Technical Guidance Manual
for
Stormwater Quality Control Measures

July 2002

Ventura Countywide Stormwater Quality Management Program

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Table of Contents

Page

Table of Contents – continued

Table of Contents – continued

Table of Contents

List of Tables

Page

Table of Contents

List of Figures

Page

Table of Contents

Appendices

SECTION 1
BACKGROUND AND GOALS

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. The regulations require metropolitan areas with a population greater than one hundred thousand and specific categories of industrial facilities, to obtain an NPDES permit for stormwater discharges.

As principal permittee, the County of Ventura Flood Control District received a countywide municipal NPDES permit for stormwater discharges from the Los Angeles Regional Water Quality Control Board. The County of Ventura Flood Control District, County of Ventura and the Cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, San Buenaventura, Santa Paula, Simi Valley, Thousand Oaks, are named as co-permittees under this permit. Under this permit, the permittees are required to develop, administer, implement, and enforce a Comprehensive Stormwater Management Program (CSWMP) to reduce pollutants in urban runoff to the maximum extent practicable (MEP). The CSWMP implemented by the co-permittees is a multi-faceted, dynamic program, which is designed to reduce stormwater pollution to the maximum extent practicable. The CSWMP emphasizes all aspects of pollution control including, but not limited to, public awareness and participation, source control, regulatory restrictions, water quality monitoring, and treatment control.

Controlling urban runoff pollution from new development during and after construction is critical to the success of the Comprehensive Stormwater Management Program. The New Development Management Program (NDMP) is an element of the Comprehensive Stormwater Management Program being implemented by the Permittees to specifically control post-construction urban runoff pollutants from new development and redeveloped areas. The goal of the NDMP is to minimize runoff pollution typically caused by land development and protect the beneficial uses of receiving waters by employing a sensible combination of pollutant source control and site-specific treatment control measures. The NDMP envisions reducing stormwater pollutants from new development by employing on-site control measures for commercial, industrial, multi-family, and single-family residential land uses

“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 which prevent and/or reduce pollutants in stormwater runoff from the project. Source Control Measures limit the exposure of materials and activities so that potential sources of pollutants are prevented from contacting storm runoff. Treatment Control Measures are reasonable, engineered systems that provide a reduction of pollutants in runoff to be consistent with the MEP standards imposed by the Federal Clean Water Act on the City and County. This manual contains design guidance for on-site source and treatment controls for new development and redevelopment projects.

In addition to the countywide permit requirements, owners/developers of some of the sites in the County may also be subject to the State of California's general permit for stormwater discharge from industrial activities (Industrial General Permit) and general permit for stormwater from construction activities (Construction General Permit). The control measures provided in this manual may assist the owner/developer in meeting the requirements of the State's permit. The stormwater management staffs of the governing Permittee agencies are available to provide assistance regarding State permit requirements.

Goals

This manual has been prepared by the County of Ventura Co-permittees to accomplish the following goals:

- Ensure that new developments reduce urban runoff pollution to the "maximum extent practicable,"
- Ensure the implementation of measures in this manual are consistent with NPDES permit and other State requirements.
- Provide guidance to developers, design engineers, agency engineers, and planners on the selection and implementation of appropriate stormwater treatment and source control measures, and
- Provide maintenance procedures to ensure that the selected control measures will be maintained to provide effective, long-term pollution control.

SECTION 2
OVERVIEW AND
USE OF THE MANUAL

Introduction

The control measures, often termed Best Management Practices or BMPs, described in this manual were selected to optimize post-construction, on-site stormwater pollution control. On-site control measures, for the purposes of this Manual, apply to infill and new development project categories listed in the Ventura Countywide Storm Water Quality Urban Impact Mitigation Management Plan (SQUIMP – see Appendix H). Applicable SQUIMP 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. SQUIMP Project Categories and Associated Pollutants of Concern

	Pollutant Category of Concern						
SQUIMP Project Category	Sediment	Nutrients	Metals	Trash and Debris	Oxygen Demand	Toxic Organics	Bacteria
Commercial Developments (≥ 100,000 SF)	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
Parking Lots (≥ 5,000 SF or 25 spaces)	X		X	X	X	X	
Hilllside Single-family Residences	X	X	X	X	X	X	X
Home Subdivisions (≥ 10 units)	X	X	X	X	X	X	X
Projects Located Within or Directly Adjacent to, or Discharging Directly to Environmentally Sensitive Area (see Appendix I)	X	X	X	X	X	X	X

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

A design decision flowchart is presented in Figure 2-1 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 key step in the process is project assessment to determine expected pollutants (see Table 2-1), receiving water quality and hydraulic conditions, and site conditions (e.g. soils, groundwater, topography), as all these conditions will influence the selection of appropriate control measures. The selection of appropriate control measures should be a collaborative effort between the project proponent and the governing agency staff. It is recommended that discussions between project planners and engineers and agency stormwater staff regarding selection of controls measures occur early in the design process.

