br>b. Outlet pipe drain time (45 min maximum) | <br>Volume = ________ $ft^3$<br>t = ________ min |
| 8. Low-flow Channel<br>a. Depth (≥ 9 in)<br>b. Flow capacity<br>(200% forebay outlet release capacity minimum) | <br>Depth = ________ in<br>Flow capacity = ________ $ft^3$ |
| 9. Vegetation (describe) | Native Grasses ________<br>Irrigated Turf ________<br>Emergent Aquatic Plants (specify type/density) ________<br>Other ________ |
| 10. Embankment Side Slopes<br>a. Interior Side Slope (no steeper than 4:1)<br>b. Exterior Side Slope (no steeper than 3:1)<br>c. Littoral Zone Slope (40:1 or flatter)<br>d. Side slope below Littoral Zone (3:1 or flatter) | <br>Int. Side Slope = ________ L:W<br>Ext. Side Slope = ________ L:W<br>Littoral Zone = ________ L:W<br>Below Litt. Zone = ________ L:W |
| 11. Inlet and outlet points (select one or both) | Energy dissipation ________<br>Erosion protection ________ |
| 12. Maintenance Access Ramp<br>e. Slope (10% maximum)<br>f. Width (16 ft minimum) | <br>Slope = ________ %<br>Width = ________ ft. |
| 13. Bypass provided? | Yes/No ________ |

Notes: ________________________________


## Description

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

An Infiltration Trench is designed to retain the stormwater quality volume in the trench and allow that volume to infiltrate into the native soil profile over the design drawdown period. Infiltrated water typically reaches the underlying groundwater. Treatment of the runoff occurs through a variety of natural mechanisms as the water flows through the trench media and the soil profile. To ensure adequate treatment and protect groundwater, the depth of unsaturated soil between the trench bottom and the maximum groundwater surface level should be a minimum of 10 feet. See **Figure 5-11** for a typical Infiltration Trench configuration. Configurations for the Infiltration Vault and Infiltration Leach Field variations of the Infiltration Trench are shown in **Figures 5-12** and **5-13**, respectively.

***Other Names:*** Percolation trench

### Advantages

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

### Limitations

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

## Planning and Siting Considerations

- Integrate Infiltration Trenches into open space buffers, undisturbed natural areas, and other landscape areas when possible
- Plan for setback requirements as listed in **Table 5-18**.
- Do not locate trenches under tree drip lines
- Pretreatment using grass buffer strips is required to protect the trench from high sediment loads (see **Figure 5-11**).

## Design Criteria

Design criteria for Infiltration Trenches are listed in **Table 5-18.** A Design Data Summary Sheet is provided at the end of this fact sheet.

**Table 5-18. Infiltration Trench Design Criteria**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Tributary Drainage Area | ≤ 5 acres | |
| Design volume | SQDV | See *Standard Calculations Fact Sheet* |
| Maximum drawdown time for SQDV | 40 hrs | Based on SQDV |
| Soil permeability range | 0.6-2 in./hr | Saturated vertical permeability |
| Minimum groundwater separation | 10 ft | Between trench bottom and seasonally high groundwater table |
| Maximum trench surcharge depth ($D_{max}$) | 10 ft | |
| Setbacks | 100 ft<br>20 ft<br>100 ft<br>– | From wells, tanks, fields, springs<br>Downslope from foundations<br>Upslope from foundations<br>Do not locate under tree drip-lines |
| Trench media material size/type | 1-3 in. | Washed gravel |
| Trench lining material | – | Geotextile fabric (see **Table 5-16**) prevents clogging |
| Observation well size | 4-6 in. | Perforated PVC pipe with removable cap |
| Pretreatment grass buffer strip length/slope | 10 ft/5% | Minimum length/maximum slope in flow direction |

## Design Procedure

### Step 1 – Calculate Water Quality Volume (SQDV)

Using the *Standard Calculations Fact Sheet*, determine the tributary drainage area and stormwater quality design volume (SQDV) for 40-hour drawdown.

### Step 2 – Calculate design depth of water surcharge in Infiltration Trench ($D_{max}$)

Maximum depth should not exceed ten (10) feet.

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

where

| | | |
|---|---|---|
| $t_{max}$ | = | Maximum drawdown time = 40 hrs |
| I | = | Site infiltration rate (soil permeability) (in/hr) |
| s | = | Safety factor |
| P | = | Porosity of Infiltration Trench gravel material (use 0.30) (Note: use of manufactured percolation tank modules can provide greater porosity than gravel.) |

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

**Step 3 – Calculate minimum surface area of Infiltration Trench bottom ($A_{min}$)**

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

where

| | | |
|---|---|---|
| $A_{min}$ | = | minimum area required ($ft^2$) |
| $D_{max}$ | = | maximum allowable depth (ft) |

**Step 4 – Design Observation Well**

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

**Step 5 – Design Bypass**

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

## Construction Considerations

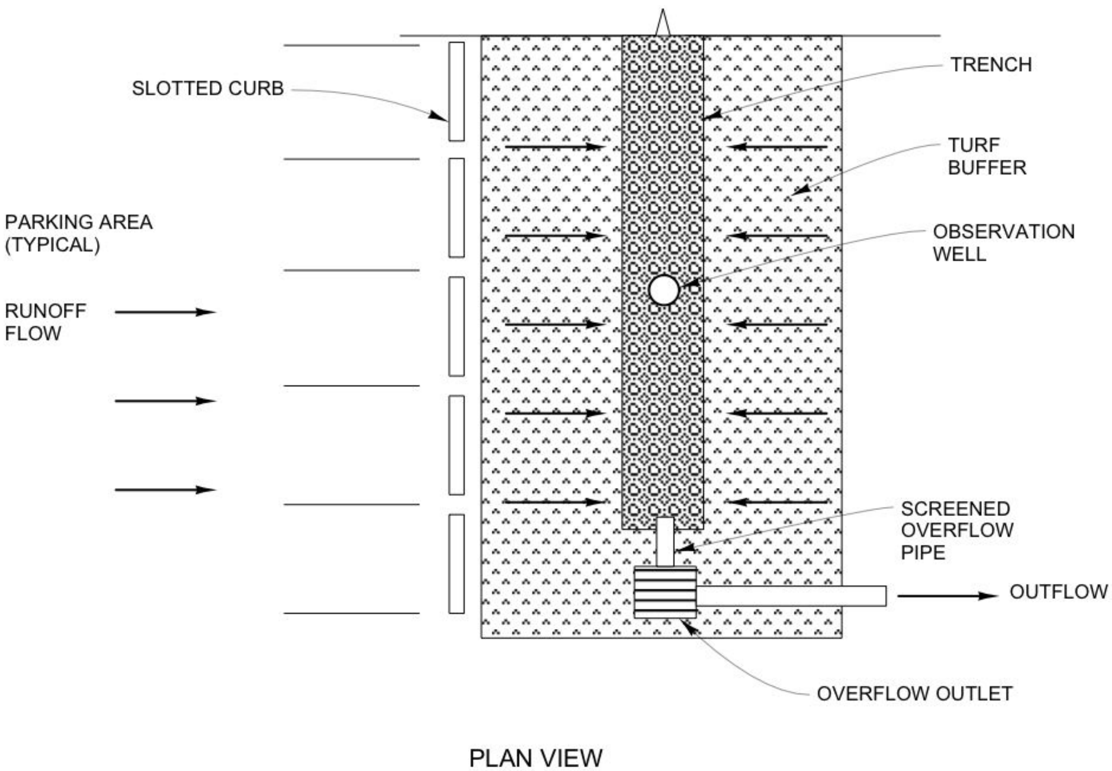
- If possible, stabilize the entire tributary area to the Infiltration Trench before construction begins. If this is not possible, divert flow around the trench site to protect it from sediment loads during construction.
- Once construction is complete, stabilize the entire tributary area to the trench before allowing runoff to enter the trench facility.
- Install filter fabric (see **Table 5-16**) on sides, bottom, and one foot below the surface of the trench (see **Figure 5-11**). 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 (1-3 inches) should be placed in the excavated trench in lifts and lightly compacted with plate compactor. Use of unwashed gravel can result in clogging.

## Long-Term Maintenance

The City may require 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 Trenches/Vaults. Such agreements will typically include requirements such as those outlined in **Table 5-19**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix C-1**.

**Table 5-19. Inspection and Maintenance Requirements for Infiltration Trenches**

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



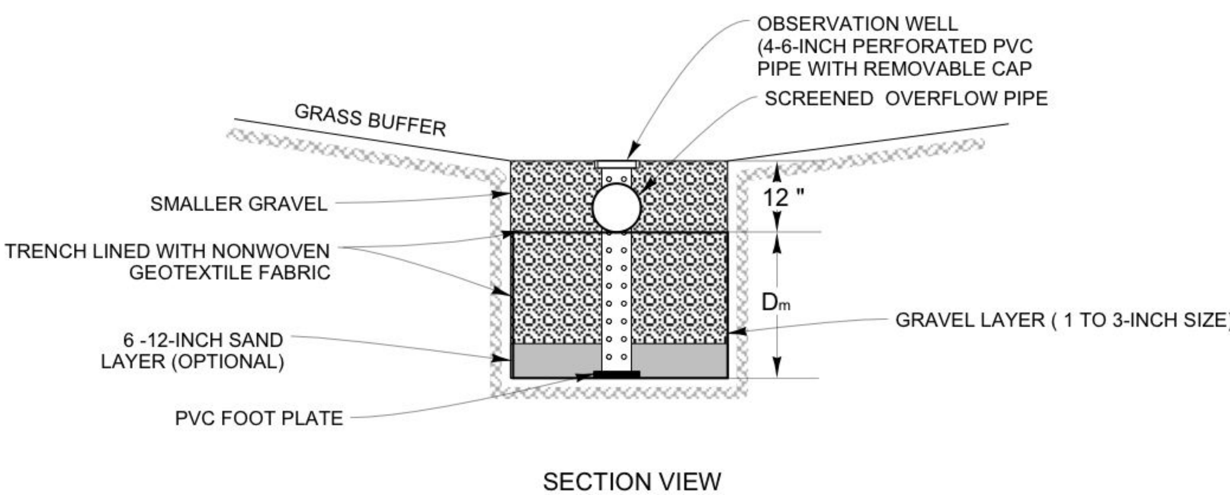




**Figure 5-11. Infiltration Trench**

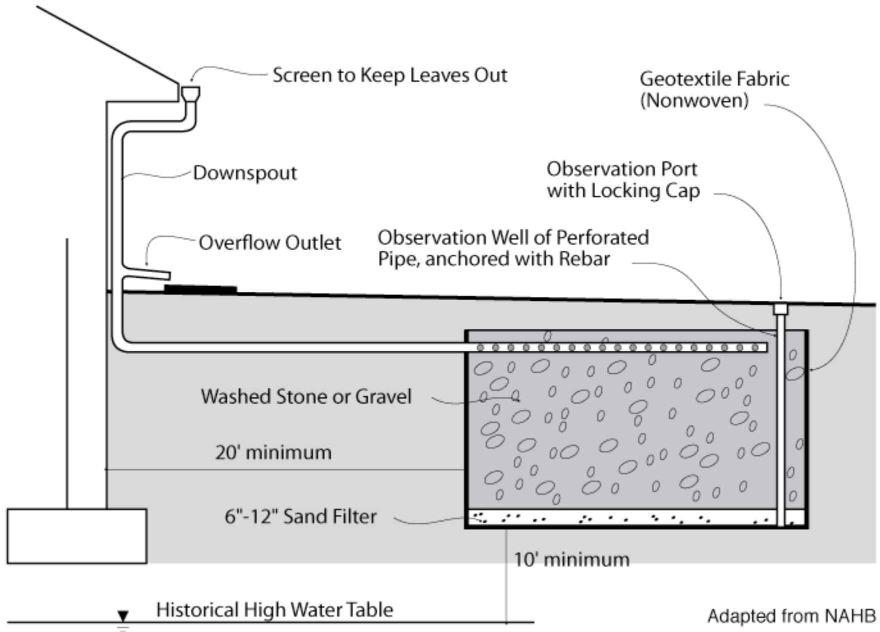



**Figure 5-12. Infiltration Vault**

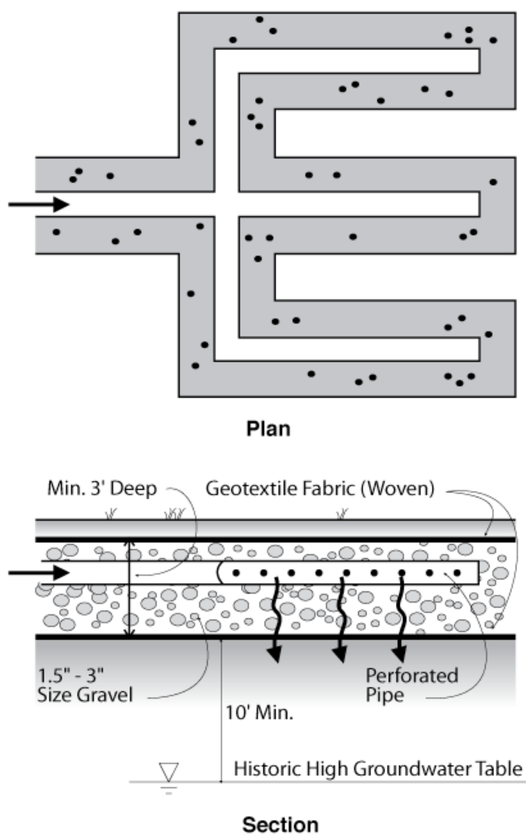



**Figure 5-13. Infiltration Leach Field**

## Design Data Summary Sheet for Infiltration Trench (Page 1 of 1)

**Designer:**________________________________________

**Company:**________________________________________

**Date:**________________________________________

**Project:**________________________________________

**Location/Trench No.:**________________________________________

| | |
|---|---|
| 1. Determine Design Water Quality Volume | |
| a. Effective tributary drainage area | $A_{eff}$ = __________ $ft^2$ |
| b. Water Quality Volume | SQDV = __________ $ft^3$ |
| 2. Determine Maximum Allowable Depth ($D_{max} \leq 10$ ft) | |
| a. Maximum drawdown time (t = 40 hrs) | t = 40 hr |
| b. Site infiltration rate (I) | I = __________ in/hr |
| c. Safety factor (s) | s = __________ |
| d. Gravel porosity (P) | P = 0.30 |
| e. $D_{max} = \dfrac{t_{max} \times I}{12 \times s \times P}$ | $D_{max}$ = __________ ft |
| 3. Determine Minimum Trench Bottom Surface Area ($A_{min} = SQDV/D_{max}$) | $A_{min}$ = __________ $ft^2$ |
| 4. Final Design Trench Dimensions | |
| a. Trench length (L) | L = __________ ft |
| b. Trench width (W) | W = __________ ft |
| c. Trench depth (D) | D = __________ ft |
| 5. Observation well diameter | Diam. = __________ in. |

Notes ________________________________________

________________________________________

## Description

An Infiltration Basin is a shallow earthen basin constructed in naturally pervious soils (usually Type A or B) designed for infiltrating stormwater. An Infiltration Basin functions by retaining the SQDV and allowing the retained runoff to percolate into the underlying native soils and into the groundwater table over a specified drawdown period. The bottoms and side slopes of the Infiltration Basins are typically vegetated with dryland grasses or irrigated turf grass.

An Infiltration Basin is designed to retain the stormwater quality volume within a basin and allow that volume to infiltrate into the native soil profile over the design drawdown period. Infiltrated water typically reaches the underlying groundwater. Treatment of the runoff occurs through a variety of natural mechanisms as the water flows through the soil profile. To ensure adequate treatment, the depth of unsaturated soil between the Infiltration Basin bottom and the seasonal maximum groundwater surface level should be a minimum of 10 feet. See **Figure 5-14** for a typical Infiltration Basin configuration.

***Other Names:*** Percolation Basin

### Advantages

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

### Limitations

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

## Planning and Siting Considerations

- Soil permeability, depth to groundwater, and design safety factors should be determined by a qualified geotechnical engineer or geologist to ensure that conditions conform to the criteria listed in **Table 5-20**.
- Integrate Infiltration Basins into open space buffers, undisturbed natural areas, and other landscape areas when possible.

- Irrigation may be required to maintain viability of vegetation on the slopes and bottom of the basin if vegetation is included in the design. Coordinate design of the general landscape irrigation system with that of the basin, as applicable.
- Plan for setback requirements (see **Table 5-20**).
- **Topography:** Not appropriate on fill or steep slopes

## Design Criteria

Design criteria for Infiltration Basins are listed in **Table 5-20**. A Design Data Summary Sheet is provided at the end of this fact sheet.