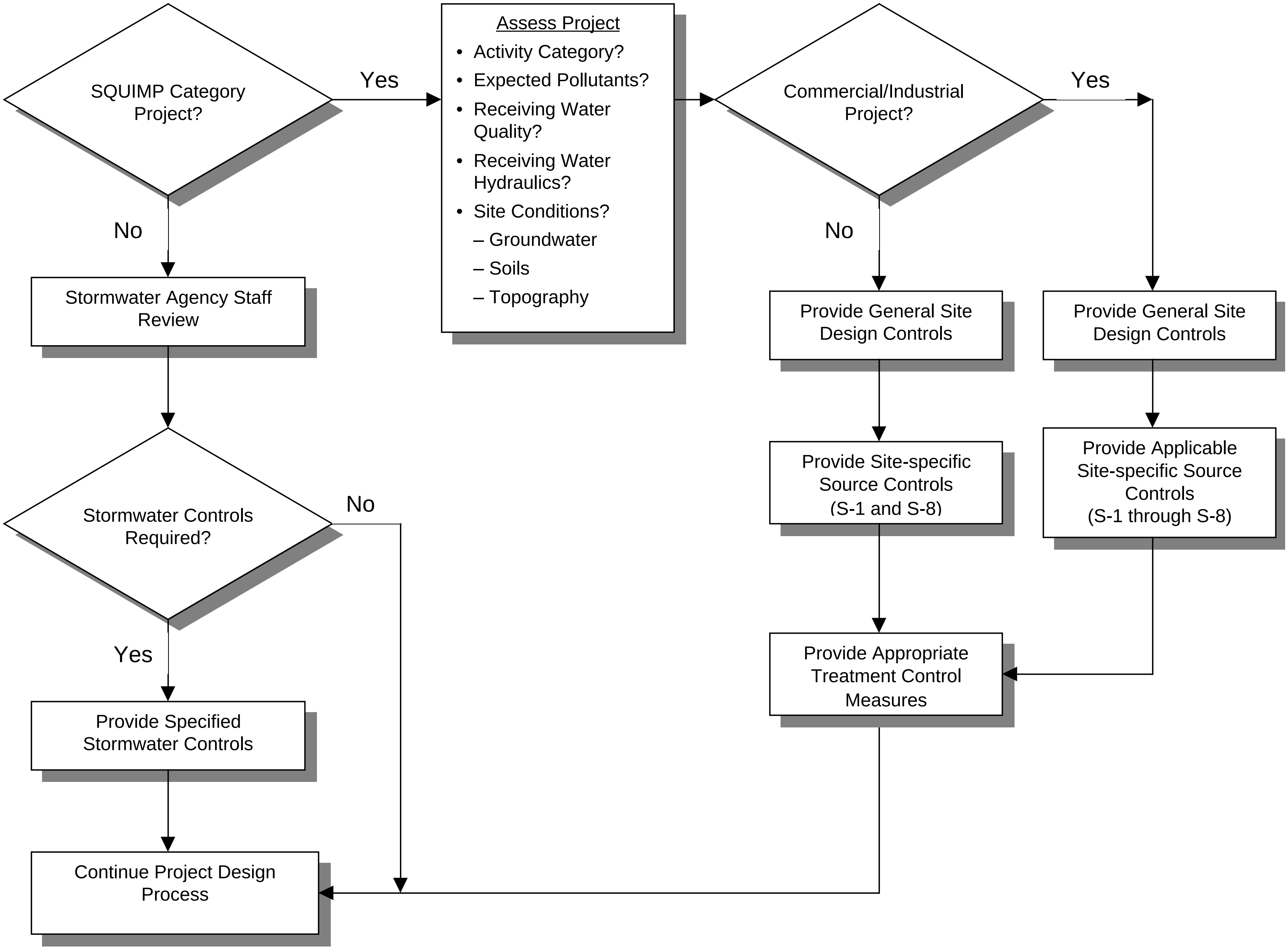


Figure 2-1. Stormwater Controls Design Decision Flowchart

If the project is determined by the governing stormwater agency to be a SQUIMP category project (see Table 2-1), the project must be designed to include the control measures specified in this Manual. Projects that are not SQUIMP category projects are still subject to stormwater agency review. Stormwater controls may be required by the governing agency for non-SQUIMP category projects, depending on the potential for discharge of pollutants in stormwater runoff.

Overview of Stormwater Pollution Control Measures

The categories of stormwater pollution controls measures specified in this Manual are summarized in Table 2-2 along with applicable projects and primary objectives of the control measures:

Table 2-2. Summary of Required Stormwater Pollution Controls Measures

Control Measure Category	Applicable Projects	Primary Objective
General Site Design Control Measures	All SQUIMP projects	Minimize the volume and rate of stormwater runoff discharge from the project site.
Site-specific Source Control Measures	Specific outdoor activities and development features: · Outdoor storage area · Trash storage area · Loading/unloading dock area · Repair/maintenance bay · Vehicle/equipment/accessory wash area · Fueling area	Prevent potential pollutants from contacting rainwater or stormwater runoff or to prevent discharge of contaminated runoff to the storm drain system or receiving water.
Treatment Control Measures	All SQUIMP projects – at least one approved treatment control measure required	Remove pollutants from stormwater runoff prior to discharge to the storm drain system or receiving water.

Site design and site-specific source controls 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. Treatment controls are also required for all projects 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 provided the project proponent can demonstrate that treatment equivalent to approved methods is achievable. Alternative control measures are further discussed at the end of Section 5. Treatment controls are required in addition to source controls to meet the SQUIMP requirement to minimize, to the maximum extent practicable, discharge of pollutants to the stormwater conveyance system. A matrix of SQUIMP 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 and 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 Controls, Site-specific Source Controls, and Treatment Controls, respectively.

Table 2-3. Control Measure Selection Matrix for SQUIMP Project Categories

SQUIMP Project Category	General Site Design Control Measures[(a)]					Site-Specific Source Control Measures[(b)]								Treatment Control Measures[(c)]
	Conserve Natural Areas (G-1)	Protect Slopes and Channels (G-2)	Control Peak Runoff Rates (G-3)	Minimize Impervious Area (G-4)	Minimize Effective Imperviousness (G-5) Turf Buffer (G-5.1) Grass-lined Channel (G-5.2)	Storm Drain Message and Signage (S-1)	Out door Storage Area Design (S-2)	Trash Storage Area Design (S-3)	Loading/unloading Dock Area Design (S-4)	Repair/maintenance Bay Design (S-5)	Vehicle/Equipment/ Accessory Washing Area Design (S-6)	Fueling Area Design (S-7)	Proof of Control Measure Maintenance (S-8)	Grass Strip Filter (T-1) Grass Swale Filter (T-2) Extended Detention Basin (T-3) Wet Detention Basin (T-4) Constructed Wetland (T-5) Detention Basin/Sand Filter (T-6) Porous Pavement Detention (T-7) Porous Landscape Detention (T-8) Infiltration Basin (T-9) Infiltration Trench (T-10) Media Filter (T-11) Proprietary Controls (T-12)[(f)]
Commercial Developments (≥ 100,000 SF)	R	R	R	R	R[(e)]	R	R[(d)]	R[(d)]	R[(d)]	R[(d)]	R[(d)]	R[(d)]	R	S
Automotive Repair Shops	R	R	R	R	R[(e)]	R	R[(d)]	R[(d)]	–	R[(d)]	R[(d)]	R[(d)]	R	S
Retail Gasoline Outlets	R	R	R	R	R[(e)]	R	R[(d)]	R[(d)]	–	R[(d)]	R[(d)]	R	R	S
Restaurants	R	R	R	R	R[(e)]	R	R[(d)]	R[(d)]	R[(d)]	–	R[(d)]	–	R	S
Parking Lots (≥ 5,000 SF or 25 spaces)	R	R	R	R	R[(e)]	R	R[(d)]	R[(d)]	–	–	–	–	R	S
Hilllside Single-family Residences	R	R	R	R	R[(e)]	R	R[(d)]	–)	–	–	–	–	R	S
Home Subdivisions (≥ 10 units)	R	R	R	R	R[(e)]	R	R[(d)]	–	–	–	–	–	R	S
Project Located Within or Directly Adjacent to, or Discharging directly to Environmentally Sensitive Area	R	R	R	R	R[(e)]	R	R[(d)]	R[(d)]	R[(d)]	R[(d)]	R[(d)]	R[(d)]	R	S

R = Required if applicable to project
R[(d)] = Required if activity area is included in the project
R[(e)] = Required unless shown to be infeasible based on site conditions. Select one or more applicable control measures
S = Select one or more applicable treatment control measures from list above.
(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
(f) = Use only on a case-by-case basis with agency staff approval or in combination with other applicable treatment control measures

SECTION 3
GENERAL SITE DESIGN
CONTROL MEASURES

Introduction

The principal objective of the General 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 controls and conveyance systems;
- Reduced pollutant loading to treatment controls; and
- Reduced hydraulic impact on receiving streams.

General Site Design Control Measures include the following design features and considerations designated G-1 through G-5:

- G-1: Conserve Natural Areas
- G-2: Protect Slopes and Channels
- G-3: Control Peak Stormwater Runoff Discharge Rates
- G-4: Minimize Impervious Area
- G-5: Minimize Effective Imperviousness

The General Site Design Control Measures described in this section are required for all SQUIMP category projects unless the project proponent demonstrates to the satisfaction of the governing stormwater agency that the particular measures are not applicable to the proposed project, or the project site conditions make it infeasible to implement the design control measure in question.

Description

Detailed descriptions and design criteria for each of the General Site Design Control Measures are presented in this section in fact sheet format.

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

Design Criteria

Slope Protection

Slope protection practices must conform to design requirements or standards set forth by local agency erosion and sediment control standards and design standards. The design criteria described in this fact sheet are intended to enhance and be consistent with these local standards.

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

Channel Protection

Control measure G-3 is intended to limit peak flow to avoid erosive conditions in unlined receiving streams. The following measures should be implemented to provide additional erosion protection unlined receiving streams. Activities and structures must conform to applicable standards and specifications of agencies with jurisdiction (e.g. U.S. Army Corps of Engineers, California Department of Fish and Game).

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

Control Peak Stormwater Runoff Discharge Rates

Purpose

Unless controlled, peak stormwater runoff rates from developed areas are typically higher than those from previously undeveloped areas. Higher peak flows can change stream morphology and increase downstream erosion that can damage stream habitat and impact aesthetic value. In addition, higher flows convey larger pollutant loads to receiving waters. Control of peak stormwater discharge rates is thus required to protect stream habitat and aesthetic value by maintaining non-erosive hydraulic conditions in unlined receiving streams during stormwater runoff events.

Design Criteria

SQUIMP category projects, excluding single family hillside residences, that directly discharge to unlined receiving streams shall implement the following interim criteria:

1. 2-year post development discharge rates shall not exceed the predeveloped discharge rates for the 2-year frequency storm event.
2. Peak flows shall be determined using the procedures set forth in the latest edition of the *Hydrology Manual* and Direct Runoff curves produced by Ventura County Public Works Agency, Flood Control Department. The designer is specifically reminded to regard minimum subarea sizes required in the *Hydrology Manual*. Where jurisdictions within Ventura County have approved alternative hydrologic calculation methods, the alternative methods may be used if they have been approved by the jurisdiction for use in design of flow-based stormwater controls.

The Ventura County Public Works Agency, Flood Control Department is currently developing a modeling procedure to establish peak flow design criteria to avoid erosive conditions. A study in the upper reaches of the Arroyo Simi (Simi Valley) is currently underway to examine the relationship between runoff discharge rates and erosion. The results of the study will be used to revise/finalize the interim peak flow criteria presented in this manual upon approval of the co-permittee cities.

Minimize Impervious Area

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 Criteria

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 foot prints of building and parking lots;
2. Cluster buildings and paved areas to maximize pervious area;
3. Use minimum allowable roadway and sidewalk cross sections and parking stall widths;
4. Include landscape islands in cul-de-sacs (where approved);
5. Use pervious pavement materials where appropriate, such as modular paving blocks, turf blocks, porous concrete and asphalt, brick, and gravel or cobbles. (Ref. BASMAA, 1999 for descriptions of pervious pavements options.)
6. Use grass-lined channels or surface swales to convey runoff instead of paved gutters. (See Fact Sheet G-5.2)

Minimize Effective Imperviousness

Purpose

Stormwater runoff flows from impervious areas typically contains higher concentrations of pollutant and higher peak flows than flows from equally-sized pervious areas. The impacts of flow from impervious areas can be reduced by employing a design strategy termed minimizing effective imperviousness. This approach involves routing runoff from impervious areas over grassy areas or other pervious areas prior to discharge to the storm drainage system or receiving water to reduce peak flows, reduce total runoff volume and provide some degree of pollutant removal. In addition to the environmental and aesthetic benefits, minimizing effective imperviousness may allow reduction in the size of downstream conveyance and treatment systems, yielding savings in development costs. Projects that employ the approaches described in this fact sheet in accordance with the specified design criteria will be allowed to reduce the value of the effective impervious ratio used later in this Manual to size treatment controls. Calculation of effective imperviousness is described later in this fact sheet.

Description and Design

Suggested design strategies to minimize effective imperviousness include G-5.1: Turf Buffer and G-5.2: Grass-lined Channel. Suggested uses of these design strategies are illustrated in Figure 3-1. These design control measures are described below along with associated design criteria. It is important to note that at least one of these control measures is required to be employed in the site design unless site conditions make it infeasible to do so. For this requirement to be waived, project proponents must demonstrate infeasibility to the satisfaction of the local stormwater agency review staff.

G-5.1: Turf Buffer

Description

Turf Buffers are uniformly graded and densely vegetated strips of turf grass. Runoff flow is distributed uniformly across the top width of the strip to achieve sheet flow down the length of the strip. Turf Buffers provide opportunity for infiltration, reduce peak flows from impervious areas and provide some degree of pollutant removal. Applications of Turf Buffers are illustrated in Figure 3-2. Turf Buffers differ from Grass-lined Channels, as they are designed to receive and maintain sheet flow as opposed to concentrated or channelized flow. Sheet flow application to the top of the Turf buffer may achieved by routing sheet flow from impervious areas, such as parking lots, directly to the top of the Turf Buffer or by redistributing concentrated flow across the top of the Turf Buffer by means of a level spreader. Turf Buffer strips, used for the purpose of minimizing effective imperviousness, are similar to Grass Strip Filters employed as a treatment control (see Section 5, Fact Sheet T-1), but differ in terms of the values used for the two principal design parameters – linear application rate (across the top width of the buffer) (cfs/ft width) and down-slope length.

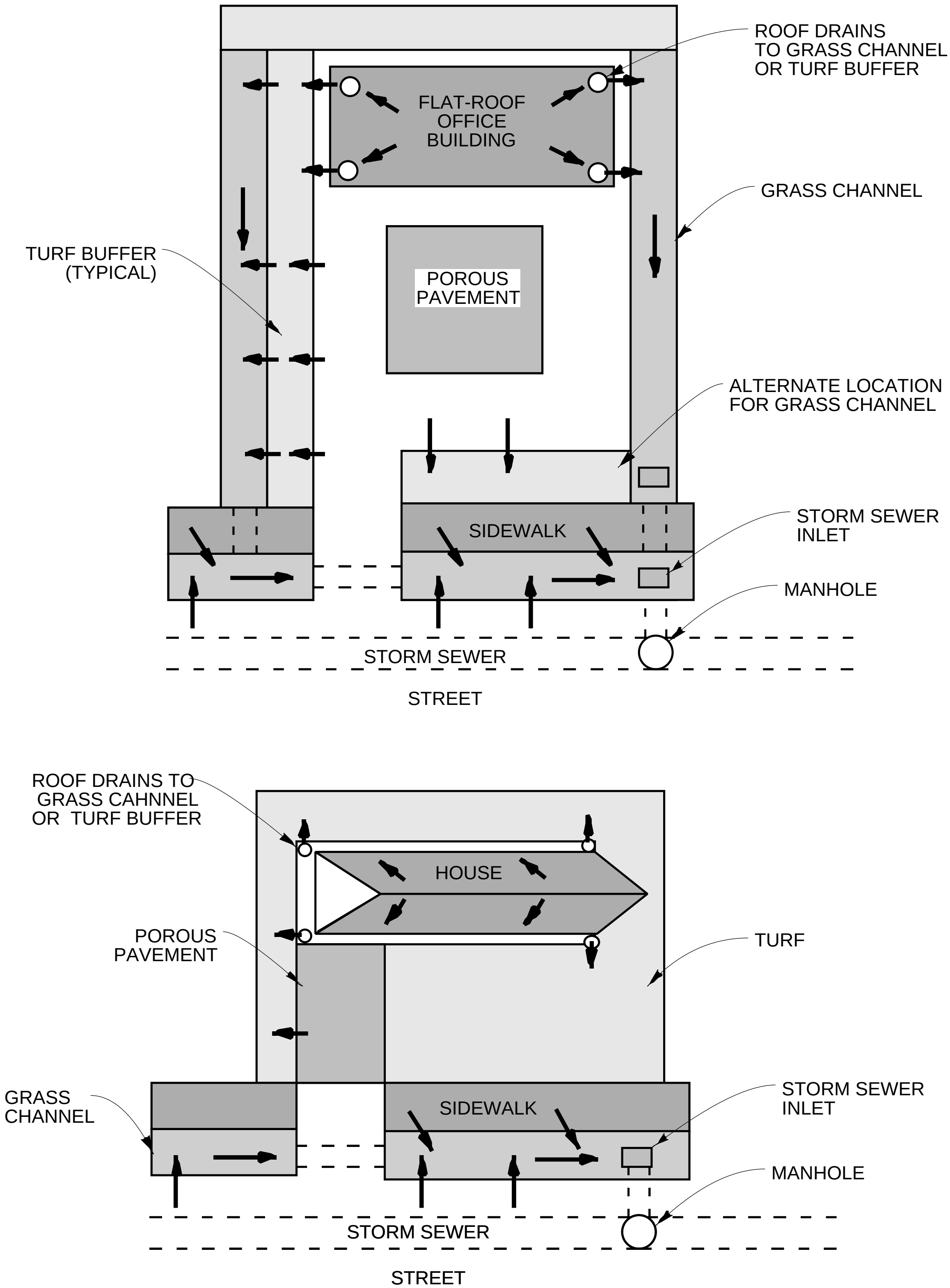


Figure 3-1 EXAMPLES OF MINIMIZING FLOW FROM IMPERVIOUS AREAS

General Application and Design Considerations

Turf Buffers 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. The contributing flow from impervious areas that can be accommodated by the Turf Buffer will be limited according to the design criteria in this fact sheet. Tributary areas are typically less than 5 acres. Several Turf Buffers may be used on a single site, each sized according to the impervious area from which it receives flow. Irrigation and regular mowing are required to maintain the turf grass cover. Turf Buffers 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. Although Turf Buffers provide some degree of pollutant removal, they do not qualify as treatment controls and must be followed by at least one of the approved treatment controls described in Section 5.