**Table 5-20. Infiltration Basin Design Criteria**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Tributary Drainage Area | ≤ 50 acres | |
| Design volume | SQDV | See *Standard Calculations Fact Sheet* |
| Soil permeability range | 0.6-2 in/h | Saturated vertical permeability. |
| Maximum drawdown time | 40 hrs. | Based on SQDV |
| Minimum groundwater separation | 10 ft | Basin bottom above seasonally high groundwater |
| Freeboard (minimum) | 1 ft | |
| Setbacks | 100 ft<br>20 ft<br>100 ft | From wells, tanks, fields, springs<br>Downslope from foundations<br>Up slope from foundations |
| Inlet/outlet erosion control | – | Energy dissipater to reduce inlet/outlet velocity |
| Forebay | | |
| a. Volume | 5-10%. | Based on SQDV |
| b. Drain time (maximum) | 45 min | |
| Embankment side slope (H:V) | ≥ 4:1<br>≥ 3:1 | Inside<br>Outside (without retaining walls) |
| Maintenance access ramp slope (H:V) | 10:1 | Or flatter |
| Maintenance access ramp width | 16 ft | Minimum – approach paved with concrete |
| Relief underdrain pipe diameter | 4 in. | Perforated plastic pipe |
| Vegetation | – | Side slopes and bottom (may require irrigation) |

## Design Procedure

### Step 1- Calculate Water Quality Volume (SQDV)

Using the *Standard Calculations Fact Sheet*, determine the tributary drainage area and stormwater quality design volume (SQDV) for 40-hour drawdown.

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

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

where

| | | |
|---|---|---|
| $t_{max}$ | = | Maximum drawdown time = 40 hrs |
| I | = | Site infiltration rate (soil permeability) (in/hr) |
| s | = | Safety factor |

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

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

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

where

| | | |
|---|---|---|
| $A_{min}$ | = | minimum area required ($ft^2$) |
| $D_{max}$ | = | maximum allowable depth (ft) |

**Step 4 – Design forebay settling basin**

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

**Step 5 – Design embankments**

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

**Step 6 – Design Maintenance Access**

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

**Step 7 – Design Security Fencing**

Provide aesthetic security fencing around the Infiltration Basin to protect habitat except when specifically waived by the stormwater agency. Fencing design shall be approved by the stormwater agency.

**Step 8 – Design Bypass**

Provide for bypass or overflow of runoff volumes in excess of the SQDV. Provide spillway or overflow structures, as applicable (see **Figure 5-14**).

**Step 9 – Design Relief Drain**

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

#### Step 10 – Select Vegetation

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

#### Step 11 – Design irrigation system

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

## Construction Considerations

- If possible, stabilize the entire tributary area to the Infiltration Basin before construction begins. If this is not possible, divert flow around the basin to protect it from sediment loads during construction or remove the top two inches of soil from the basin floor after the entire site has been stabilized.
- Once construction is complete, stabilize entire tributary area to the basin before allowing runoff to enter infiltration facility.
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment.
- Construct basin using equipment with extra wide, low-pressure tires. Prevent construction traffic from entering basin.
- 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 may require 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 Basins. Such agreements will typically include requirements such as those outlined in **Table 5-21**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix C-1**.

**Table 5-21. Inspection and Maintenance Requirements for Infiltration Basins**

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

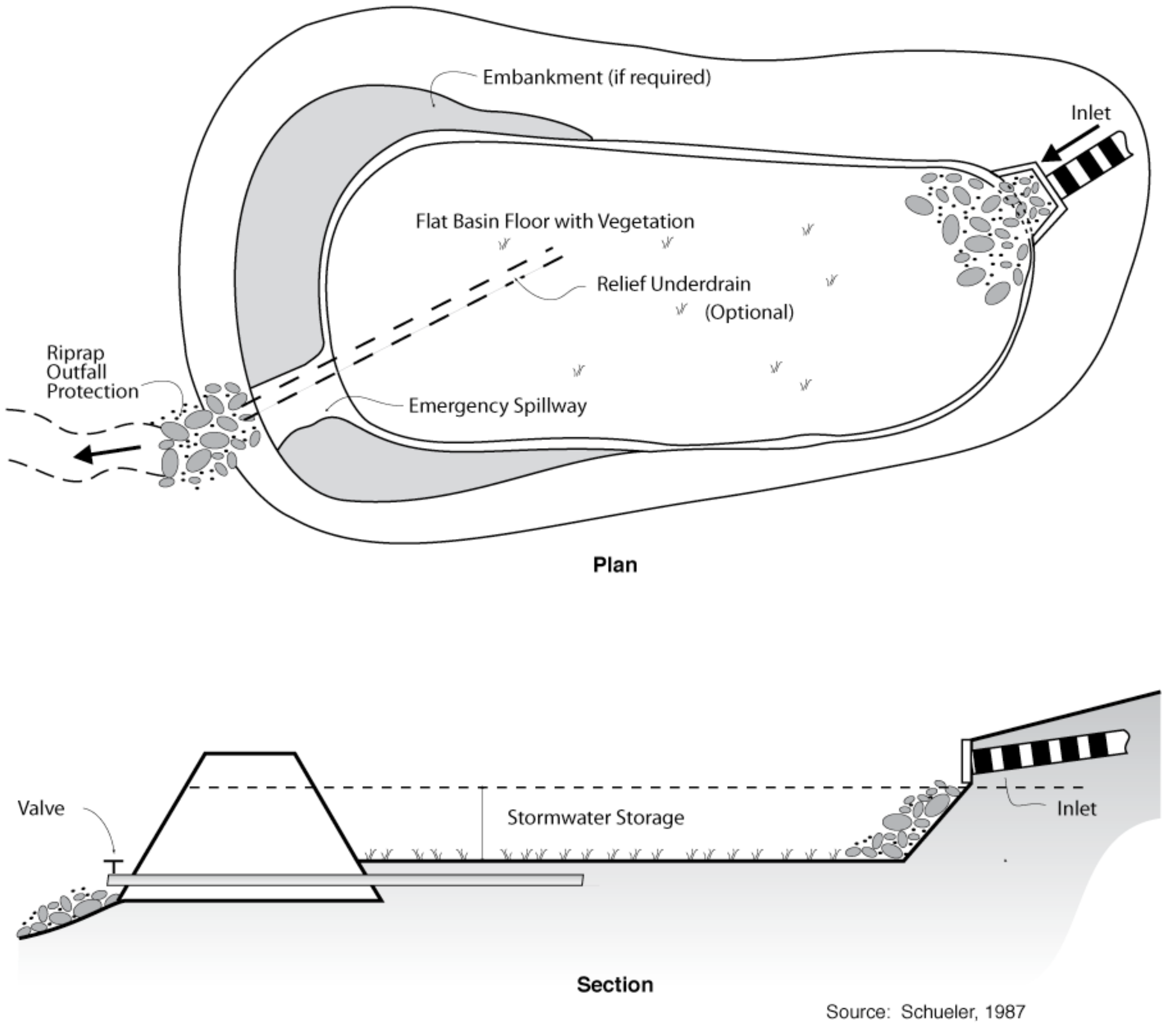



**Figure 5-14. Infiltration Basin**

## Design Data Summary Sheet for Infiltration Basin (Page 1 of 1)

**Designer:**______________________________

**Company:**______________________________

**Date:**______________________________

**Project:**______________________________

**Location:**______________________________

| | |
|---|---|
| 1. Determine Design Water Quality Volume<br>a. Tributary drainage area<br>b. Water Quality Volume | <br>Area = ____________ $ft^2$<br>SQDV = ____________ $ft^3$ |
| 2. Determine Maximum Allowable Depth ($D_{max} \leq 10$ ft)<br>a. Maximum drawdown time (t = 40 hrs)<br>b. Site infiltration rate (I)<br>c. Safety factor (s)<br>e. $D_{max} = \frac{t_{max} \times I}{12 \times s}$ | <br>t = ____40____ hr<br>I = ____________ in/hr<br>s = ____________<br>$D_{max}$ = ____________ ft |
| 3. Determine Minimum Allowable Basin Bottom Area ($A_{min} = SQDV/D_{max}$) | $A_{min}$ = ____________ $ft^2$ |
| 4. Forebay Volume ($V_{FB}$) | $V_{FB}$ = ____________ $ft^3$ |
| 5. Bypass/Outlet Control Structure (Check type) | _____ Overflow Structure<br>_____ Spillway |
| 6. Vegetation (Check type used or describe "Other") | _____ Native grasses<br>_____ Irrigated turf grass<br>_____ Other ____________<br>____________ |

Notes ______________________________

______________________________

______________________________

______________________________

## Description

Photo Credit: American Rivers

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 5-15** and **5-16** for typical Vegetated Swale configurations.

### Advantages

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

> Do not confuse a Vegetated Swale with a *Grass Swale* (T-1) or a *Stormwater Planter* (T-9). A *Grass Swale* has steeper side slopes and treats runoff via grass filtration. *Stormwater Planters* are level containers that feature only vertical flow of runoff into the soil medium.

### Limitations

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

## Planning and Siting Considerations

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

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

## Design Criteria

Design criteria for Vegetated Swales are listed in **Table 5-22**. Note that the sizing of the Vegetated Swale is volume-based. A Design Data Summary Sheet is provided at the end of this fact sheet.

**Table 5-22. Vegetated Swale and Vegetated Street Swale Design Criteria**

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

## Design Procedure

### Step 1 – Calculate Stormwater Quality Design Volume (SDQV)

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

### Step 2 – Determine Swale Geometry

Based on criteria in **Table 5-22** and site conditions, determine appropiate values for the following swale geometry design elements:

- Bottom width
- Side slope
- Storage depth ($D_{storage}$)
- Top width
- Longitudinal slope

### Step 3 – Determine Cross-Sectional Area of Swale Storage

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

### Step 4 – Determine Swale Length

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

### Step 5 – Design Inlet Controls

For flow introduced along the length of the swale through curb cuts, provide minimum curb cut widths of 12 inches. For swales that receive direct concentrated runoff at the upstream end, provide an energy dissipater, as appropriate, and a flow spreader such as a pea gravel diaphragm flow spreader at the upstream end of the swale. (See **Figure 5-3** in T-2: Grass Filter Strip for schematic of pea gravel flow spreader.)

### Step 6 – Select Vegetation

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

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

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

### Step 7 – Design irrigation system

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

## Construction Considerations

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

## Long-Term Maintenance

The City may require 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 Vegetated Swales. Such agreements will typically include requirements such as those outlined in **Table 5-23**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix C-1**.

**Table 5-23. Inspection and Maintenance Requirements for Vegetated Swales**

| Activity | Schedule |
|---|---|
| Trim vegetation (as applicable) and remove weeds to limit unwanted vegetation | As required |
| Remove litter and debris from landscape area | As required |
| Use integrated pest management (IPM) techniques | As required |
| Inspect the 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 |

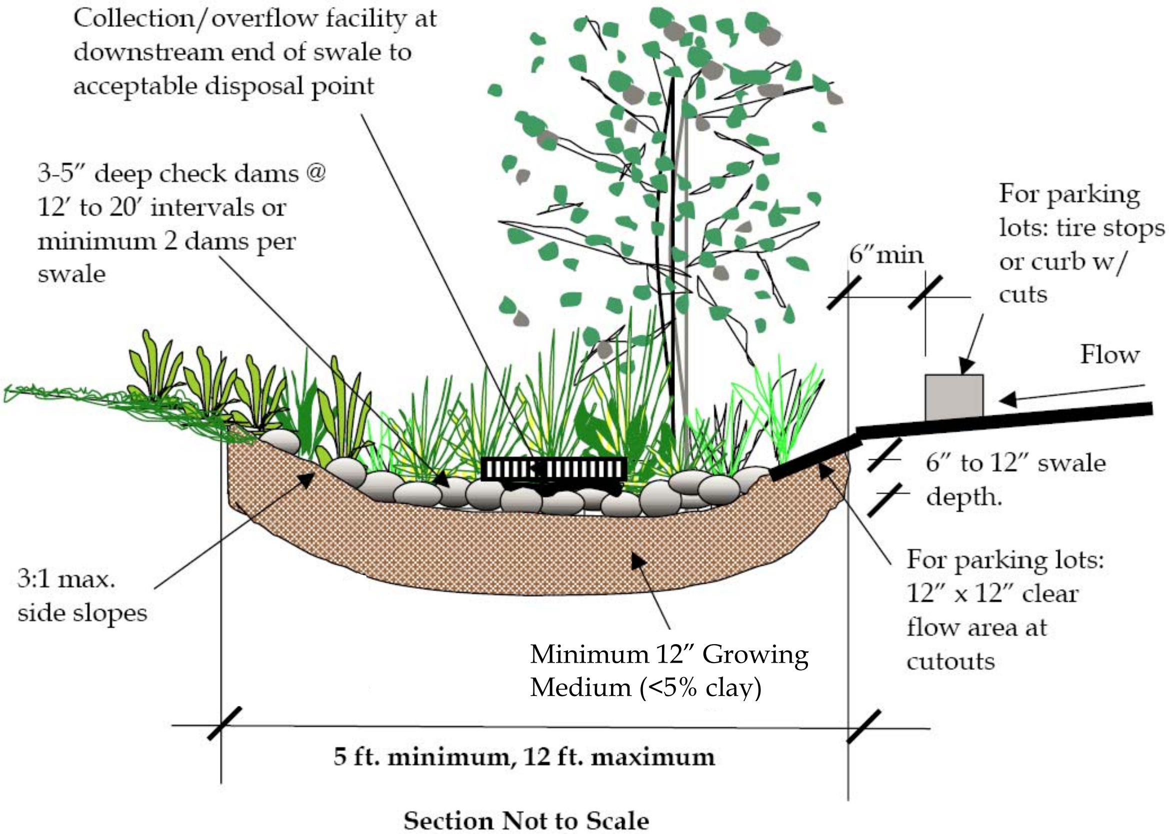



Figure 5-15. Vegetated Swale

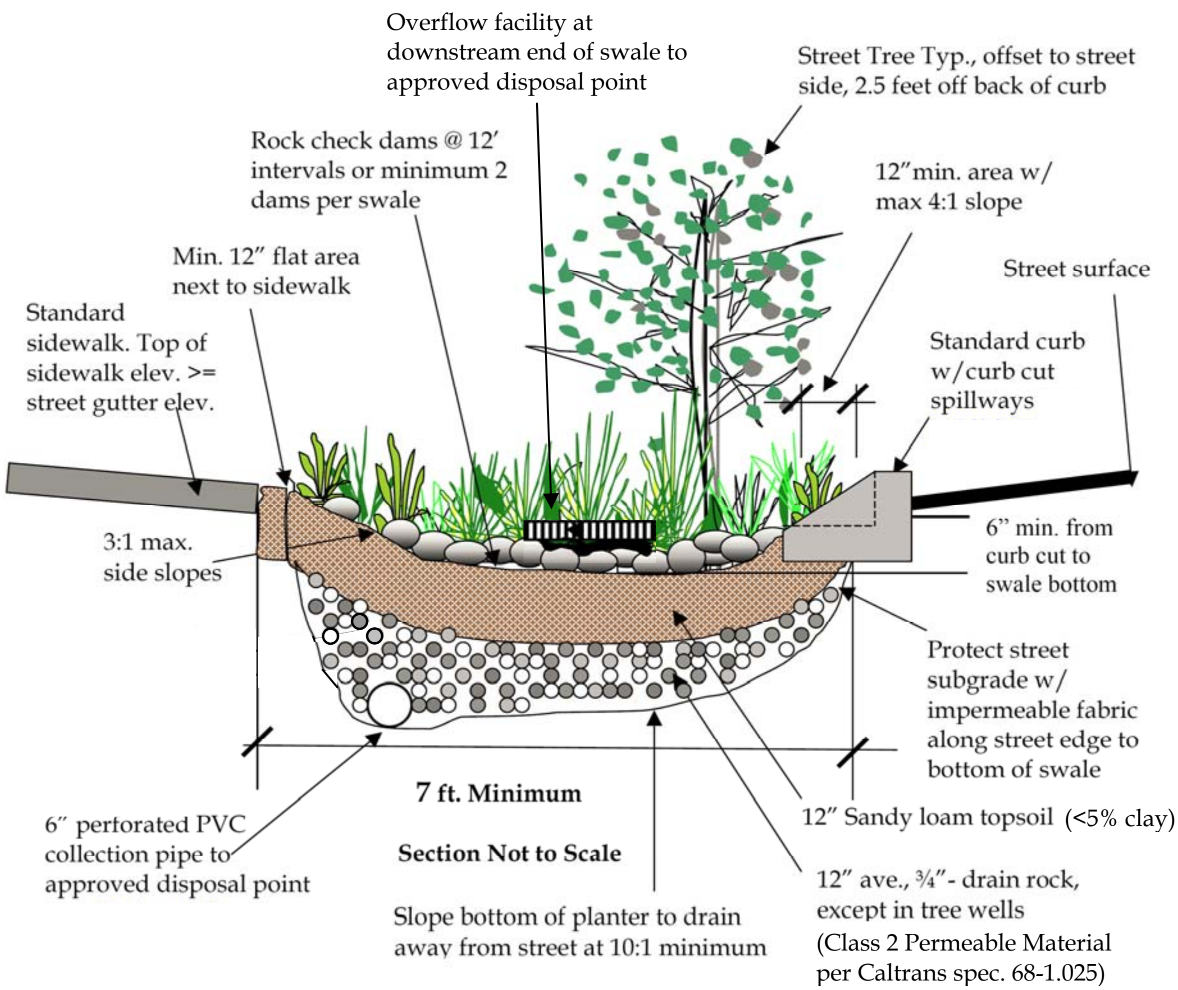



**Figure 5-16. Vegetated Street Swale with Underdrain**

## Design Data Summary Sheet for Vegetated Swale (Page 1 of 1)

**Designer:**____________________

**Company:**____________________

**Date:**____________________

**Project:**____________________

**Location/Planter No.:**____________________

| | |
|---|---|
| 1. Determine Stormwater Quality Design Volume | |
| a. Tributary drainage area | Area = ________ $ft^2$ |
| b. Stormwater Quality Design Volume | SQDV = ________ $ft^3$ |
| 2. Determine Swale Geometry | |
| a. Bottom width ($W_{bottom}$) | $W_{bottom}$ = ________ ft |
| b. Side slope | Side slope = ________ % |
| c. Storage depth ($D_{storage}$) | $D_{storage}$ = ________ ft |
| d. Top width ($W_{top}$) | $W_{top}$ = ________ ft |
| e. Longitudinal slope | Longitudinal slope = ________ % |
| 3. Determine Cross-Sectional Area of Swale Storage | |
| a. $A_{storage} = D_{storage} \times \frac{W_{bottom} + W_{top}}{2}$ | $A_{storage}$ = ________ $ft^2$ |
| 4. Determine Swale Length | |
| a. $L_{swale} = \frac{SQDV}{A_{storage}}$ | $L_{swale}$ = ________ ft |
| b. Number of check dams (one every 12 to 20 ft) | No. check dams = ________ |
| 5. Design Inlet Controls (choose one) | ____ Curb cuts (width 12 in. minimum)<br>____ Upstream energy dissipater |
| 6. Vegetation (type and number per 100 $ft^2$ of swale area) | |
| a. Large shrubs/Small trees (4 minimum) | ____ Large shrubs/Small trees |
| b. Shrubs/Large grass-like plants (6 minimum) | ____ Shrubs/Large grass-like plants |
| c. Ground cover (1 per foot, minimum) | ____ Ground cover |