Design Criteria and Procedure

Principal design criteria for Turf Buffers are summarized in Table 3-1. See Figure 3-2 for dimensional relationships.

Table 3-1. Turf Buffer Design Criteria

Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.1 x $Q_{P,\ 50yr}$
Maximum linear application rate (q_a)	cfs/ft width	0.05
Minimum width (normal to flow) (W_{TB})	ft	(SQDF) / (q_a)
Minimum length (flow direction) (L_{TB})	ft	8 (minimum)
Maximum slope (flow direction)	%	4 (maximum)
Vegetation	–	Turf grass (irrigated)

Design procedure and application of design criteria are outlined in the following steps:

1. Design Flow — Determine Stormwater Quality Design Flow (SQDF) for impervious area to be mitigated.

   $Q_{P,\ SQDF} = 0.1 \times Q_{P,\ 50yr}$ (see Calculation Fact Sheet, Section 5)

2. Minimum Width — Calculate minimum width of the Turf Buffer (W_{TB}) normal to flow direction.

   W_{TB} = (SQDF) / (q_a)

   W_{TB} = (SQDF) / 0.05 cfs/ft (minimum)

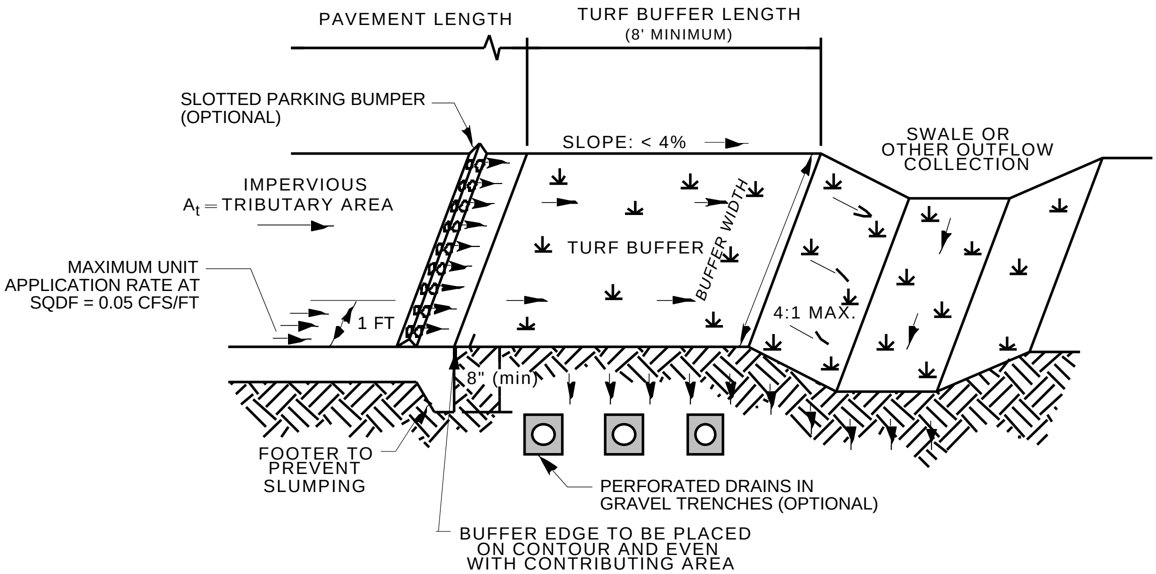
3. Minimum Length — Length of the Turf Buffer (L_{GB}) in the direction of flow shall not be less than 8 feet.

   L_{TB} = 8 feet (minimum)

4.	Maximum Slope	Slope of the ground in the direction of flow shall not be greater than 4 percent.
5.	Flow Distribution	Incorporate a device at the upstream end of the Turf Buffer to evenly distribute flows along the top width, such as slotted curbing, modular block porous pavement, or other spreader devices. Concentrated flow delivered to the Turf Buffer must be distributed evenly by means of a level spreader of similar concept.
6.	Vegetation	Provide irrigated perennial turf grass to yield full, dense cover (See Appendix F for suitable grasses).
7.	Outflow Collection	Provide a means for outflow collection and conveyance (e.g. grass channel/swale, storm drain, street gutter)

Design Example

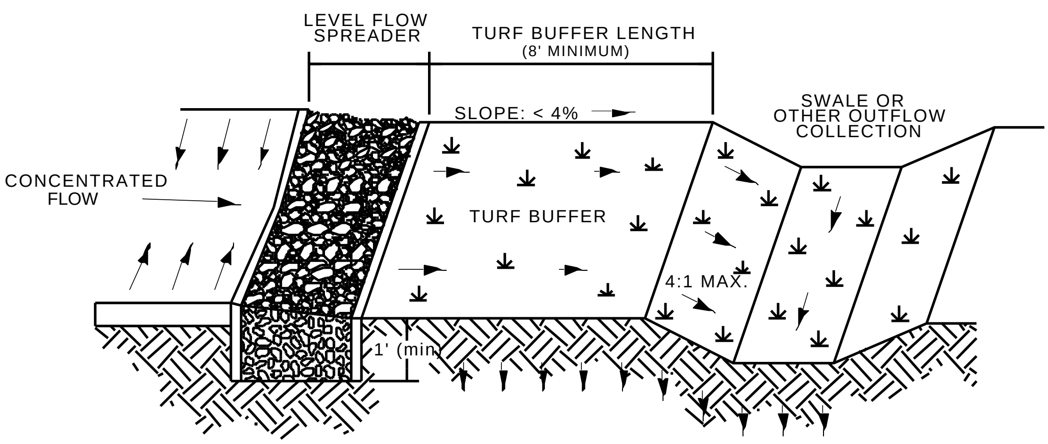
A completed design form follows as a design example. Blank design forms are provided in Appendix G.



SHEET FLOW CONTROL

NOT TO SCALE

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



CONCENTRATED FLOW CONTROL

NOT TO SCALE

Figure 3-2 TURF BUFFER

Design Procedure Form for G-5.1: Turf Buffer

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Design Flow	$Q_{P,\,SQDF}$ = 1.0 cfs
2. Design Width W_{GB} = (SQDF) / 0.05 cfs/ft	W_{GB} = 20.0 ft.
3. Design Length (8 ft minimum)	L_{GB} = 8.0 ft.
4. Design Slope (4 percent maximum)	L_{GB} = 3.0 %
5. Flow Distribution (Check type used or describe “Other”)	__X__ Slotted curbing _____ Modular Block Porous Pavement _____ Level Spreader _____ Other __________
6. Vegetation (describe)	Tall Fescue
7. Outflow Collection (Check type used or describe “Other”)	__X__ Grass Channel/Swale _____ Street Gutter _____ Storm Sewer _____ Underdrain Used _____ Other __________

Notes ____

G-5.2: Grass-lined Channels

<u>Description</u>

Grass-lined Channels are densely vegetated drainageways with gentle sideslopes and gradual longitudinal slopes in the direction of flow that collect and slowly convey runoff to downstream points of discharge. Grass-lined Channels provide an opportunity for infiltration, reduce peak flows from impervious areas and provide some degree of pollutant removal. Applications of Grass Swale are illustrated in Figure 3-3. Grass-lined Channels, used for the purpose of minimizing effective imperviousness, are similar to Grass Swale Filters employed as a treatment control (see Section 5, Fact Sheet T-1), but differ in terms of design depth of flow and minimum contact time.

<u>General Application and Design Considerations</u>

Grass-lined 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 Turf Buffers and are located adjacent to impervious areas to be mitigated. Their use should be incorporated into the site and master drainage planning. The contributing flow from impervious areas that can be accommodated by the Grass-lined Channels will be limited according to the design criteria in this fact sheet. Tributary areas are typically less than 5 acres. Several Grass-lined Channels may be used on a single site, each sized according to the impervious area from which it receives flow. Irrigation and regular mowing are required to maintain the turf grass cover. Grass-lined Channels are not the same as Grass Swale Filters. Consequently, Grass-lined Channels do not qualify as treatment controls and must be followed by at least one of the approved treatment controls described in Section 5.

<u>Design Criteria and Procedure</u>

Principal design criteria for Grass-lined Channels are summarized in Table 3-2 (Ref. Figure 3-3).

Table 3-2 Grass-lined Channel Design Criteria

Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.1 x $Q_{P,\ 50yr}$
Channel geometry	–	Trapezoidal or triangular
Maximum channel side slope	H:V	4 :1
Minimum slope in flow direction	%	0.2 (provide underdrains for slopes < 0.5)
Maximum slope in flow direction	%	2.0 (provide grade-control checks for slopes >2.0)
Maximum flow velocity	ft/sec	1.5 (based on Manning n = 0.05)
Maximum depth of slow at SQDF	ft.	2.0 (based on Manning n = 0.05)
Vegetation	–	Turf grass

Design procedure and application of design criteria are outlined in the following steps:

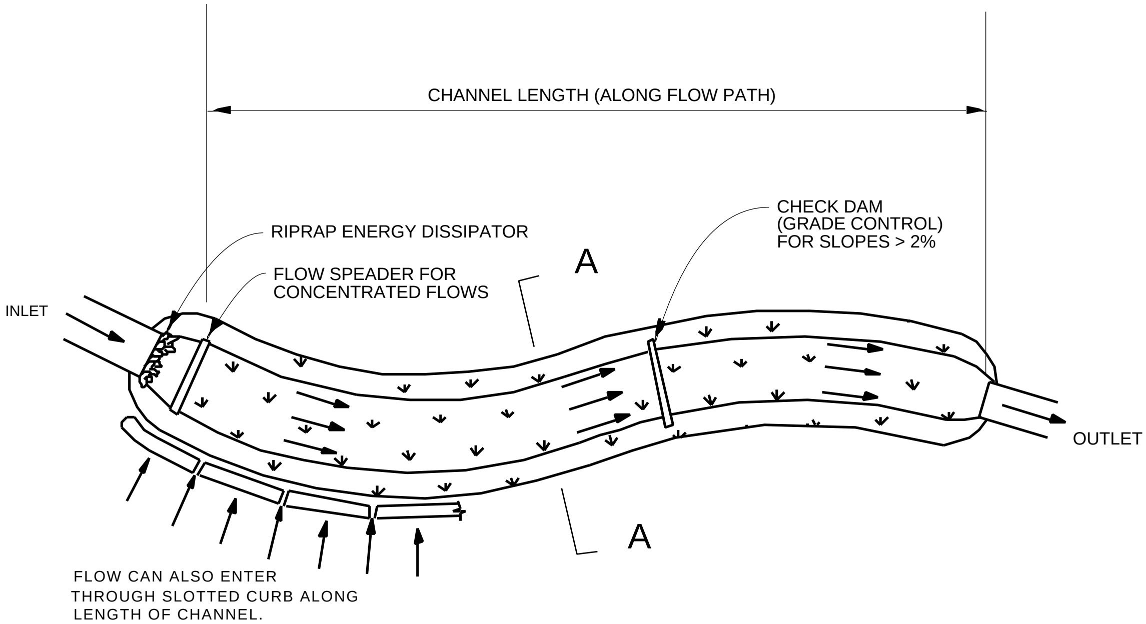
1.	Design Flow	Determine Stormwater Quality Design Flow (SQDF) for impervious area to be mitigated.

$$Q_{P,\ SQDF} = 0.1 \times Q_{P,\ 50yr} \text{ (see Fact Sheet, Section 5)}$$

2.	Channel Geometry	Use trapezoidal or triangular cross section.
3.	Maximum Side Slope	Side slopes shall not be steeper than 4:1 (5:1 or flatter preferred).
4.	Minimum Slope	Slope of the channel in the direction of flow shall not be less than 0.2 percent. Channel with slopes less than 0.5 percent should be provided with underdrains (see Figure 3-3).
5.	Maximum Slope	Slope of the channel in the direction of flow shall not be greater than 2 percent. Provide grade control checks for slopes greater than 2.0 percent (see Figure 3-3).
6.	Flow Velocity	Maximum flow velocity at design flow should not exceed 1.5 ft/sec. based on a Mannings n = 0.05.
7.	Flow Depth	Maximum depth of flow at design flow should not exceed 2.0 ft. based on a Mannings n = 0.05.
8.	Vegetation	Provide irrigated perennial turf grass to yield full, dense cover. (See Appendix F for suitable grasses).
9.	Drainage and Flood Control	Provide sufficient flow depth for flood event flows to avoid flooding of critical areas or structures.

Design Example

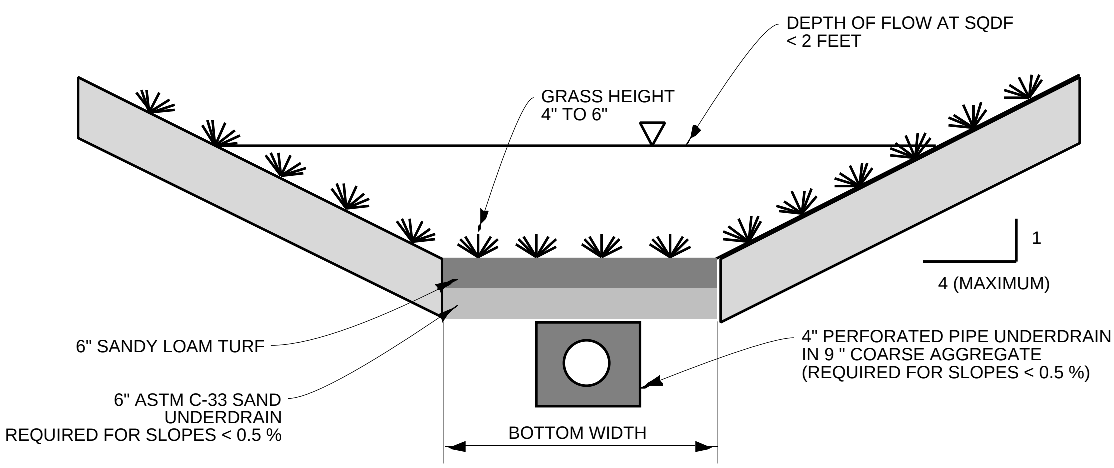
A completed design form follows as a design example. Blank design forms are provided in Appendix G.



TRAPEZOIDAL GRASS -LINED CHANNEL – PLAN

NOT TO SCALE

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



TRAPEZOIDAL GRASS-LINED CHANNEL – SECTION

NOT TO SCALE

Figure 3-3 GRASS-LINED CHANNEL

Design Procedure Form for G-5.2: Grass-lined Channel

Designer:________________________________

Company:________________________________

Date:________________________________

Project:________________________________

Location:________________________________

1. Design Flow	$Q_{P, SQDF}$ = 10.0 cfs
2. Channel Geometry	
A. Channel Bottom Width (b)	b = 20.0 ft.
B. Side slope (Z)	Z = 4:1
3. Depth of flow at SQDF (d) (2 ft max, Manning n= 0.05)	d = 1.4 ft.
4. Design Slope	
A. s = 2 percent maximum	s = 0.32 %
B. No. of grade controls required	______ (number)
6. Vegetation (describe)	Tall Fescue
7. Outflow Collection (Check type used or describe "Other")	X Grated Inlet _____ Infiltration Trench _____ Other ________

Notes ________________________________

Calculating Effective Imperviousness

The effective imperviousness of a site may be reduced if flow from impervious areas are routed over general site design controls G-5.1: Turf Buffers and/or G-5.2: Grass-lined Channels that are designed in conformance to the criteria presented in this fact sheet.