Notes ____________________


## Description

A Stormwater Planter is a low-lying vegetated planter containing layers of topsoil, a sand/peat mixture, and gravel that receives runoff from downspouts or piped inlets or sheet flow from adjoining paved areas. A shallow surcharge zone is provided above the vegetated surface for temporary storage of the SQDV. During stormwater events, runoff accumulates in the surcharge zone and gradually infiltrates into the underlying sand/peat bed, filling the void spaces of the bed. Treatment of the runoff occurs through a variety of natural mechanisms as the runoff infiltrates through the root zone of the vegetation and during detention of the runoff in the underlying sand/peat bed.

If Infiltration Stormwater Planters are used, the volume of runoff can be reduced through infiltration into underlying soils. For planters underlain with expansive soils or located next to buildings where infiltration of runoff is undesirable, the Flow-through Stormwater Planter with an impermeable bottom liner should be employed. This type of planter features an impermeable bottom liner to prevent infiltration and a perforated underdrain pipe to collect treated runoff. The underdrain gradually dewaters the sand/peat bed over the drawdown period and discharges the runoff to downstream conveyance. If infiltration of runoff is acceptable or desired, the Infiltration Stormwater Planter should be used. If underlying soils are rapidly permeable with permeability greater than the sand/peat layer (typically types A or B soils), the planter can be installed without an underdrain pipe, in which case the SQDV will infiltrate into the underlying soil profile. If less permeable underlying soils (types C or D) are present, an underdrain is required, but a portion of the infiltrated runoff will infiltrate into the underlying soil. See **Figures 5-17** and **5-18** 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 area available for stormwater detention
- Reduces peak flows during small storm events
- Attractive
- Easy to maintain

### Limitations

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

- Not suitable for steeply sloping areas

## Planning and Siting Considerations

- Select location where site topography is relatively flat and allows runoff drainage to the Stormwater Planter.
- Integrate Stormwater Planters into other landscape areas when possible.
- Stormwater Planters may be located within landscape areas as “rain gardens” and may have a non-rectangular footprint to fit the site landscape design.
- In expansive soils, locate Stormwater Planters far enough from structure foundations so as to avoid damage to structures (as determined by a structural or geotechnical engineer), or use a Flow-through Stormwater Planter.
- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the planter is properly designed, constructed, and operated.

## Design Criteria

Design criteria for Stormwater Planters are listed in **Table 5-24**. A Design Data Summary Sheet is provided at the end of this fact sheet.

**Table 5-24. Stormwater Planter Design Criteria**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Drainage area | ≤ 1 acre | Ideally suited for small areas such as parking lot islands, perimeter building planters, street medians, roadside swale features, and site entrance or buffer features. Can be implemented on a larger scale, provided the SQDV and average depth requirements are met. |
| Design volume | SQDV | See *Standard Calculations Fact Sheet* |
| Design drawdown time | 12 hrs | Period of time over which SQDV drains from planter. |
| Design average surcharge depth ($d_s$) | 6-12 in. | |
| Depth to groundwater | > 10 ft | From planter soil surface (for Infiltration Stormwater Planter 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 |
| Gravel layer | 9 in. | AASHTO #8 Coarse Aggregate |

## Design Procedure

**Step 1 – Calculate Water Quality Volume (SQDV)**

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

**Step 2 – Design average surcharge depth ($d_s$)**

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

**Step 3 – Calculate planter surface area ($A_S$)**

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

$A_S = SQDV/d_s$ (see **Figures 5-18** and **5-19**)

**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 5-18** and **5-19**. Thoroughly mix 75% sand (ASTM C-33) with 25% peat for filtration and adsorption of contaminants. Place filter fabric between sand/peat mixture and gravel layer.
- Gravel layer – Provide 9-inch gravel layer (AASHTO #8 Coarse Aggregate)

**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 Flow-through Stormwater Planter with an impermeable liner (see **Figure 5-19**). Otherwise, use an Infiltration Stormwater Planter and install a non-woven geotextile membrane below the gravel layer to allow infiltration.

**Step 6 – Select vegetation**

Select vegetation that:

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

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

**Step 7 – Design overflow device**

Provide an overflow device with an inlet to storm drainage system. Set the overflow inlet elevation above the SQDV surcharge water level. A drop inlet or an overflow standpipe with an inverted opening are appropriate overflow devices (see **Figures 5-18** and **5-19**).

## Construction Considerations

- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.

- Install sediment controls (e.g., staked straw wattles) around the planter to prevent high sediment loads from entering the planter during ongoing construction activities.
- 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 final acceptance of a private development project, which includes treatment control measures such as Stormwater Planters. Such agreements will typically include requirements such as those outlined in **Table 5-25**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix C-1**.

**Table 25. Inspection and Maintenance Requirements for Stormwater Planters**

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

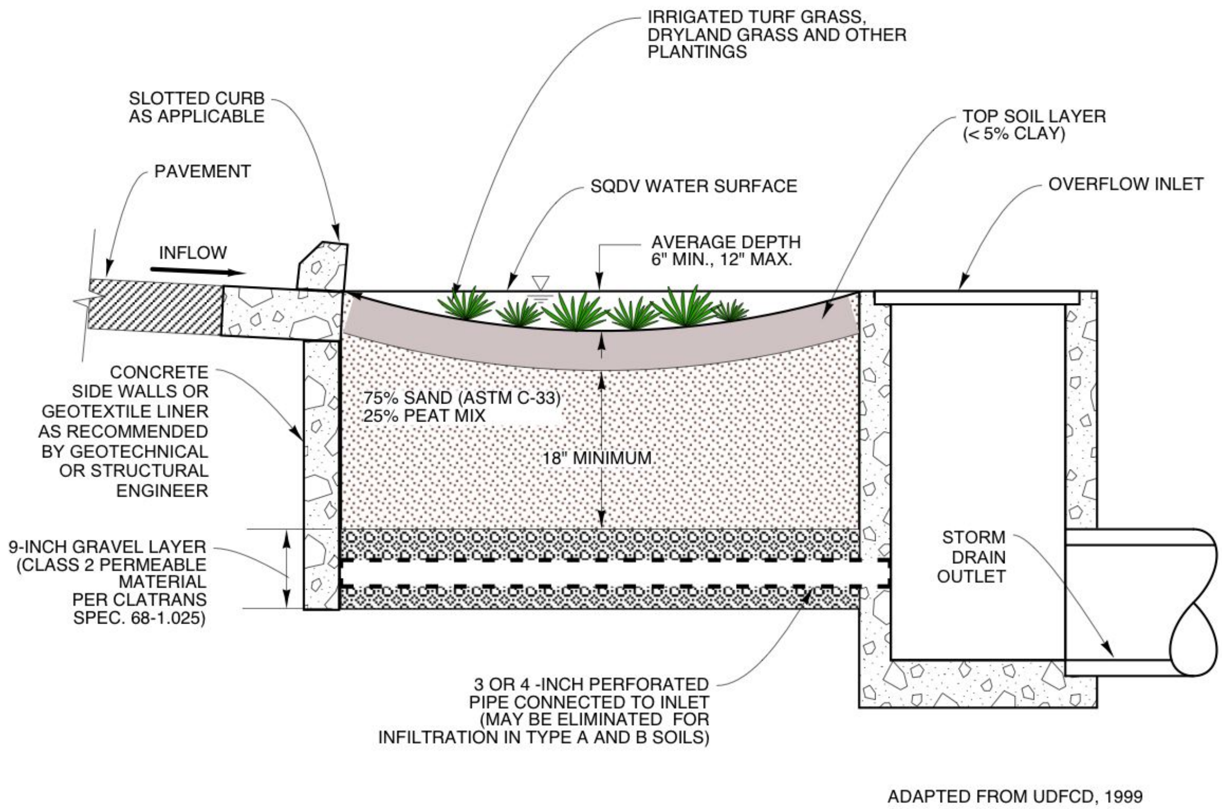



**Figure 5-17. Infiltration Stormwater Planter Configuration**

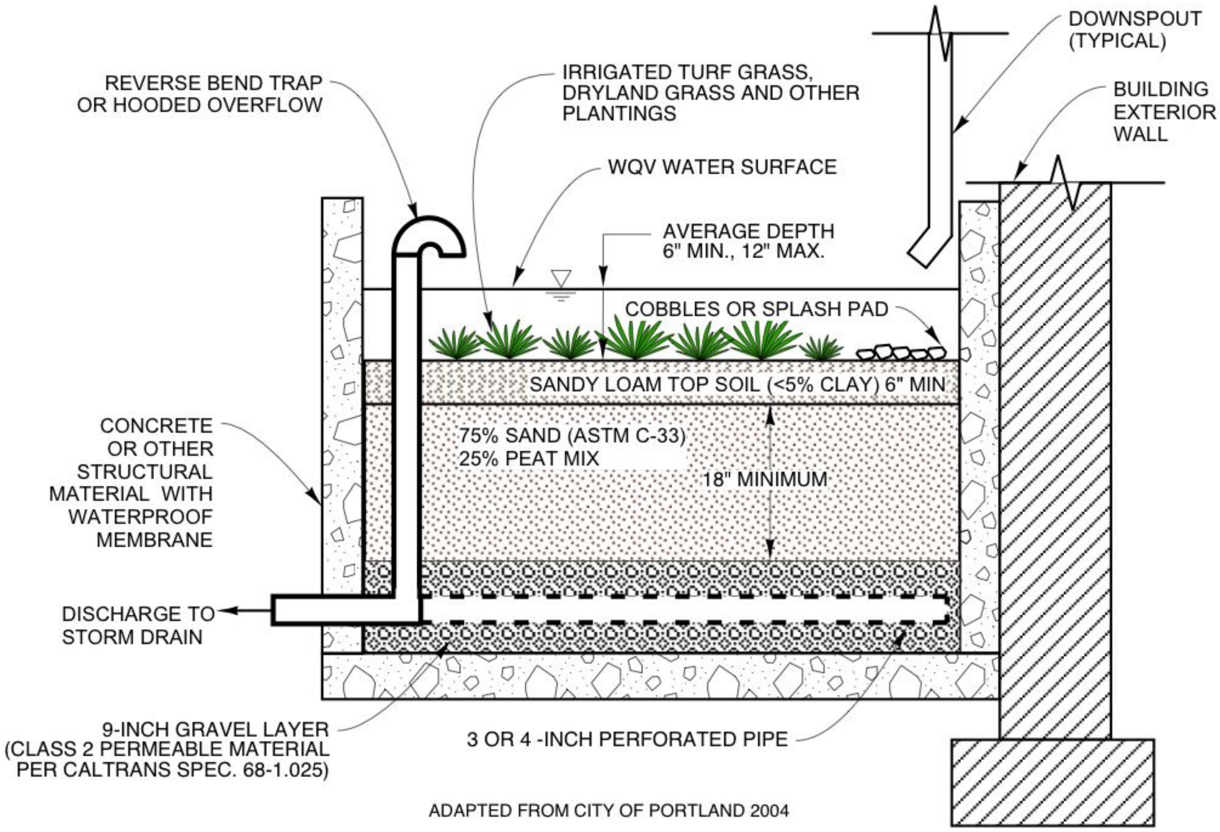



**Figure 5-18. Flow-through Stormwater Planter Configuration**

## Design Data Summary Sheet for Stormwater Planter (Page 1 of 1)

**Designer:**______________________________

**Company:**______________________________

**Date:**______________________________

**Project:**______________________________

**Location/Planter No.:**______________________________

| | |
|---|---|
| 1. Determine Stormwater Quality Design Volume<br>a. Effective tributary drainage area<br>b. Stormwater Quality Design Volume | <br>$A_{eff}$ = ______________ $ft^2$<br>SQDV = ______________ $ft^3$ |
| 2. Design average surcharge depth ($d_s$)<br>$d_s$ = 6 - 12 inches (0.5-1 foot) | <br>$d_s$ = ______________ ft |
| 3. Design Planter Surface Area ($A_s$)<br>$A_s$ = SQDV/$d_s$ | <br>$A_s$ = ______________ $ft^2$ |
| 4. Base Course Layers<br>a. Topsoil (6 in. minimum)<br>b. Sand/Peat Layer (18 in. minimum)<br>c. Gravel Layer (9 in. minimum) | <br>________ in.<br>________ in.<br>________ in. |
| 5. Planter Type (check type used) | _____ Infiltration without underdrain<br>_____ Infiltration with underdrain<br>_____ Flow-through with impermeable liner |
| 6. Vegetation (describe) | ______________________________<br>______________________________<br>______________________________ |
| 7. Overflow Device (check type used or describe "Other") | _____ Drop inlet<br>_____ Standpipe<br>_____ Other ______________________<br>______________________________<br>______________________________ |

Notes ______________________________

______________________________

______________________________

Photo Credit: Sacramento Stormwater Quality Partnership

## Description

A Media Filter is a two-stage constructed 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 course and is underdrained with perforated pipe. As stormwater flows into the system, large particles settle out in the first basin and finer particles and other pollutants are removed in the filter basin. The above-ground Austin Sand Filter is presented in this fact sheet. Underground Media Filter variations include the Underground (DC) Sand Filter and the linear or perimeter (Delaware) Sand Filter.

A typical configuration of an Austin Sand Filter is shown in **Figure 5-19**. Principal components of the unit include a sedimentation basin and a filter bed. The sedimentation basin is designed to hold the entire SQDV and to release that volume to the filter bed over the design drawdown time of 40 hours. Large sediment is removed by settling in the sedimentation basin. Fine particles and other pollutants are removed in the filtration basin as the runoff passes through the filter bed media. Runoff in excess of the SQDV is bypassed around the treatment unit. Configurations for the DC Underground and Delaware Linear Sand Filter variations are shown in **Figures 5-20** and **5-21**, respectively.

### Advantages

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

### Limitations

- Potential for clogging of media. Upstream treatment controls to remove large sediment may be required to prevent or minimize media clogging.
- Significant head loss through treatment units may limit use on flat surfaces.
- More expensive to construct than many other types of treatment controls.

## Planning and Siting Considerations

- Media Filters are generally suited for sites where there is no base flow and the sediment load is relatively low.
- Media 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 controls.

- Selection of a Media 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 Linear 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 Linear Sand Filters can operate with as little as two (2) feet of head.
- 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

Design Criteria for the Austin Sand Filter are summarized in **Table 5-26**.