Calculation Procedure

The allowable reduction in impervious percentage is determined with the use of Figure 3-4 as described in the following steps:

1. Estimate the total imperviousness (impervious percentage) of the site by the determining the weighted average of individual areas of like imperviousness. Table 3-3 may be used as guide for estimating imperviousness of typical site elements.

Table 3-3. Recommended Percent Imperviousness for Typical Site Elements

Site Element	Percent Imperviousness
Asphalt/concrete pavement	100
Gravel pavement	40
Roofs	90
Porous pavement	35[1]
Lawn/turf	0
Open space	0

1. Variable with product type, assumes porous subsoil and use of underdrains

Table 3-4 may be used as an aid in calculating total imperviousness.

Table 3-4. Calculation Sheet for Determination of Total Imperviousness

Site Element	Unit Area (ft^2)	Percent Imperviousness	Weighting Factor[2]	Weighted % Imperviousness [3,4]
Asphalt/concrete pavement		100		
Gravel pavement		40		
Roofs		90		
Porous pavement		35[5]		
Lawn/turf		0		
Open space		0		
Total Contributing Area[1]		–	–	

1. Total contributing area = sum of unit areas
2. Weighting factor = unit area / total contributing area
3. Weighted imperviousness = weighting factor x percent imperviousness
4. Total imperviousness = sum of weighted imperviousness
5. Variable with product type, assumes porous subsoil and use of underdrains

2. Enter Figure 3-4 along the horizontal axis with the value of total imperviousness calculated in Step 1. Move vertically up Figure 3-4 until the appropriate curve (G-5.1 or G-5.2 employed individually or G-5.1 and G-5.2 employed together) is intercepted. Move horizontally across Figure 3-4 until the vertical axis is intercepted. Read the Effective Imperviousness value along the vertical axis.

   Note that if G-5.1 and/or G-5.2 are implemented on only a portion of the site, the site may be divided and effective imperviousness determined for the portion of the site for which site design controls have been implemented. The resulting effective imperviousness may be combined with total imperviousness of the remainder of the site to determine a weighted average total imperviousness for the entire site.

Calculation Example

The calculation procedure described above is illustrated by the following example.

Design Conditions:

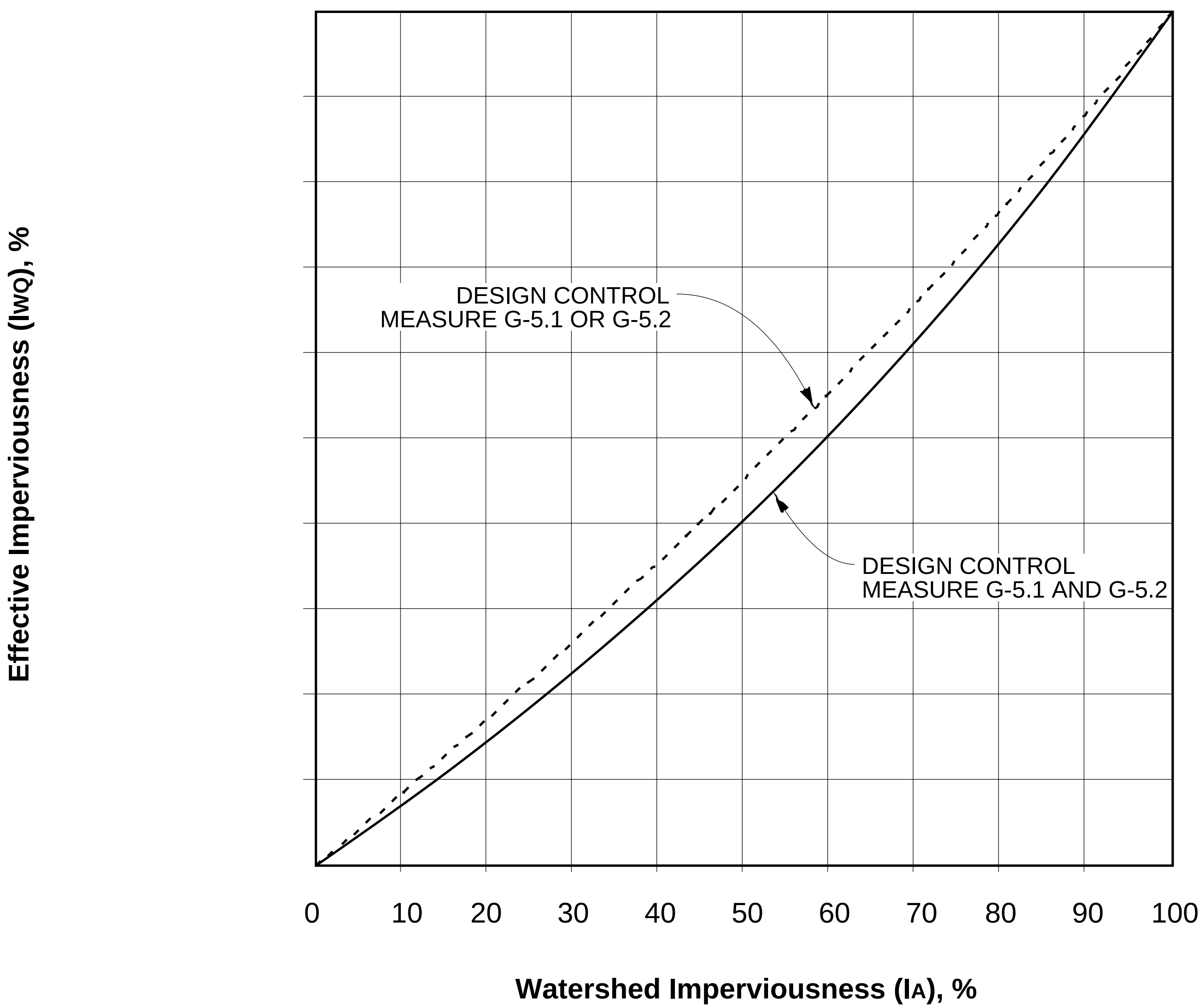
1. All flow from impervious areas is routed over a Turf Buffer (G-5.1).
2. The site consists of the site elements and associated units areas shown in Table 3-5.

Table 3-5. Example Calculation Sheet for Determination of Total Imperviousness

Site Element	Unit Area (ft^2)	Percent Imperviousness	Weighting Factor[4]	Weighted % Imperviousness [5,6]
Asphalt/concrete pavement	10,000	100	0.20	20
Gravel pavement	0	40		
Roofs	10,000	90	0.20	18
Porous pavement	0	35		
Lawn	20,000	0	0.40	0
Open space	10,000	0	0.20	0
Total Contributing Area[3]	50,000	–	–	38

Calculations:

3. Total contributing area = sum of unit areas
4. Weighting factors = unit area/total contributing area
5. Weighted imperviousness = Weighting factor x percent imperviousness
6. Total imperviousness = sum of weighted imperviousness
7. Effective imperviousness = 32 percent (from Figure 3-4)



G-5.1: TURF BUFFER
G-5.2: GRASS-LINED CHANNEL

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Figure 3-4. DETERMINATION OF EFFECTIVE IMPERVIOUSNESS

SECTION 4
SITE-SPECIFIC SOURCE CONTROL MEASURES

Introduction

Source control measures are low-technology practices designed to prevent pollutants from contacting stormwater runoff or to prevent discharge of contaminated runoff to the storm drainage system. This section addresses site-specific, structural type source control measures consisting of specific design features or elements. Non-structural type source control measures; such as good housekeeping and employee training are not included in this manual. The California Industrial Best Management Practice Manual may be consulted for this type of practice (SWQTF, 1993). The governing stormwater agency may require additional source control measures not included in this manual for specific pollutants, activities or land uses.