**Table 5-26. Austin Sand Filter Design Criteria**

| Design Parameter | Criteria | Notes |
|---|---|---|
| **Sedimentation Basin** | | |
| Tributary Drainage Area | ≤ 50 acres | |
| Minimum basin volume | SQDV | See *Calculation of Stormwater Quality Design Flow and Volume Fact Sheet* |
| Minimum/Maximum basin water depth ($d_{SB}$) | 3ft/10 ft | |
| Minimum length/width ratio | 2:1 | |
| Design drawdown time | 40 hrs | Based on SQDV |
| Freeboard | 1 ft | Above maximum water surface elevation |
| Maximum inlet velocity | 3 ft/sec | Provide inlet energy dissipater as required to limit inlet velocity to 3 ft/sec |
| **Filtration Basin** | | |
| Minimum storage volume above filter bed | 20% | Based on SQDV |
| Minimum storage depth above filter bed ($d_s$) | 3 ft | |
| Minimum gravel depth over sand filter | 2 in. | |
| Minimum sand depth in filter bed ($d_f$) | 18 in. | |
| Coefficient of permeability for sand filter (k) | 3.5 ft/d | 0.146 ft/h |
| Slope of sand filter surface | 0% | |
| Minimum gravel cover over underdrain | 2 in. | |
| Sand size, diameter | 0.02-0.04 in. | |
| Underdrain gravel size, diameter | 0.5-2 in. | |
| Minimum inside diameter of underdrain | 6 in. | |
| Underdrain pipe type | PVC | Schedule 40 (or heavier) |
| Minimum slope of underdrain | 1% | |
| Minimum underdrain perforation, diameter | 0.375 in. | |
| Minimum perforations per row | 6 | |
| Minimum space between perforation rows | 6 in. | |
| Design drawdown time ($t_f$) | 40 hrs | Based on SQDV |
| Minimum gravel bed depth, ($d_g$) | 16 in. | |

## Design Procedure – Sedimentation Basin

The design procedure and application of design criteria for the Austin Sand Filter Sedimentation Basin are outlined in the following steps.

**Step 1 – Determine Stormwater Quality Design Volume (SQDV)**

Using the *Calculation of Stormwater Quality Design Flow and Volume Fact Sheet*, determine the tributary drainage area and stormwater quality design volume (SQDV) for 40-hour drawdown.

**Step 2 – Determine Sedimentation Basin Volume ($V_{sb}$)**

The volume of the sedimentation basin must be greater than or equal to the SQDV.

$$V_{sb} \geq SQDV$$

**Step 3 – Determine Sedimentation Basin Depth ($d_{sb}$)**

The allowable depth of water in the sedimentation basin will be governed by the available hydraulic head at the site, which will be based on the difference in elevation between the sedimentation basin inlet and the filter bed outlet. The design $d_{sb}$ value should be greater than or equal to 3 feet and less than or equal to 10 feet:

$$10 \text{ ft} \geq d_{sb} \geq 3 \text{ ft}$$

Select a design depth in the allowable range that yields the required $V_{sb}$ given any footprint area constraints for the site.

**Step 4 – Determine Sedimentation Basin Area ($A_{sb}$)**

$$A_{sb} = V_{sb} / d_{sb}$$

**Step 5 – Determine Sedimentation Basin Shape**

Determine overall length ($L_{sb}$) and width ($W_{sb}$) dimensions to yield the $A_{sb}$ given any footprint area constraints for the site.

$$A_{sb} = L_{sb} \times W_{sb}$$

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 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 Inlet/Outlet Design**

Basin inlet and outlet points should be provided with an energy dissipation structure 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 SQDV to the filter basin over a 40-hour period. See Fact Sheet T-5 Extended Detention Basin for outlet works design procedure.

**Step 7 – Determine 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 purposes 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 sediment and removes it from the basin flow regime. In so doing, the sediment trap inhibits resuspension of solids during subsequent runoff events, improving long-term removal efficiency. The trap also maintains adequate volume to hold the water quality volume 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 10 percent of the sedimentation basin volume. All water collected in the sediment trap shall drain out within 40 hours. The invert of the drain pipe should be above the surface of the sand bed of the filtration basin. The minimum grading of the piping to the filtration basin should be 1/4 inch per foot (two (2) percent slope). Access for cleaning the sediment trap drain system is necessary.

**Step 9 – Determine Basin Liner Design**

If the sedimentation basin is an earthen structure and an impermeable liner is required to protect groundwater quality, the liner shall provide a maximum permeability of $1x10^{-6}$ 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 5-27** unless the basin has been excavated to bedrock.

## Design Procedure – Filtration Basin

The design procedure and application of design criteria for the Austin Sand Filter Filtration Basin are outlined in the following steps.

**Step 1 – Determine Minimum Filtration Basin Storage Volume**

The storage capacity of the filtration basin above the surface of the filter media should be greater than or equal to 20 percent of the SQDV. This capacity is necessary in order to account for backwater effects resulting from partially clogged filter media.

$$V_{fbs} \geq 0.2 \times SQDV$$

**Step 2 – Determine Filter Bed Surface Area**

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 design filter bed area should be the larger of the minimum area required for storage and the minimum area required for flow.

a. Determine minimum filter surface area required for storage ($A_{fbs}$)

$$A_{fbs} = V_{fbs} / d_{fbs}$$

where

$V_{fbs}$ = Storage volume above filter bed

$A_{fbs}$ = Filter surface area based on storage, $ft^2$

$d_{fbs}$ = Depth of storage above filter bed, ft (3 ft minimum)

b. Determine minimum filter surface area required for flow ($A_{ff}$)

$$A_{ff} = \frac{(SQDV)(d_f)}{(k)(d_{fbs} + d_f)(t_f)}$$

where

SQDV = Stormwater Quality Design Volume, $ft^3$

$A_{ff}$ = Filter surface area based on flow, $ft^2$

$d_f$ = Filter bed depth, ft

k = Coefficient of permeability for sand filter, ft/hr (0.146 ft/h)

$d_{fbs}$ = Depth of storage above filter bed, ft

$t_f$ = Time required for runoff volume to pass through filter, hrs (40 hrs)

c. Use the larger of $A_{fbs}$ and $A_{ff}$ as design value for filter bed area

**Step 3 – Design Inlet Structure**

The inlet structure should spread the flow uniformly across the surface of the filter media. Flow spreaders, weirs, or multiple orifice openings are recommended.

**Step 4 – Design Filter Bed**

The filter (sand) bed may be either of the two configurations given below. Note: Sand bed depths are final, consolidated depths. Consolidation effects must be taken into account.

a. Sand Bed with Gravel Underdrain (**Figure 5-22A**)

The sand layer shall be a minimum depth of 18 inches and shall consist of 0.02 to 0.04-inch diameter sand. Below the sand is a layer of 0.5 to 2-inch diameter gravel that provides a minimum of two (2) inches of cover over the top of the underdrain lateral pipes. No gravel is required under the lateral pipes. A layer of geotextile fabric meeting the specifications in **Table 5-27** must separate the sand and gravel and must be wrapped around the lateral pipes.

Drainage matting meeting the specifications in **Table 5-27** should be placed under the laterals to provide for adequate vertical and horizontal hydraulic conductivity to the laterals.

In areas with high sediment load (total suspended solids concentration ≥ 200 mg/L), the two-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 5-27.**

b. Sand Bed with Trench Underdrain (**Figure 5-22B**)

The top layer shall be 12-18 inches of 0.02 to 0.04-inch diameter sand. Laterals shall be placed in trenches with a covering of 0.5 to 2-inch gravel and geotextile fabric (see **Table 5-27**). The laterals shall be underlain by a layer of drainage matting (see **Table 5-27**).

In areas with high sediment load (total suspended solids concentration ≥ 200 mg/L), the two-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 5-27**.

**Step 5 – Design Underdrain Piping**

The 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 polyvinyl chloride or greater strength. The minimum grade of piping shall be 1/8 inch per foot (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 draw-down time is to be associated with sand filter, only with the sedimentation basin. Thus, it is not necessary to have a specifically-designed orifice for the filter bed outlet structure.

**Step 6 – 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 $1 \times 10^{-6}$ 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 5-27** unless the basin has been excavated to bedrock.

**Table 5-27. Geotextile Fabric Specifications for Media Filters**

| Property | Test Method | Specifications |
|---|---|---|
| **Geotextile Fabric** | | |
| Material | | Non-woven geotextile fabric |
| Unit Weight | | 8 oz./yd (minimum) |
| Filtration Rate | | 0.08 in./sec (minimum) |
| Puncture Strength | ASTM D-751 (Modified) | 125 lbs (minimum) |
| Mullen Burst Strength | ASTM D-751 | 400 psi (minimum) |
| Tensile Strength | ASTM-D-1682 | 300 lbs (minimum) |
| Equivalent Opening Size | US Standard Sieve | No. 80 (minimum) |
| **Drainage Matting** | | |
| Material | | Non-woven geotextile fabric |
| Unit Weight | | 20 oz./yd (minimum) |
| Flow Rate (fabric) | | 180 gpm/ft$^2$ (minimum) |
| Permeability | ASTM D-2434 | 12.4 x 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 psi (minimum) |
| Equivalent 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 (minimum) |
| Filtration Rate | | 120 gpm/ft$^2$ (minimum) |
| Puncture Strength | ASTM D-751 (Modified) | 60 lbs (minimum) |
| Thickness | | 0.8 in. (minimum) |

## Construction Considerations

- Erosion and sediment control measures must be configured to prevent any inflow of stormwater into the sand filter during its construction.
- The sand 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. Should construction runoff enter the filter system prior to site revegetation, all contaminated materials must be removed and replaced with new, clean materials.
- The top of the sand 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 the weepholes at a minimum slope of one-half (0.5) percent.

## Long-Term Maintenance

The City may require 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 will typically include requirements such as those outlined in **Table 5-28**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix C-1**.

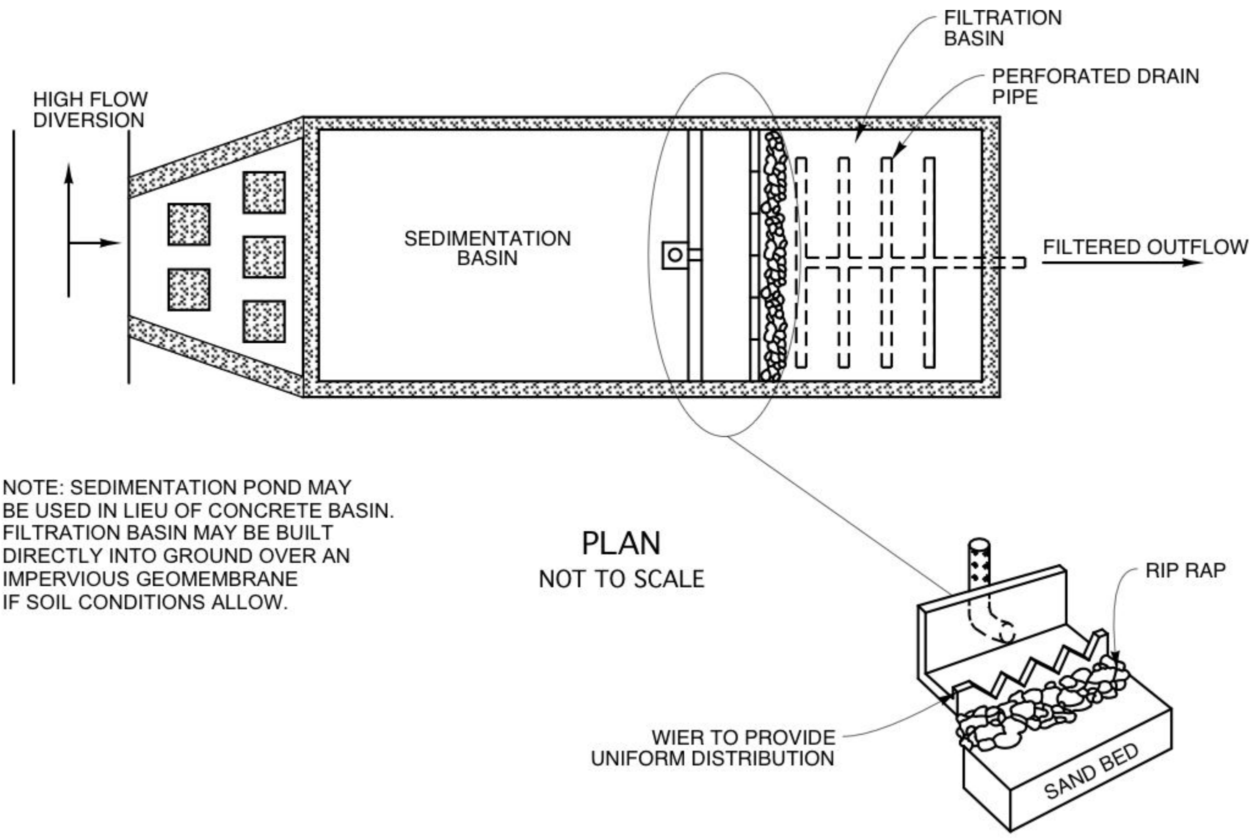
**Table 5-28. Inspection and Maintenance Requirements for Media Filters**

| 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 the facility after a large rain event to determine whether the facility is draining completely within 72 hours | 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 control measure | At least weekly during wet season or before significant storm events |
| Remove top two inches of sand and dispose of sediment if facility drain time exceeds 72 hours. 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 10 years or when the sediment occupies 10 percent of the basin volume, whichever is less |
| Dispose of sand, gravel, or filter cloth contaminated with petroleum hydrocarbons in accordance with all applicable laws | As required |

## References

California Stormwater Quality Association (CASQA). *Stormwater Best Management Practice Handbook – New Development and Redevelopment*. January 2003.

Denver Colorado Urban Drainage and Flood Control District (UDFCD). *Urban Drainage Criteria Manual, Volume 3 – Best Management Practices*. 1999.