This section describes control measures for specific types of sites or activities that have been identified as potential significant sources of pollutants in stormwater. Each of the measures specified in this section should be implemented in conjunction with appropriate nonstructural source control measures to optimize pollution prevention.

The measures addressed in this section apply to both stormwater and non-stormwater discharges. Non-stormwater discharges are the discharge of any substance, such as cooling water, process wastewater, etc., to the storm drainage system or water body that is not composed entirely of stormwater. Stormwater that is mixed or commingled with other non-stormwater flows is considered non-stormwater. Discharges of stormwater and non-stormwater to the storm drainage system or a water body may be subject to local, state, or federal permitting prior to any discharge commencing. The appropriate agency should be contacted prior to any discharge. Discuss the matter with the stormwater staff if you are uncertain as to which agency should be contacted.

Some of the measures presented in this section require connection to the sanitary sewer system. Connection and discharge to the sanitary sewer system without prior approval or obtaining the required permits is prohibited. Contact the stormwater staff of the governing agency to obtain information regarding obtaining sanitary sewer permits from the various agencies within Ventura County. Discharges of certain types of flows to the sanitary sewer system may be cost prohibitive. The designer is urged to contact the appropriate agency prior to completing site and equipment design of the facility.

Description

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

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

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

(a) Refer to Fact Sheets in Section 4 for detailed information and design criteria

(b) SQUIMP requirements for proper design of parking lots are covered by requirements for General Site Design Control Measures (see Section 3) and Treatment Control Measures (see Section 5).

Purpose

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

Design Criteria

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

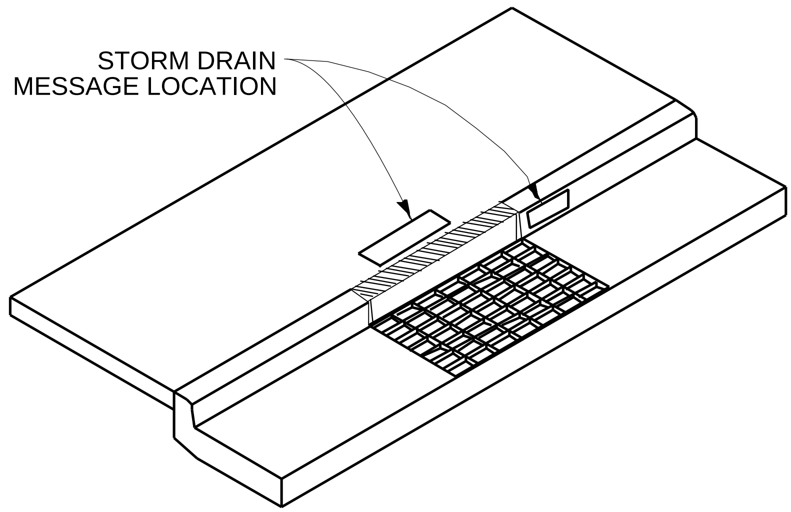
Storm drain message markers or placards are required at all storm drain inlets within the boundary of the development project. The marker should be placed in clear sight facing toward anyone approaching the inlet from either side (see Figure 4-1). All storm drain inlet locations must be identified on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

Some local agencies within the County have approved storm drain message placards for use. Consult local agency stormwater staff to determine specific requirements for placard types and methods of application.

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

Maintenance Requirements

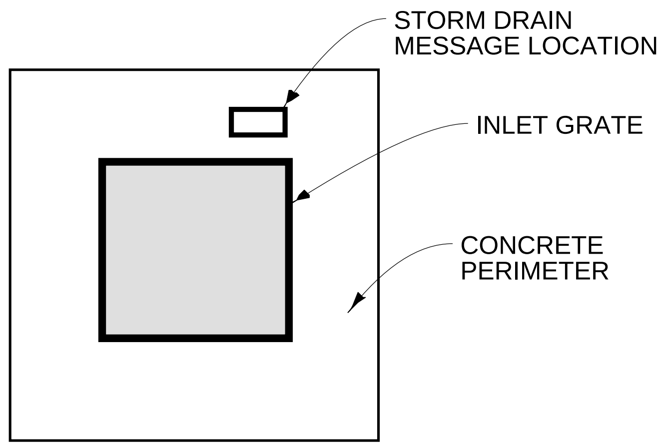
Legibility of markers and signs shall be maintained. If required by the agency with jurisdiction over the project, the owner/operator or homeowner's association shall enter into a maintenance agreement with the agency or record a deed restriction upon the property title to maintain the legibility of placards 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 LOCAL AGENCY.**



AREA TYPE INLET

FIGURE 4-1. STORM DRAIN MESSAGE LOCATION

Purpose

Materials that are stored outdoors could become sources of pollutants in stormwater runoff if not handled or stored properly. Materials could be in the form of raw products, by-products, finished products, and 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 do not have to be prevented from stormwater contact. However, these materials may have toxic effects on receiving waters if allowed to be discharged with stormwater in significant quantities. Accumulated material on an impervious surface could result in significant debris and sediment being discharged with stormwater runoff causing a significant impact on the rivers or streams that receive the runoff.

Materials may be stored in a variety of ways, including bulk piles, containers, shelving, stacking, and tanks. Stormwater contamination may be prevented by eliminating the possibility of stormwater contact with the material storage areas either through diversion, cover, or capture of the stormwater. Control measures may also include minimizing the storage area. Control measures are site specific, and must meet local agency requirements.

Design Criteria

Design requirements for material storage areas are governed by Building and Fire Codes, and by current City or County ordinances and zoning requirements. Source controls described in the 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 area when storing materials outside that will contribute significant pollutants to the storm drain.

Source Control Design Feature	Design Criteria
Surfacing	• Construct the storage area base with a material impervious to leaks and spills.
Covers	• Install a cover that extends beyond the storage area, or use a manufactured storage shed for small containers.
Grading/Containment	• Minimize the storage area. • Slope the storage area towards a dead-end sump to contain spills. • Grade or berm storage areas to prevent run-on from surrounding areas. • Direct runoff from downspouts/roofs away from storage areas.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Purpose

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 the forces of water or wind into nearby storm drain inlets, channels, and/or creeks. Waste handling operations that may be sources of stormwater pollution include dumpsters, litter control, and waste piles. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff associated with trash storage and handling.

Design Criteria

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

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

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

Source Control Design Feature	Design Criteria
Surfacing	• Construct the storage area base with a material impervious to leaks and spills.
Screens/Covers	• Install a a screen or wall around trash storage area to prevent off-site transport of loose trash. • Use lined bins or dumpsters to reduce leaking of liquid wastes. • Use water-proof lids on bins/dumpsters or provide a roof to cover enclosure (local agency discretion) to prevent rainfall from entering containers
Grading/Contouring	• Berm or grade the waste handling area to prevent runon of stormwater. • Do not locate storm drains in immediate vicinity of the trash storage area.
Signs	• Post signs on all dumpsters informing users that hazardous materials are not to be disposed of therein.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g. screens, covers and signs) must be maintained by the owner/operator. Maintenance agreements between the local agency and the owner/operator may be required. Some agencies will require maintenance deed restrictions to be recorded of the property title. If required by the local agency, maintenance agreements or deed restrictions must be executed by the owner/operator before improvement plans are approved. Refer to Appendix C and D for a further guidance regarding maintenance plans agreements.