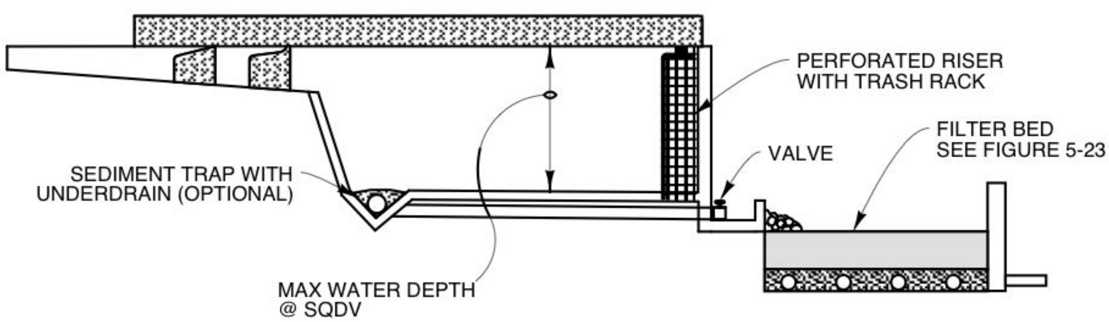




**Figure 5-19. Austin Sand Filter Configuration**

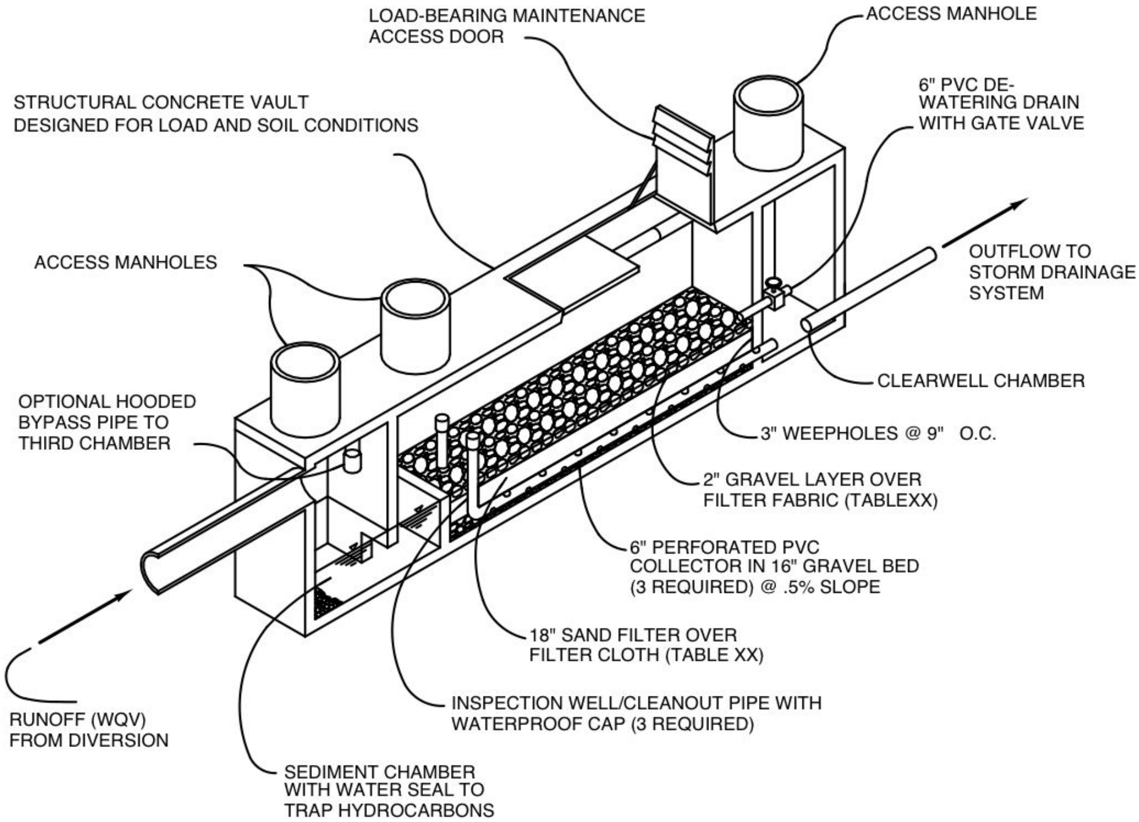



**Figure 5-20. DC Underground Sand Filter Configuration**

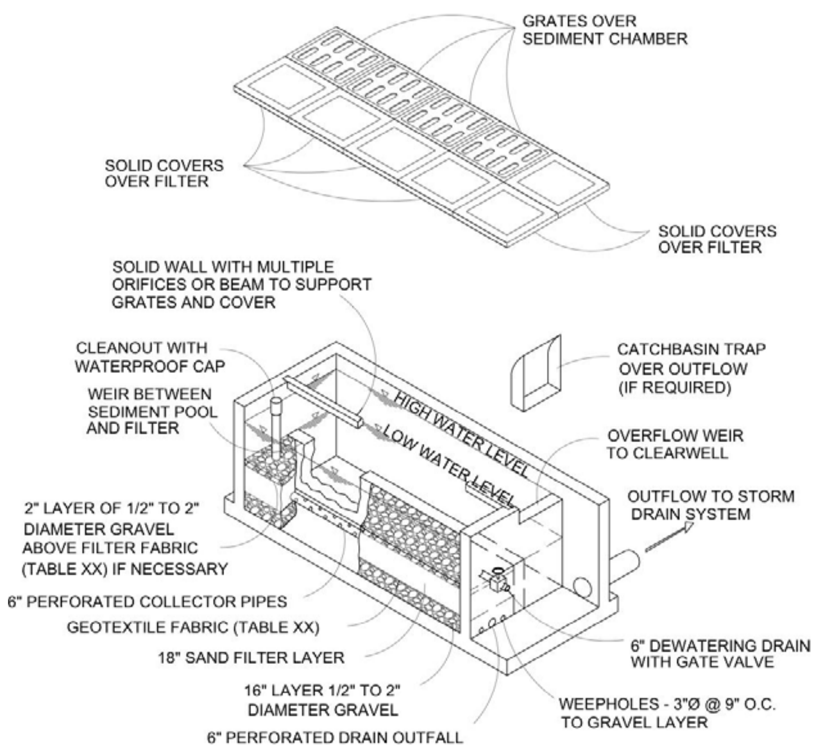



**Figure 5-21. Delaware Linear Sand Filter Configuration**

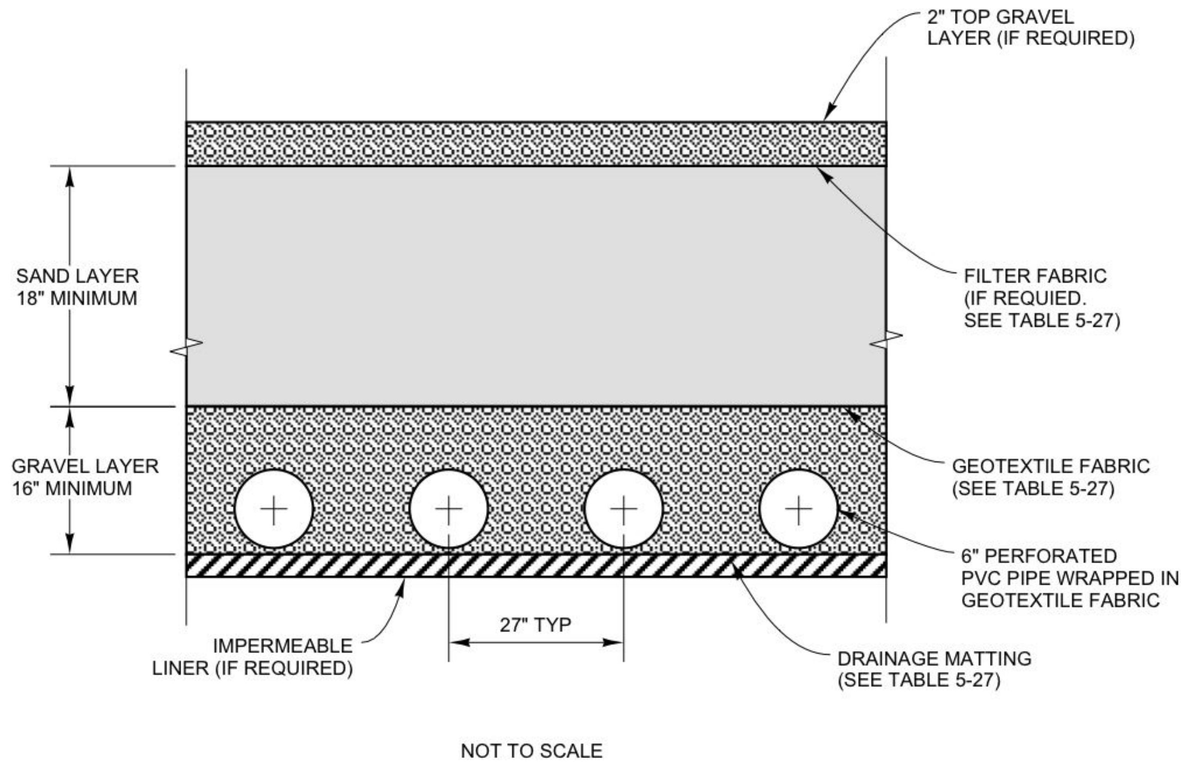



**Figure 5-22A. Filter Bed with Gravel Underdrain**

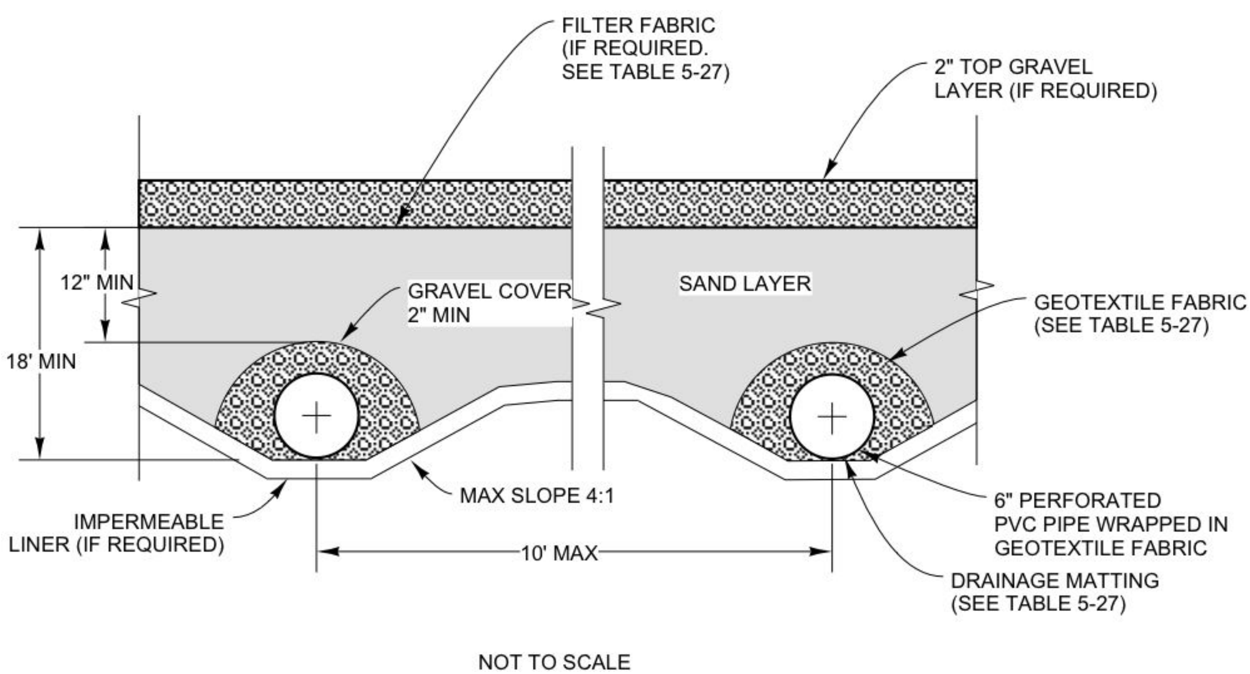



**Figure 5-22B. Filter Bed with Trench Underdrain**

## Design Data Summary Sheet for Austin Sand Filter (Page 1 of 1)

**Designer:**______________________________

**Company:**______________________________

**Date:**______________________________

**Project:**______________________________

**Location:**______________________________

| | | |
|---|---|---|
| 1. Determine Design Water Quality Volume | | |
| a. Effective tributary drainage area | $A_{eff}$ = ________ | $ft^2$ |
| b. Water Quality Volume (based on 40 h drawdown) | SQDV = ________ | $ft^3$ |
| 2. Sedimentation Basin Volume ($V_{sb}$ ≥ SQDV) | $V_{sb}$ = ________ | $ft^3$ |
| 3. Sedimentation Basin Depth (3 ft ≤ $d_{sb}$ ≤ 10 ft) | $d_{sb}$ = ________ | ft |
| 4. Sedimentation Basin Area ($A_{sb}$= $V_{sb}$ / $d_{sb}$) | $A_{sb}$ = ________ | $ft^2$ |
| 5. Sedimentation Basin Shape | | |
| a. Sedimentation Basin Length ($L_{sb}$) | $L_{sb}$ = ________ | ft |
| b. Sedimentation Basin Width ($W_{sb}$) | $W_{sb}$ = ________ | ft |
| c. Sedimentation Basin L:W Ratio (2:1 minimum) | L:W = ________ | |
| 6. Filtration Basin Storage Volume ($V_{fbs}$ ≥ 0.2 x SQDV) | $V_{fbs}$ = ________ | $ft^3$ |
| 7. Filter Bed Surface Area | | |
| a. Minimum filter surface area for storage ($A_{fbs}$) | | |
| $A_{fbs}$ = $V_{fbs}$ / $d_{fbs}$ | $A_{fbs}$ = ________ | $ft^2$ |
| where | | |
| $d_{fbs}$ = Depth of storage above filter bed (3 ft min.) | $d_{fbs}$ = ________ | ft |
| b. Minimum filter surface area for flow ($A_{ff}$) | | |
| Sand Bed Depth ($d_f$ ≥ 1.5 ft) | $d_f$ = ________ | ft |
| Coefficient of permeability for sand (k = 0.146 ft/h) | k = ________ | ft/h |
| Time required to pass through filter ($t_f$ = 40 h) | $t_f$ = ________ | h |
| $A_{ff} = \frac{(SQDV)(d_f)}{(k)(d_{fbs} + d_f)(t_f)}$ | $A_{ff}$ = ________ | $ft^2$ |
| c. Final design filter bed surface area ($A_{fb}$) | $A_{fb}$ = ________ | $ft^2$ |
| 8. Filter Bed Design (Check Type Used) | ________ Sand Bed with Gravel Underdrain<br>________ Sand Bed with Trench Underdrain | |

Notes ______________________________

______________________________

## Description

A Porous Pavement Filter consists of an installation of modular block porous pavement that is flat in all directions and is provided with a surcharge zone to temporarily store the SQDV draining from the tributary area. Stormwater runoff infiltrates into the porous pavement and its sublayers of sand and gravel and slowly exits through an underdrain.

Modular block porous pavement consists of open void concrete block units laid upon a two-layer sand and gravel subgrade. The surface pavement voids are filled with sand. An alternative approach is to use stabilized grass porous pavement, consisting of grass turf reinforced with plastic rings and filter fabric underlain by gravel. A typical cross section of a Porous Pavement Filter system is shown in **Figure 5-23**.

### Advantages

- Porous Pavement Filter basins can reduce peak flows during small storm events
- Modular block patterns, colors, and materials can serve functional and aesthetic purposes.

### Limitations

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

## Planning and Siting Considerations

- Should only be installed on flat surfaces.
- May be used in low vehicle-movement zones. Potential applications include the following:
  - Low vehicle movement airport zones;
  - Parking aprons and maintenance roads;
  - Crossover/emergency stopping/parking lanes on divided highways;
  - Residential street parking lanes;
  - Residential driveways;
  - 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 the block voids, but it may require irrigation and lawn care.

- In cases when the subsoils are not free draining, an impermeable liner should be provided to contain the water in the gravel pack and to mitigate concerns about expansive soils.
- Should be located far enough from foundations in expansive soils so as to limit damage to potential structures.
- When a commercial or an industrial site may be handling chemicals and petroleum products that may spill to the ground, an impermeable liner with an underdrain is required to prevent groundwater and soil contamination.

## Design Criteria

Design Criteria for the Porous Pavement Filter are summarized in **Table 5-29**.

**Table 5-29. Porous Pavement Filter Design Criteria**

| Design Parameter | Criteria | Notes |
|---|---|---|
| Drawdown time for SQDV | 12 h | Minimum |
| SQDV | 80% annual capture | Use **Figure 5-1** @ 12-hr drawdown |
| Surcharge storage volume above pavement | 100% | Based on SQDV |
| Depth of surcharge zone | 2 in | Above pavement |
| Modular Porous Block Type | 40% | Open surface area |
| Porous Pavement Infill | ASTM C-33 Sand or equivalent | |
| Base courses | 1-in sand (ASTM C-33) over 9-in gravel | |
| Perimeter Wall Width | 6 in | |

## Design Procedure

### Step 1 – Determine Stormwater Quality Design Volume (SQDV)

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

### Step 2 – Determine Basin Surcharge Storage Volume

The basin surcharge storage volume above pavement is equal to 100 percent of the SQDV.

$$V_{BS} = 1.0 \times SQDV$$

### Step 3 – Determine Basin Surface Area

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

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

### Step 4 – Select Block Type

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

**Step 5 – Porous Pavement Infill**

The Modular Block Pavement openings should be filled with ASTM C-33 graded sand (fine concrete aggregate, not sandy loam turf).

**Step 6 – Provide Base Courses**

Provide 1-inch sand over 9-inch gravel base courses as shown in **Figure 5-23.**

**Step 6 – Provide Perimeter Wall**

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

**Step 7 – Install Subbase**

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

**Step 7 – Provide Overflow**

Provide an overflow, possibly with an inlet to a storm sewer, set at 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.

## Construction Considerations

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

## Long-Term Maintenance

The City may require 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 Porous Pavement Filters. Such agreements will typically include requirements such as those outlined in **Table 5-30**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix C-1**.

**Table 5-30. Inspection and Maintenance Requirements for Porous Pavement Filters**

| Activity | Schedule |
|---|---|
| Inspect pavements to determine if runoff is infiltrating properly. If infiltration is significantly reduced, remove surface sand by vacuuming. Dispose of and replace old sand with fresh sand. | At least twice during the wet season after significant storms. Additional inspections after periods of heavy runoff are desirable. |
| If stabilized grass 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. |

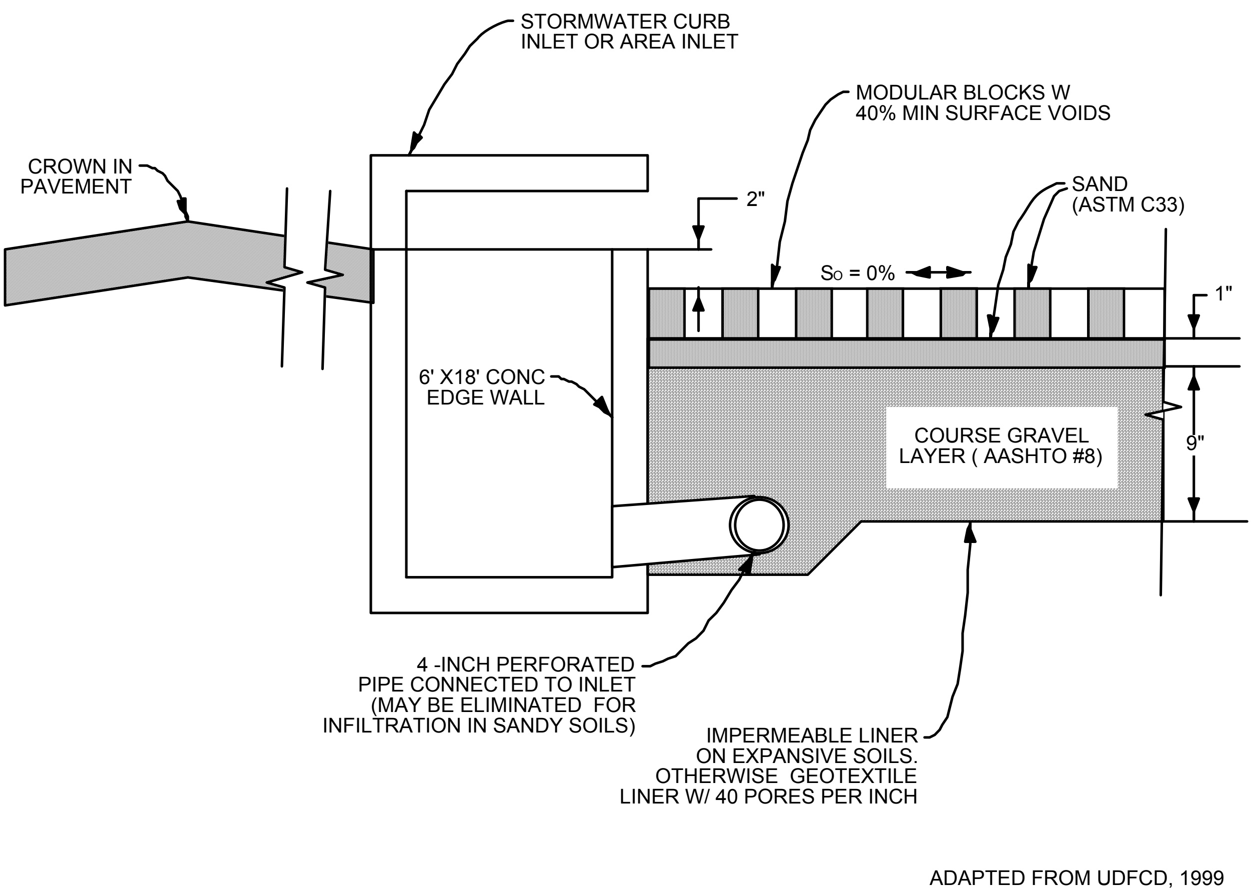



**Figure 5-23. Porous Pavement Filter**

## Design Data Summary Sheet for Porous Pavement Filter (Page 1 of 1)

**Designer:** ______________________

**Company:** ______________________

**Date:** ______________________

**Project:** ______________________

**Location:** ______________________

| | |
|---|---|
| 1. Determine Stormwater Quality Design Volume (SQDV) | |
| a. Effective tributary drainage area | $A_{eff}$ = ____________ $ft^2$ |
| b. Stormwater Quality Design Volume (based on 12 h drawdown) | SQDV = ____________ $ft^3$ |
| 2. Basin Surcharge Storage Volume ($V_{bs}$ = SQDV) | $V_{bs}$= ____________ $ft^3$ |
| 3. Basin Surface Area | |
| a. Design Volume (SQDV) | SQDV = ____________ $ft^3$ |
| b. $A_s$ = Design Volume/(0.17 ft) (based on surcharge depth of 2 in) | $A_s$ = ____________ $ft^2$ |
| 4. Porous Block Type | Block name: ____________ |
| | Manufacturer: ____________ |
| a. Minimum open area = 40% | Open Area = ____________ % |
| b. Minimum thickness = 4 in | Thickness = ____________ in |
| 5. Base Course (Check) | |
| a. ASTM C33 Sand Layer (1 in) | Sand Layer ____________ |
| b. AASHTO M43-No.8 Gravel Layer (9 in) | Gravel Layer ____________ |

Notes ______________________

## 5.4 PROPRIETARY AND ALTERNATIVE TREATMENT CONTROL MEASURES

The standard Treatment Control Measures (**Fact Sheets T-1 through T-11**) included in this Section are non-proprietary designs that have been reviewed and evaluated by the City and determined to be generally acceptable. Because the performance of these measures has already been demonstrated and reviewed by the City, the plan check review and approval process will be routine for development projects that have selected one of these Treatment Control Measures from this Manual.

### 5.4.1 Proprietary Treatment Control Measures

The City recognizes, however, that these non-proprietary Treatment Control Measures may not be appropriate for all projects due to physical site constraints. Thus, the City will allow the use of proprietary control measures that have been approved for general use by the City in those projects where the use of non-proprietary Treatment Control Measures (**Fact Sheets T-1 through T-11**) has been demonstrated by the applicant to the satisfaction of the City to be infeasible or impractical. Proprietary devices that are approved by the City for general use are listed in **Appendix H** along with the sizing criteria and criteria used for approval. This list will be updated periodically when additional proprietary devices are added to the approved list or conditions for approval change.

In general, any proprietary device must be designed to treat the SQDV or the SQDF. However, use of alternative sizing criteria is allowed for certain devices as indicated in **Appendix H**. Procedures to calculate the SQDV and SQDF are provided in the **Fact Sheet T-0**. Site runoff in excess of the design capacity may be diverted around or through the treatment device. Any proposed device must include all maintenance requirements indicated in **Appendix D-2** and as indicated in **Section 6,** and all operation and construction requirements as recommended by the manufacturer.

### 5.4.2 Alternative Treatment Control Measures

The City encourages the development of innovative stormwater control measures and may consider allowing the use on a pilot basis of limited number of promising alternative proprietary control measures that are not on the approved list in **Appendix H**. In order for a pilot project to be considered for proprietary devices, the manufacturer and/or property owner must commit to participating in and funding a monitoring program to verify the device's performance. The monitoring program must conform to a monitoring protocol specified by the City. Site designers should anticipate additional review time and contact the City stormwater staff early in the process to request consideration of pilot installation projects.

# 6.0 Control Measure Maintenance

Continued effectiveness of control measures specified in this Manual depends on diligent ongoing inspection and maintenance. To ensure that such maintenance is provided, the City requires submittal of a Maintenance Plan and execution of a Maintenance Agreement with the owner/operator of stormwater control measures prior to final acceptance of a private development project, which may include one or more of the control measures detailed in Sections 3,4, and 5. The property owner or his/her designee is responsible for compliance with the agreement. Requirements for the maintenance plan and agreement are presented and discussed in this section. Sample agreements are presented in **Appendix C-1**.

## 6.1 MAINTENANCE PLAN

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

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

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

**A. Site Map:**

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

**B. Baseline Descriptions:**

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

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

**C. Spill Plan:**

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

**D. Facility Changes:**

1. Operational or facility conditions or changes that significantly affect the character or quantity of pollutants discharging into the stormwater control measures may require modifications to the Maintenance Plan and/or additional stormwater control measures.

**E. Training:**

1. Identify appropriate persons to be properly trained and assure documentation of training.
2. Training to include:
   a. Good housekeeping procedures defined in the plan
   b. Proper maintenance of all pollution mitigation devices
   c. Identification and cleanup procedures for spills and overflows
   d. Large-scale spill or hazardous material response
   e. Safety concerns when maintaining devices and cleaning spills

**F. Basic Inspection and Maintenance Activities:**

1. Create and maintain on site, a log for inspector names, dates, and stormwater control measure devices to be inspected and maintained. Provide a checklist for each inspection and maintenance category.
2. Perform and document annual testing of any mechanical or electrical devices prior to wet weather.
3. Report any significant changes in stormwater control measures to the site management. As appropriate, assure mechanical devices are working properly and/or landscaped BMP plantings are irrigated and nurtured to promote thick growth.
4. Note any significant maintenance requirements due to spills or unexpected discharges.
5. As appropriate, perform maintenance and replacement as scheduled and as needed in a timely manner to assure stormwater control measures are performing as designed and approved.
6. Assure *unauthorized* low-flow discharges from the property do not bypass stormwater control measures (see Permit § D.2.c and Attachment 9, p.1 for a definition of Authorized Non-Stormwater Discharges).
7. Perform an annual assessment of each pollution-generating operation and its associated stormwater control measures to determine if any part of the pollution reduction train can be improved.

**G. Revisions to Pollution Mitigation Measures:**

1. If future correction or modification of 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.

## 6.2 MAINTENANCE AGREEMENT

Verification of maintenance provisions is required for all control measures specified in this Manual, whether Site Design Control Measures (see **Section 3**), Site-specific Control Measures (see **Section 4**), or Treatment Control Measures (see **Section 5**). Verification, at a minimum, shall include:

1. The owner/developer's signed statement accepting responsibility for inspection and maintenance until the responsibility is legally transferred. A sample Owners Certification statement is provided in **Appendix C-2**; and either
    a. 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
    b. Written text in project conditions, covenants, and restrictions for residential properties that assign maintenance responsibilities to the Home Owners Association for the inspection and maintenance of the control measures; or
    c. A legally enforceable maintenance agreement that assigns responsibility for the inspection and maintenance of post-construction control measures to the owner/operator. A Maintenance Agreement with the City must be executed by the owner/operator before occupancy of the project is approved. Sample Maintenance Agreement forms are provided in **Appendix C-1**.

Appendix A

# Glossary of Terms and List of Acronyms

## GLOSSARY OF TERMS

**Automotive Repair Shop:** A facility that is categorized in any one of the following SIC codes: 5013, 5014, 5541, 7532-7534, or 7536-7539.

**Berm:** An earthen mound used to direct the flow of runoff around or through a structure.

**Best Management Practice (BMP):** Any program, technology, process, siting criteria, operational methods or measures, or engineered systems, which when implemented prevent, control, remove, or reduce pollution. Includes schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent, eliminate, or reduce the pollution of "waters of the United States". BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage. (40 CFR §122.2)

**Buffer Strip or Zone:** Strip of erosion-resistant vegetation over which stormwater runoff is directed.

**Catch Basin (also known as Inlet or Storm Drain Inlet):** Box-like underground concrete structure with openings in curbs and gutters designed to collect runoff from streets and pavements.

**Clean Water Act (CWA):** (33 U.S.C. 1251 et seq.) Requirements of the NPDES program are defined under Sections 301, 307, 402, 318 and 405 of the CWA.

**Commercial Development:** Under Attachment 4 and City of Davis policy, commercial development is defined as any development on undeveloped private land that is not for heavy industrial or residential use where the total impervious area created is greater than or equal to 5,000 square feet. The category includes, but is not limited to, hospitals, laboratories and other medical facilities; educational institutions; recreational facilities; commercial nurseries; multi-apartment buildings; car wash facilities; mini-malls and other business complexes; shopping malls; hotels; office buildings; public warehouses; and other light industrial facilities.

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

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

**Construction General Permit:** An NPDES permit issued by the SWRCB for the discharge of stormwater associated with construction activity from soil disturbance of one (1) acres or more. (Construction General Permit No. CAS000002).

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

**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 runoff at reduced peak flow rates.

**Discharge:** A release or flow of stormwater or other substance from a conveyance system or storage container.

**Erosion:** The wearing away of land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices relating to farming, residential or industrial development, road building, or timber cutting.

**Excavation:** The process of removing earth, stone, or other materials, usually by digging.

**Facility:** A collection of industrial processes discharging stormwater associated with industrial activity within the property boundary or operational unit.

**Filter Fabric:** Geotextile of relatively small mesh or pore size that is used to: (a) allow water to pass through while keeping sediment out (permeable); or (b) prevent both runoff and sediment from passing through (impermeable).

**Grading:** The cutting and/or filling of the land surface to a desired shape or elevation.

**Hazardous 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 (i.e., ignitability, corrosivity, reactivity, or toxicity) or appears on special EPA or state lists. Regulated under the federal Resource Conservation and Recovery Act (RCRA) and the California Health and Safety Code.

**Home subdivisions of 10 housing units or more:** Any subdivision being developed for 10 or more single-family homes, multi-family homes, condominiums, and apartments.

**Illicit Discharges:** Any discharge to an MS4 that is not composed entirely of stormwater except discharges authorized by an NPDES permit (other than the NPDES permit for discharges from the municipal separate storm sewer) and discharges resulting from emergency fire fighting activities.

**Industrial General Permit:** An NPDES Permit (No. CAS000001) issued by the SWRCB for the discharge of stormwater associated with industrial activity. (Board Order 97-03-DWQ)

**Infiltration:** The downward entry of water into the surface of the soil.

**Inlet:** An entrance into a ditch, storm sewer, or other waterway.

**Integrated Pest Management (IPM):** An ecosystem-based strategy that focuses on long-term prevention of pests or pest-related damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant plant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatment is implemented with the goal of removing only the target organism.

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

**Municipal Separate Storm Sewer System (MS4):** A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains): (i) designed or used for collecting or conveying stormwater; (ii) which is not a combined sewer; and (iii) which is not part of a POTW as defined at Title 40 of the CFR 122.2. A “Small MS4” is defined as an MS4 that is not a permitted MS4 under the Phase I regulations. This definition of a Small MS4 applies to MS4 operated within cities and counties as well as governmental facilities that have systems of storm sewers.

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

**NPDES (National Pollutant Discharge Elimination System) Permit:** An authorization, license, or equivalent control document issued by EPA or an approved state agency to implement the requirements of the NPDES program. NPDES is the national program for administering and regulating Sections 301, 307, 318, 402, and 405 of the Clean Water Act (CWA). In California, the SWRCB has issued General Permits for stormwater discharges associated with industrial activities and construction activities.

**Parking Lot:** Land area or facility for the temporary parking or storage of motor vehicles used personally, for business, or for commerce with an impervious surface area of 5,000 square feet or more, or with 25 or more parking spaces.

**Permeability:** A property of soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

**Point Source:** Any discernible, confined, and discrete conveyance from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural stormwater runoff.

**Pollutant:** A substance introduced into the environment that adversely affects the usefulness of a resource.

**Pollution Prevention (P2):** Practices and actions that reduce or eliminate the generation of pollutants.

**Precipitation:** Any form of rain or snow.

**Pretreatment:** Treatment of wastewater before it is discharged to a wastewater collection system.

**Receiving Stream: A**ny natural or man-made surface water body that receives and conveys stormwater runoff (defined for purposes of this Manual only).

**Restaurant:** A stand-alone facility that sells prepared foods and drinks for consumption, including stationary lunch counters and refreshment stands selling prepared foods and drinks for immediate consumption (SIC code 5812), where the total impervious area for development is greater than 5,000 square feet.

**Retail Gasoline Outlet:** Any facility engaged in selling gasoline and lubricating oils.

**Retention:** The storage of stormwater to prevent it from leaving the development site; may be temporary or permanent.

**Runoff:** Water originating from rainfall, melted snow, and other sources (e.g., sprinkler irrigation) that flows over the land surface to drainage facilities, rivers, streams, springs, seeps, ponds, lakes, wetlands, and shallow groundwater.

**Run-on:** Stormwater surface flow or other surface flow which enters property or an area other than that where it originated. Off-site stormwater surface flow or other surface flow which enters the site.

**Sedimentation:** The process of depositing soil particles, clays, sands, or other sediments that were picked up by runoff.

**Sediments:** Soil, sand, and minerals washed from land into water, usually after rain, that accumulate in reservoirs, rivers, and harbors, destroying aquatic animal habitat and clouding the water such that adequate sunlight might not reach aquatic plants. Farming, mining, and building activities without proper implementation of BMPs will expose sediment materials, allowing them to be washed off the land after rainfalls.

**Significant Materials:** Includes, but not limited to, raw materials; fuels; materials such as solvents, detergents, and plastic pellets; finished materials such as metallic products; raw materials used in food processing or production; hazardous substances designed under Section 101(14) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, commonly known as Superfund); any chemical the facility is required to report pursuant of Section 313 of Title III of the Superfund Amendments and Reauthorization Act (SARA); fertilizers; pesticides; and waste products such as ashes, slag, and sludge that have the potential to be released with stormwater discharges.

**Significant Quantities:** The volume, concentrations, or mass of a pollutant in stormwater discharge that can cause or threaten to cause pollution, contamination, or nuisance that adversely impact human health or the environment and cause or contribute to a violation of any applicable water quality standards for receiving water.

**Significant Redevelopment –** Under Attachment 4 and City of Davis policy, significant redevelopment is defined as a net increase in impervious area of 5,000 square feet or more on an already-developed site. Significant redevelopment includes, but is not limited to, expansion of a building footprint or addition or replacement of a structure; structural development including an increase in gross floor area and/or exterior construction or remodeling; replacement of impervious surface that is not part of a routine maintenance activity; and land disturbing activities related with structural or impervious surfaces. Where significant redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing development, and the existing development was not subject to development standards under this Manual, the numeric sizing criteria listed for items 2 through 8 below applies only to the addition, and not to the entire development. Conversely, if the redevelopment results in an increase of fifty percent or more of the impervious surfaces of a previously existing development, then the entire development (new plus existing areas) are subject to development standards under this Manual.

**Source Control BMPs:** Any schedules of activities, structural devices, prohibitions of practices, maintenance procedures, managerial practices or operational practices that aim to prevent stormwater pollution by reducing the potential for contamination at the source of pollution.

**Source Reduction (also Source Control):** The technique of stopping and/or reducing pollutants at their point of generation so that they do not come into contact with stormwater.

**Storm Drain System:** Network of above and below-ground structures for transporting stormwater to streams or outfalls.

**Storm Drains:** Above- and below-ground structures for transporting stormwater 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 Pollution Prevention Plan (SWPPP):** A written plan that documents the series of phases and activities that, first, characterizes a site, and then prompts site owners/operators to select and implement actions which prevent the pollution of stormwater discharges.

**Stormwater:** Stormwater runoff, snow-melt runoff, surface runoff, and drainage, excluding infiltration and irrigation tail water. 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.

**Structural BMP or Control Measure:** Any structural facility designed and constructed to mitigate the adverse impacts of stormwater and urban runoff pollution (e.g., canopy, structural enclosure). The category may include both Treatment Control BMPs and Source Control BMPs.

**Treatment Control BMP (or Measure):** 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:** 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.

## LIST OF ACRONYMS

| | |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| ASTM | American Society for Testing Materials |
| BMPs | Best Management Practices |
| CASQA | California Stormwater Quality Association |
| CFR | Code of Federal Regulations |
| CWA | Clean Water Act (Federal Water Pollution Control Act of 1972 as amended in 1987) |
| IPM | Integrated Pest Management |
| LID | Low Impact Development |
| MS4 | Municipal Separate Storm Sewer System |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| PCC | Portland cement concrete |
| RCRA | Resource Conservation and Recovery Act |
| RWQCB | Regional Water Quality Control Board |
| SIC | Standard Industrial Classification |
| SQDF | Stormwater Quality Design Flow |
| SQDV | Stormwater Quality Design Volume |
| SWPPP | Stormwater Pollution Prevention Plan |
| SWQCP | Stormwater Quality Control Plan |
| SWRCB | State Water Resources Control Board |

Appendix B

# Standard Calculations for Diversion Structure Design

## INTRODUCTION

Storm water runoff in excess of the water quality flow or volume is to be diverted around or through the treatment control measure. The following paragraphs provide equations and design criteria necessary to design diversion structures to divert runoff in excess of the SQDV or SDQF around or through the treatment control measures.

## DIVERSION STRUCTURE DESIGN

Capture or isolation of the SQDV is typically achieved by employing one of the following techniques:

- Divert the SQDV into the treatment control measure from the on-site storm drain system using weirs or orifices at or upstream of the point of entrance to the treatment control measure.
- Bypassing flows in excess of the SQDV within the treatment control measure using weirs and pipes for channel or pipe storm drain systems or routing excessive flows through a vegetated swale.

By employing diversion techniques, the water quality flow or volume is treated and discharged to the storm drain system and runoff that exceeds the water quality flow or volume is diverted or bypassed, untreated, directly to the downstream storm drain system.

Equations and criteria to design a diversion structure are provided below. Alternative designs may be considered subject to approval.

All diversion structures are designed using the on-site storm design event. The drainage design storm is established by the City of Davis and is not the same as the stormwater quality design flow or volume. The drainage design storm is used to design the conveyance system, i.e. pipes, swales, etc. of the site without regard for treatment. The design engineer must ensure sufficient head room in the on-site system above the diversion to accommodate overflows.

### Diverting Flows at the Inlet or Upstream of the Treatment Control Device

Diverting flow at the inlet to the treatment control is the more common approach to divert excess runoff. Figure B-1 illustrates the more commonly used diversion structures. The height of the weir to divert the flow is determined a follows:

#### *Treatment Control Measures Designed Based on the SQDV*

1. Determine the SQDV (see Section 5).
2. Utilizing design techniques provided in the treatment control measure fact sheets, determine the maximum height of the water level in the treatment control measure when the entire SQDV is being held.

3. Set the height of the diversion weir to the maximum height of the water level.
4. Determine weir dimensions needed to divert peak flows of the drainage design storm using the following equation for a rectangular sharp-crested weir:

$$Q_d = C \times L \times h^{1.5} \qquad \textit{eqn B-1}$$

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 B-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 B-1. Weir Discharge Coefficient (C) for Rectangular Sharp-crested Weirs Without End Contractions[1]**

| | Head (h) over weir, ft | | | | | | |
|---|---|---|---|---|---|---|---|
| **H/h** | **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 SQDF*

1. Establish the size of the on-site drainage system (pipe diameter or dimensions) based on the drainage design storm.
2. Determine the SQDF (see Section 5).
3. Determine the depth of flow in the on-site drainage system when carrying the SQDF using Manning's equation (eqn B-2).

$$SQDF = \frac{1.49}{n}(A)(R)^{\frac{2}{3}}(s)^{\frac{1}{2}} \qquad \textit{eqn B-2}$$

Where: $SQDF$ = Water Quality Flow, cfs

$n$ = Manning's roughness coefficient

$A$ = Cross sectional area of drainage pipe or channel, $ft^2$

R = Hydraulic radius, ft

S = Slope of pipe or channel, ft/ft

4. Using nomographs or computer programs, determine the depth of flow at SQDF. Set the weir height at this depth.
5. Using Equation B-1, establish weir dimensions. Provide sufficient head room in treatment control to accommodate flows over the weir.

## Bypassing Excess Flows within the Treatment Control Measure

For certain site conditions, bypassing runoff in excess of the SQDV must be achieved in the treatment control measure. When this occurs, the control measure must be designed to ensure the bypass system can be accommodated in the unit, i.e. sufficient depth, width and length to accommodate pipes, length of weirs, etc. The following discusses design considerations for the different treatment control measures.

### *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 SQDV and SQDF. Design of these measures is similar to the approach described above under diverting flows at the inlet to the treatment control measure. Bypass for filtration devices occurs in the sedimentation chamber.

#### *Weirs*

Weirs are commonly used to bypass excess storm events. Determining the height of the weir is based on the maximum water elevation in a treatment control device when holding the entire SQDV. To design the weir, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV.

#### *Orifices*

Orifices can be considered in place of weirs or pipes. To avoid drawing floatables into the bypass, a hooded orifice (see Figure B-2) should be designed using the equation B-3:

$$Q_d = C \times A \times (2gh)^{0.5}$$ *eqn B-3*

Where: $Q_d$ = Peak flow rate for drainage design storm, cfs

C = Orifice discharge coefficient, (use 0.6)

A = Area of orifice, $ft^2$

h = Depth of the water above midpoint of orifice, ft

g = 32.2 $ft/sec^2$

Hoods should extend into one-third of the permanent pool depth or one-foot whichever is greater. Commercial catch basin traps can be used in lieu of a hood.

Determining the elevation of the orifice is based on determining the maximum water elevation in a treatment control device when holding the entire SQDV. Use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV to establish the elevation of the mid-point of the orifice opening.

The size of the orifice is determined by using Equation B-3 for the orifice to bypass the peak flow of the on-site storm.

Ensure sufficient head room in the treatment unit to accommodate flows through orifice.

### *Pipes*

Pipes can also be employed to bypass excess runoff. Determining the invert elevation of the bypass inlet is based on determining the maximum water elevation in a treatment control device when holding the entire SQDV. To do this, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV to design a diversion weir.

For filtration control measures, a hooded inlet using a 90° elbow should be considered at the inlet to the bypass pipe to prevent drawing floatables into the bypass (see Figure B-2). Hoods should extend into one-third of the permanent pool depth or one-foot whichever is greater. Commercial catch basin traps can be used in lieu of a hood.

For infiltration control measures (see Figure B-3) bypass pipes are perforated and wrapped with filter fabric to avoid drawing sediment and small particles into the bypass pipe. Hoods are not necessary for these overflow pipes.

Bypass pipes are sized using the Manning's equation (Equation B-4) and sized to pass the peak flow of the drainage design storm, and assume the bypass pipes are flowing full. With this assumption, the Manning's equation, Equation B-4, reduces to:

$$D = \left( \frac{2.159 Q_d n}{s^{\frac{1}{2}}} \right)^{\frac{3}{8}} \qquad \textit{eqn B-4}$$

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***

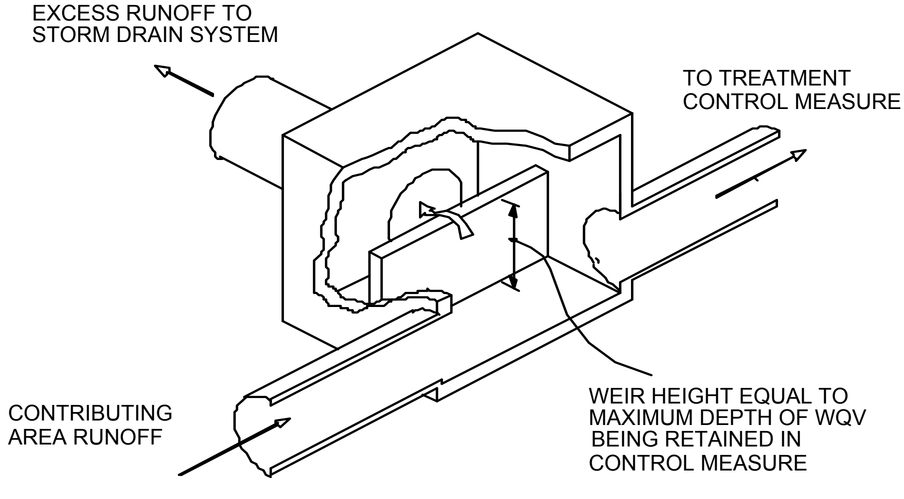
The depth of flow in a Vegetated Swale at SQDF is determined using a roughness coefficient of 0.2. If additional flows beyond the SQDF are to be directed to the vegetated swale, the roughness coefficient for these flows will be lower (approximately 0.03), because the flows exceeding the SQDF do not flow through the swale and are only influenced by surface friction/roughness. Swales with distinctly different roughness coefficients can be designed using an equivalent roughness coefficient that is determined based on the roughness associated with the wetted perimeters (P). For most on-site Vegetated Swale designs, there will be two different “n” values. An equivalent “$n_e$” value can be determined using equation B-5:

$$n_e^{\frac{3}{2}} = \frac{P_1 n_1^{\frac{3}{2}} + P_2 n_2^{\frac{3}{2}}}{P} \qquad \textit{eqn B-5}$$

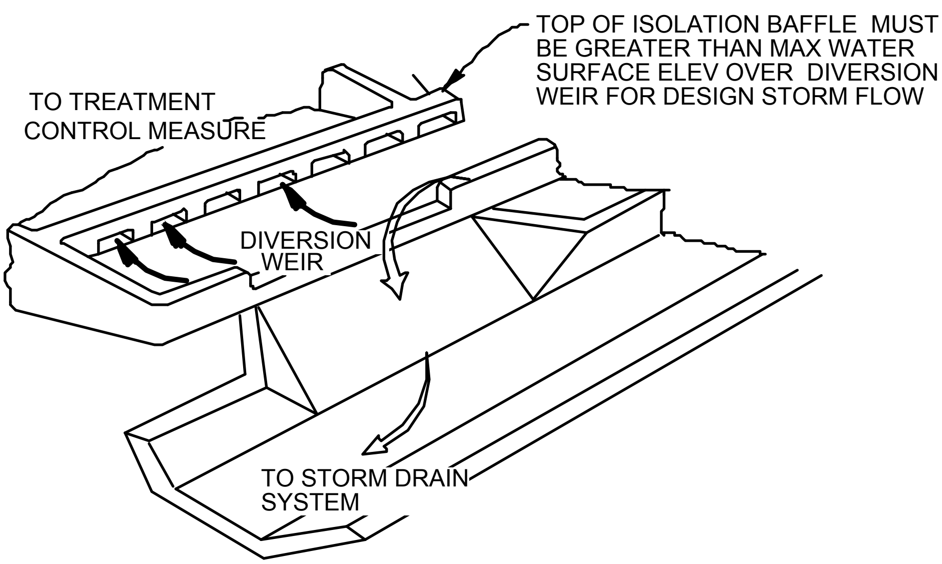
An iterative approach is used to develop an equivalent “$n_e$” that can be calculated with most computer hydraulic program applications:

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 B-2 substituting the peak flow of the drainage design storm for the SQDF;
3. Use the calculated depth to determine the wetted perimeter for the drainage system;
4. Use the wetted perimeter associated with each “n” for the drainage system and using Equation B-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 T-2.

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 B-1. Common Diversion Structures at Inlets**

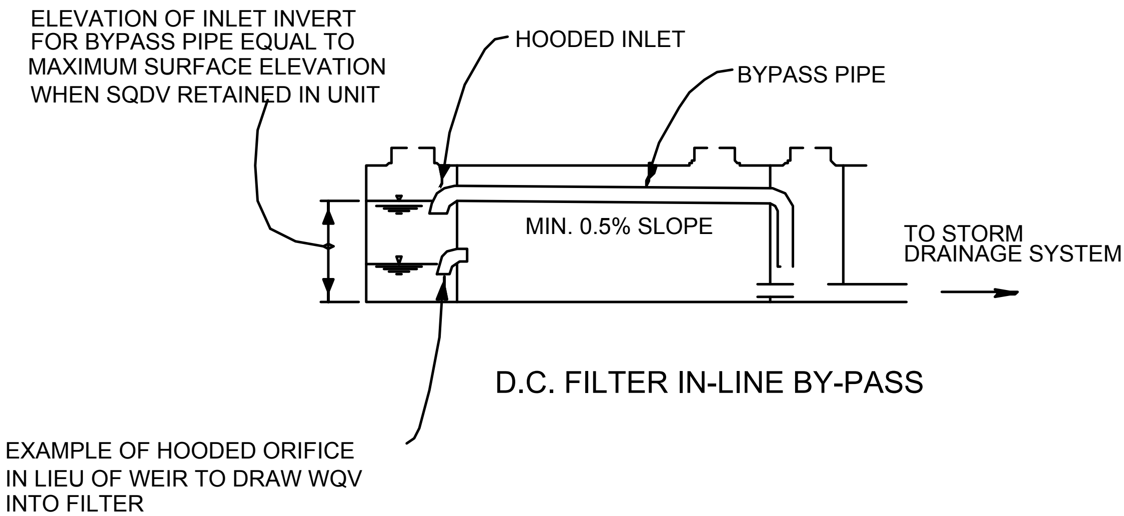



**Figure B-2. Illustration of Pipe Bypass in a Filtration Device**

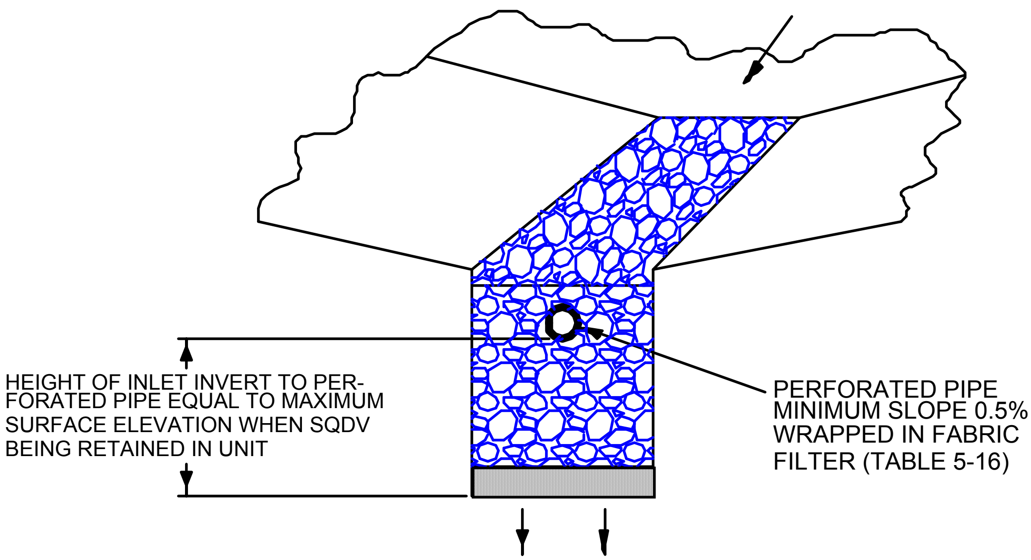



**Figure B-3. Illustration of Pipe Bypass in Infiltration Trench**

Appendix C-1

# Stormwater Treatment Device Access and Maintenance Agreement

**(Long Form)**

Recorded at the request of:
City of Davis

__________________________________________

After recording, return to:
City of Davis
City Clerk

__________________

__________________

**Stormwater Treatment Device
Access and Maintenance
Agreement**

**OWNER: __________________________________________________**

**PROPERTY ADDRESS:________________________________________**

**APN:_______________________________________________________**

**THIS AGREEMENT** is made and entered into in____________________, California, this___day of______________, by and between_______________________________________, hereinafter referred to as "Owner" and the CITY OF DAVIS, a municipal corporation, located in the County of Yolo, State of California hereinafter referred to as "CITY";

**WHEREAS,** the Owner owns real property ("Property") in the City of Davis, County of Yolo, 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 required the project to employ on-site control measures to minimize pollutants in urban runoff;

**WHEREAS,** the Owner has chosen to install a ___________________________________ __________________________________________________, hereinafter referred to as "Device", as the on-site control measure to minimize pollutants in urban runoff;

**WHEREAS,** said Device has been installed in accordance with plans and specifications accepted by the City;

**WHEREAS,** said Device, with installation on private property and draining only private property, is a private facility with all 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, including, but not necessarily limited to, filter material replacement and sediment removal, is required to assure peak performance of Device and that, furthermore, such maintenance activity will require compliance with all Local, State, or Federal laws and regulations, including those pertaining to confined space and waste disposal methods, in effect at the time such maintenance occurs;

**NOW THEREFORE,** it is mutually stipulated and agreed as follows:

1. Owner hereby provides the City or City's designee complete access, of any duration, to the Device and its immediate vicinity at any time, upon reasonable notice. In the event of emergency, as determined by City's Director of Public Works, no advance notice will be provided for the purpose of inspection, sampling, testing of the Device or to undertake all necessary repairs or other preventative measures at owner's expense as provided in paragraph 3 below. City shall make every effort at all times to minimize or avoid interference with Owner's use of the Property.

2. Owner shall use its best efforts diligently to maintain the Device in a manner assuring peak performance at all times. All reasonable precautions shall be exercised by Owner and Owner's representative or contractor in the removal and extraction of material(s) from the Device and the ultimate disposal of the material(s) in a manner consistent with all relevant laws and regulations in effect at the time. As may be requested from time to time by the City, the Owner shall provide the City with documentation identifying the material(s) removed, the quantity, and disposal destination.

3. In the event Owner, or its successors or assigns, fails to accomplish the necessary maintenance contemplated by this Agreement, within five (5) days of being given written notice by the City, the City is hereby authorized to cause any maintenance necessary to be done and charge the entire cost and expense to the Owner or Owner's successors or assigns, including administrative costs, attorneys fees and interest thereon at the maximum rate authorized by the Civil Code from the date of the notice of expense until paid in full.

4. The City may require the owner to post security in form, and for a time period satisfactory to the City, of guarantee the performance of the obligations stated herein. Should the Owner fail to perform the obligations under the Agreement, the City may, in the case of a cash bond, act for the Owner using the proceeds from it, or in the case of a surety bond, require the sureties to perform the obligations of the Agreement. As an additional remedy, the Director of Public Works may withdraw any previous stormwater related approval with respect to the property on which a Device has been installed until such time as Owner repays to City its reasonable costs incurred in accordance with paragraph 3 above.

5. This agreement shall be recorded in the Office of the Recorder of Yolo County, California, at the expense of the Owner and shall constitute notice to all successors and assigns of the title to said Property of the obligation herein set forth, and also a lien in such amount as will fully reimburse the City, including interest as herein above set forth, subject to foreclosure in event of default in payment.

6. In event of legal action occasioned by any default or action of the Owner, or its successors or assigns, then the Owner and its successors or assigns agree(s) to pay all costs incurred by the City in enforcing the terms of this Agreement, including reasonable attorney's fees and costs, and that the same shall become a part of the lien against said Property.

7. It is the intent of the parties hereto that burdens and benefits herein undertaken shall constitute covenants that run with said Property and constitute a lien there against.

8. The obligations herein undertaken shall be binding upon the heirs, successors, executors, administrators and assigns of the parties hereto. The term "Owner" shall include not only the present Owner, but also its heirs, successors, executors, administrators, and assigns. Owner shall notify any successor to title of all or part of the Property about the existence of this Agreement. Owner shall provide such notice prior to such successor obtaining an interest in all or part of the Property. Owner shall provide a copy of such notice to the City at the same time such notice is provided to the successor.

9. Time is of the essence in the performance of this Agreement.

10. Any notice 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: |
| --- | --- |
| ______________________ | ______________________________ |
| ______________________ | ______________________________ |
| ______________________ | ______________________________ |
| ______________________ | ______________________________ |

**IN WITNESS THEREOF,** the parties hereto have affixed their signatures as of the date first written above.

**APPROVED AS TO FORM:**

________________________________

City Attorney

**CITY OF DAVIS:**

________________________________

Name:____________________________

Title:_____________________________

**OWNER:**

________________________________

Name:____________________________

Title:_____________________________

**OWNER:**

________________________________

Name:____________________________

Title:_____________________________

**ATTEST:**

____________________________

City Clerk Date

**NOTARIES ON FOLLOWING PAGE**

**EXHIBIT A**

***(Legal Description)***

**EXHIBIT B**

***(Map/Illustration)***

**(Short Form)**

Recorded at the request of and mail to :

______________________________

______________________________

______________________________

## Covenant and Agreement Regarding Stormwater Treatment Device Maintenance

The undersigned hereby certify that we are the owners of hereinafter legally described real property located in the City of Davis, County of Yolo, State of California.

**Legal Description**: ______________________________________________________________

______________________________________________________________

as recorded in Book __________________________, Page_______, Records of Yolo County,

which property is located and known as **(Address):** ____________________________________

______________________________________________________________.

And in consideration of the City of Davis allowing____________________________________

______________________________________________________________

on said property, we do hereby covenant and agree to and with said City to maintain according to the Maintenance Plan (Attachment 1), all structural stormwater treatment devices including the following:

______________________________________________________________

______________________________________________________________.

This Covenant and Agreement shall run all of the above described land and shall be binding upon ourselves, and future owners, encumbrances, their successors, heirs, or assignees and shall continue in effect until released by the authority of the City upon submittal of request, applicable fees, and evidence that this Covenant and Agreement is no longer required by law.

**NOTARIES ON FOLLOWING PAGE**

# 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 Davis Manual of Stormwater Quality Control Standards for New Development and Redevelopment (Manual).

The undersigned understands that stormwater pollution control measures are enforceable requirements under the 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 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 ______________________________________

Appendix D-1

# Project Stormwater Quality Control Plan Guidance

**This appendix identifies the basic information that shall be included and format that shall be followed in a Project Stormwater Quality Control Plan pursuant to the City of Davis Manual of Stormwater Quality Control Standards for New Development and Redevelopment (Manual).**

**A. Cover page including:**

1. Project Name
2. Owner/Developer's name and contact information
3. Plan Preparer's name, contact information, professional registration stamp and signature
4. Date submitted (first submittal)
5. Date revised (subsequent submittals, as required)

**B. Owner's Certification Statement (see Appendix C-2 for sample statement)**

**C. Project Description**

1. Project Category (see Table 2-3)
2. Narrative description of project – size, location, land uses, etc.
3. Site maps
   a. Provide a vicinity map showing the location of the project relative to principal landmarks.
   b. Provide a site map showing boundaries of the site, acreage and drainage patterns/contour lines. Show each discharge location from the site and any drainage flowing onto the site.
   c. Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.
   d. With legend, show locations of expected sources of pollution generation (outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, industrial clarifiers, wash-racks, etc). Identify any areas having contaminated soil or where toxins are stored or have been stored/disposed of in the past.
   e. With legend, indicate types and locations of structural stormwater control measures that will be built to permanently control stormwater pollution.

**D. Stormwater Pollution Control Measures**

1. Provide summary matrix indicating each type of control measure provided (refer to **Table 2-3**).
2. Site Design Control Measures
   a. Describe the controls provided under each Site Design Control Measure (D-1 through D-4). Indicate how site design will conform to design criteria listed in the Manual.

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 to the project.

c. If implementation of a Site Design Control Measure is not feasible due to project site conditions, provide a statement of justification describing why implementation is not feasible.

3. Site-Specific Source Control Measures

   a. Describe the site-specific control measures to be provided. Indicate how design of site-specific control measures will conform to design criteria listed in the Manual.

4. Treatment Control Measures

   a. Describe the treatment control measures to be provided.

   b. Summarize design data for treatment control measures on appropriate design procedure forms (see Appendix G for forms). Provide detailed supporting calculations for design data values in a clear and organized manner.

**E. Maintenance Plan and Responsibility**

1. Provide a summary of structural control measures to be provided and parties responsible for maintenance of each control. Indicate any anticipated transfer of responsibility due to future transfer of ownership or annexation.

2. Provide complete contact information for each listed responsible party

3. Provide a statement that a detailed Maintenance Plan will be prepared in accordance with Manual requirements (see Appendix D-2 for guidance).

Appendix D-2

# Maintenance Plan Guidance

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

## A. Site Map

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

## B. Baseline Descriptions

1. List the property owners and persons responsible for operation and maintenance of the stormwater control measures on site. Include phone numbers and addresses.
2. Identify the intended method of providing financing for operation, inspection, routine maintenance, and upkeep of stormwater control measures.
3. List all permanent stormwater control measures. Provide a brief description of stormwater control measures selected and if appropriate, facts sheets or additional information.
4. As appropriate for each stormwater control measure provide:
   a. A written description and check-list of all maintenance and waste disposal activities that will be performed. Distinguish between the maintenance appropriate for a 2-year establishment period and expected long-term maintenance. For example, maintenance requirements for vegetation in a constructed wetland may be more intensive during the first few years until the vegetation is established. The post-establishment maintenance plan shall address maintenance needs (e.g. pruning, irrigation, weeding) for a larger, more stable system. Include maintenance performance procedures for facility components that require relatively unique maintenance knowledge, such as specific plant removal/replacement, landscape features, or constructed wetland maintenance. These procedures shall provide enough detail for a person unfamiliar with maintenance to perform the activity, or identify the specific skills or knowledge necessary to perform and document the maintenance.

b. A description of site inspection procedures and documentation system, including record-keeping and retention requirements.

c. An inspection and maintenance schedule, preferably in the form of a table or matrix, for each activity for all facility components. The schedule shall demonstrate how it will satisfy the specified level of performance, and how the maintenance/inspection activities relate to storm events and seasonal issues.

d. Identification of the equipment and materials required to perform the maintenance.

5. As appropriate, list all housekeeping procedures for prohibiting illicit discharges or potential illicit discharges to the storm drain. Identify housekeeping BMPs that reduce maintenance of treatment control measures.

**C. Spill Plan**

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

**D. Facility Changes**

1. Operational or facility changes which significantly affect the character or quantity of pollutants discharging into the stormwater control measures will require modifications to the Maintenance Plan and/or additional stormwater control measures.

**E. Training**

1. Identify appropriate persons to be trained and assure proper training.
2. Training to include:
   a. Good housekeeping procedures defined in the plan.
   b. Proper maintenance of all pollution mitigation devices.
   c. Identification and cleanup procedures for spills and overflows.
   d. Large-scale spill or hazardous material response.
   e. Safety concerns when maintaining devices and cleaning spills.

**F. Basic Inspection and Maintenance Activities**

1. Create and maintain on site, a log for inspector names, dates, and stormwater control measure devices to be inspected and maintained. Provide a checklist for each inspection and maintenance category.
2. Perform annual testing of any mechanical or electrical devices prior to wet weather.

3. Report any significant changes in stormwater control measures to the site management. As appropriate, assure mechanical devices are working properly and/or landscaped BMP plantings are irrigated and nurtured to promote thick growth.
4. Note any significant maintenance requirements due to spills or unexpected discharges.
5. As appropriate, perform maintenance and replacement as scheduled and as needed in a timely manner to assure stormwater control measures are performing as designed and approved.
6. Ensure low-flow discharges from the property are directed to stormwater control measures.
7. Perform an annual assessment of each pollution generation operation and its associated stormwater control measures to determine if any part of the pollution reduction train can be improved.

**G. Revisions to Pollution Mitigation Measures**

1. If future correction or modification of pass stormwater control measures or procedures is required, the owner shall obtain approval from the City prior to commencing any work. Corrective measures or modifications shall not cause discharges to by-pass or otherwise impede existing stormwater control measures.

**H. Monitoring & Reporting Program**

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

Appendix E

# Hydrologic Soil Groups

This appendix includes information on the Hydrologic Soil Groups in Yolo County to use in designing various stormwater control measures. The hydrologic soil information presented here should be used as a general overview. For more specific information, consult the *Yolo County Soil Survey* (USDA, NRCS) or contact the NRCS at (530) 662-3986.

## 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 E-1. Typical Infiltration Rates**

| Soil Type (Hydrologic Soil Group) | Soil Type VCFCD | Infiltration Rate (in/hr) |
|---|---|---|
| A | 6, 7 | 1.00 – 8.3 |
| B | 4, 5 | 0.5 – 1.00 |
| C | 2, 3 | 0.17 – 0.27 |
| D | 1 | 0.02 – 0.10 |

Infiltration rates shown represent the range covered by multiple sources, e.g. ASCE, BASMAA, etc.

## HYDROLOGIC SOIL GROUPS

The hydrologic soil groups are classified by the USDA Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service. There are four hydrologic soil groups: A, B, C and D. Soils may be classified by two groups. Soil groups A and B have the highest infiltration rates, unless the soils under consideration have been compacted during construction. Soil groups A and B are typically the best candidate soils for construction of infiltration facilities. Sites with soil groups C and D are usually more appropriate for detention basins.

Soils in group A have a low runoff potential and high infiltration rate, as the soils typically are sands and gravel. Soil group B includes soils with moderate infiltration rates when completely wetted. Group B soils are sandy loam soils with moderately fine to moderately coarse textures. Soils in group C have slow infiltration rates when thoroughly wetted and these soils typically are silty-loam soils with an impeding layer or soils with moderately fine to fine texture. Group D soils have a high runoff potential and very slow infiltration rate when thoroughly wetted. Group D soils include clay soils with high swelling potential, soils in a permanent high water table and shallow soils over nearly impervious material.

Appendix F

# 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. Grasses native to the Central Valley of California are preferred, but 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 the City Wildlife Resource Specialist regarding selection of appropriate vegetation.

A sample list of appropriate vegetative covers, intended as a guide for landscape design, is provided in **Table F-1**. Contact the Natural Resources Conservation Service (NRCS) or the California Native Grasslands Association (CNGA) for additional information.

**Table F-1. Sample List of Appropriate Vegetative Covers**

| Plant Name Common (Latin) | Appropriate Species | Maintenance and Usage Notes |
|---|---|---|
| Creeping Wildrye (*Leymus*) | (*L. triticoides*)** | Slow to establish. Low maintenance. Dry to moist sites. Readily spreads by rhizomes. |
| 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. Tolerates shade and compacted soils. Rapid germination. Lawns, swales, erosion control.* |
| Ryegrass (*Lolium*) | Perennial (*L. perenne*) | Moderate maintenance. Heat intolerant. Fast sprouting. Swales.* |
| Brome (*Bromus*) | Blando (*B. mollis*) | Non-irrigated Sites |
| | California (*B. carinatus*)** | Non-irrigated Sites |
| Meadow Barley (*Hordeum*) | (*H. brachyantherum*)** | Irrigated and Non-irrigated Sites |
| Kentucky Bluegrass | (*Poa pratensis*) | Irrigated Sites |
| Zorro Fescue (*Vulpia*) | (*V. myuros*) | Irrigated and Non-irrigated Sites |
| Slender Wheatgrass (*Elymus*) | (*E. trachycaulus*)** | Slow to establish. Low maintenance. Dry to moist locations. Shade tolerant. |

Notes:

*Generally, this species will require supplemental irrigation. **California Native

Sources:

- American Society of Civil Engineers (ASCE)
- Metropolitan Washington Council of Governments (MWCG), Center for Watershed Protection
- Sunset
- California Native Grasslands Association (CNGA)
- United States Department of Agriculture: Natural Resources Conservation Service (NRCS)—Field Office Technical Guide
- Manual of Standards for Erosion and Sediment Control Measures, Association of Bay Area Governments. 1995.

Appendix G

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Appendix H

# 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 within the Davis City limits.

To provide a rational basis for approval of proprietary devices, the City has elected to recognize as approved for general use those proprietary devices that have been approved for general 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 use from the following stormwater programs:

- Sacramento Stormwater Quality Partnership (website: http://www.sacstormwater.org/)
- State of Washington Department of Ecology (DOE) Stormwater Program (website: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html)

The City may recognize lists from other programs in the future and will update Appendix H accordingly. The proprietary devices currently approved for general use by the City are listed in **Table H-1** along with contact information, sizing criteria and basis of approval. This list will be updated periodically when additional proprietary devices are added to the approved list. Any proposed device listed in **Table H-1** must include all maintenance, operation, and construction requirements as indicated in Appendix D-1 and D-2 and as recommended by the manufacturer.

**Table H-1. Proprietary Stormwater Treatment Devices Approved for General Use by City of Davis**

| Proprietary Device | Manufacturer | Approval Basis | Sizing Criteria[1] |
|---|---|---|---|
| 1. Stormvault Mitigation System | CONTECH Stormwater Solutions<br>Website: www.contech-cpi.com/stormwater/13 | Sacramento Stormwater Quality Partnership general use designation | Water Quality Capture Volume at 6-hour drain time (ASCE Manual and Report on Engineering Practice No. 87) |
| 2. StormFilter | CONTECH Stormwater Solutions<br>Website: www.contech-cpi.com/stormwater/13 | Washington DOE general use designation for basic treatment | Stormwater Quality Design Flow (see Fact Sheet T-0) |
| 3. Media Filtration System (MFS) | CONTECH Stormwater Solutions<br>Website: www.contech-cpi.com/stormwater/13 | Washington DOE general use designation for basic treatment | Stormwater Quality Design Flow (see Fact Sheet T-0) @ 9.0 gpm /cartridge |
| 4. Filterra System | Americast<br>Website: www.filterra.com | Washington DOE conditional use designation for basic treatment | Stormwater Quality Design Flow (Fact Sheet T-0) @ 50 in/hr infiltration |
| 5. EcoStorm plus Stormwater Filtration System | Royal Environmental Systems, Inc<br>Website: www.royalenterprises.net | Washington DOE pilot use designation[2] for basic treatment | Stormwater Quality Design Flow (see Fact Sheet T-0) @ 350 gpm/unit |
| 6. Aqua-Filter System | AquaShield, Inc.<br>Website: www.aquashieldinc.com | Washington DOE pilot use designation[2] for basic treatment | Stormwater Quality Design Flow (see (Fact Sheet T-0) @ 5.0 gpm/cartridge |

1. Sizing criteria or hydraulic loading rates used to size the device for the proposed application must be consistent with the criteria currently listed as the basis for approval by the approving agency.
2. Devices designated as approved for pilot use must be monitored for field performance by the manufacturer in accordance with Washington DOE field monitoring protocol at a minimum of one site within the City.