Purpose

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

Design Criteria

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

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

Source Control Design Feature	Design Criteria
Surfacing	• Construct floor surfaces with material that is compatible with materials being handled in the loading/unloading area.
Covers	• Cover loading/unloading areas to a distance of at least 3 feet beyond the loading dock or install a seal or door skirt to be used for all material transfers between the trailer and the building.
Grading/Contouring	• Grade or berm storage areas to prevent run-on from surrounding areas. • Direct runoff from downspouts/roofs away from loading areas.
Emergency Storm Drain Seal	• Do not locate storm drains in the loading dock area. Direct connections to storm drains from depressed loading docks are prohibited. • Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces, such as depressed loading docks. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Purpose

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

Design Criteria

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

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

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

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Outdoor Vehicle/Equipment/Accessory Washing Area Design

Purpose

Washing vehicles and equipment in areas where wash water flows onto the ground can pollute storm water. 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 maintenance and repair areas are governed by Building and Fire Codes, and by current local agency ordinances, and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment washing areas. All hazardous and toxic wastes must be prevented from entering the storm drain system.

Source Control Design Feature	Design Criteria
Surfacing	• Construct the vehicle/equipment wash area floors with Portland cement concrete.
Covers	• Provide a cover that extends over the entire wash area.
Grading/Contouring	• Berm or grade the maintenance/repair area to prevent runon and runoff of stormwater or runoff of spills. • Grade or berm the wash area to contain the wash water within the covered area and direct the wash water to treatment and recycle or pretreatment and proper connection to the sanitary sewer system. Obtain approval from the governing agency before discharging to the sanitary sewer. • Direct runoff from downspouts/roofs away from wash areas. • Do not locate storm drains in the immediate vicinity of the wash area.
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Purpose

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

Design Criteria

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

Source Control Design Feature	Design Criteria
Surfacing	• Fuel dispensing areas must be paved with Portland cement concrete. The fuel dispensing area is defined as extending 6.5 feet from the corner of each fuel dispenser or the length at which the hose and nozzle assemble may be operated plus 1 foot, whichever is less. The paving around the fuel dispensing area may exceed the minimum dimensions of the "fuel dispensing area" stated above. • Use asphalt sealant to protect asphalt paved areas surrounding the fueling area.
Covers	• The fuel dispensing area must be covered[1], and the cover's minimum dimensions must be equal to or greater than the area within the grade break or the fuel dispensing area, as defined above. The cover must not drain onto the fuel dispensing area.
Grading/Contouring	• The fuel dispensing area shall have a 2% to 4% slope to prevent ponding and must be separated from the rest of the site by a grade break that prevents run-on of stormwater to the extent practicable. • Grade the fueling area to drain toward a dead-end sump. • Direct runoff from downspouts/roofs away from fueling areas. • Do not locate storm drains in the immediate vicinity of the fueling area.

1. If fueling large equipment or vehicles that would prohibit the use of covers or roofs, the fueling island should be designed to sufficiently accommodate the larger vehicles and equipment and to prevent run-on and run-off of stormwater. Grade to direct stormwater to a dead-end sump.

Source Control Design Feature	Design Criteria
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Proof of Control Measure Maintenance

Purpose

Continued effectiveness of control measures specified in this manual depend on diligent ongoing inspection and maintenance. To ensure that such maintenance is provided, the governing stormwater agency may require both a Maintenance Agreement and a Maintenance Plan from the owner/operator of stormwater control measures.

Maintenance Agreement

On-site treatment control measures are to be maintained by the owner/operator. Maintenance agreements between the governing agency and the owner/operator may be required. A Maintenance Agreement with the governing agency must be executed by the owner/operator before occupancy of the project is approved. A sample Maintenance Agreement form is provided in Appendix C.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the governing agency'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;
- Responsible party for operation and maintenance.

Additional guidelines for Maintenance Plans are provided in Appendix D.

SECTION 5

TREATMENT CONTROL MEASURES

Introduction

Treatment control measures are required to augment source controls to reduce pollution from stormwater discharges to the maximum extent practicable. 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, receiving water conditions, and state industrial permit requirements, when applicable. Land requirements, and costs to design, construct and maintain treatment control measures vary by treatment control measure.

Unlike flood control measures that are designed to handle peak flows, stormwater treatment control measures are designed to treat the more frequent, lower-flow storm events, or the first flush portions of 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. It's the flow and volume from such small events, referred to as the Stormwater Quality Design Flow (SQDF) and Stormwater Quality Design Volume (SQDV), that is targeted for treatment. There is marginal water quality benefit gained by sizing treatment facilities to handle flows or volumes greater than the SQDF or SQDV.

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

The stormwater treatment control measures specified in this section are the more common non-proprietary measures being implemented nationwide. Studies have shown these measures to be reasonably effective if properly installed and maintained. The relative effectiveness of treatment controls specified in this section for removal of pollutants of concern is shown in Table 5-1. 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 preferred and will ensure timely plan check review. Alternative technologies that provide equivalent treatment must be approved by the governing stormwater agency on a case by case basis and may result in additional time for agency review and approval, unless coordinated in advance with the agency staff.

Unless otherwise agreed to by the governing stormwater agency, the landowner, site operator, or homeowner's association is responsible for the operation and maintenance of the treatment control measures. 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 Appendix D of this Manual. The Plan must be made available at the agency's request. In addition, a maintenance agreement with the governing agency may be required. The example maintenance agreements are included in Appendix C.

In addition to maintenance, the governing agency 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 agency, or both. Monitoring may be required for a period of time to help the agency evaluate the effectiveness of treatment control measures in reducing pollutants in stormwater runoff.

Description

This section provides fact sheets for design and implementation of recommended treatment control measures. The fact sheets include siting, design, and maintenance requirements to ensure optimal performance of the measures. This manual also contains calculation fact sheets and worksheets to aid in the design of water quality treatment control measures.

Table 5-1. Effectiveness of Treatment Controls Measures for Removal of Pollutants of Concern

Pollutant of Concern	**Stormwater Treatment Control Measures[(a)]**										
	Grass Strip Filter (T-1)	Grass Swale Filter (T-2)	Extended Detention Basin (T-3)	Wet Detention Basin (T-4)	Constructed Wetland (T-4)	Detention Basin/Sand Filter (T-6)	Porous Pavement Detention (T-7)	Porous Landscape Detention (T-8)	Infiltration Basin (T-9)	Infiltration Trench (T-10)	Media Filter (T-11)
Sediment	H	M	H	H	H	H	H	H	H	H	H
Nutrients	M	L	M	M	M	M	M	M	M	M	M
Metals	M	M	M	M	M	M	M	M	M	M	M
Trash and Debris	H	H	H	H	R	R	R	R	R	R	R
Oxygen Demand	M	M	M	M	M	M	M	M	M	M	M
Toxic Organics	M	M	M	M	M	M	M	M	M	M	M
Bacteria	M	L	L	H	M	M	M	M	M	M	M

(a) = Refer to Fact Sheets in Section 5 for detailed information and design criteria
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
R = Recommended for use only downstream of other treatment controls recommend for removal of trash and debris

Calculation of Stormwater Quality Design Flow and Volume

Introduction

The primary control strategy for all of the treatment control measures specified in this Section is to treat the Stormwater Quality Design Flow (SQDF) or Stormwater Quality Design Volume (SQDV) of the storm water runoff. The following paragraphs present calculation procedures and design criteria necessary to determine the SQDF and SQDV.

The treatment control measure equations specified in this Section are listed in Table 5-2 along with the basis of design, SQDF or SQDV, to be used for the listed control measure.

Table 5-2. Sizing Criteria for Treatment Control Measures

Treatment Control Measure	Design Basis
T-1: Grass Strip Filter	SQDF
T-2: Grass Swale Filter	SQDF
T-3: Dry Detention Basin	SQDV
T-4: Wet Detention Basin	SQDV
T-5: Constructed Wetland	SQDV
T-6: Detention Basin/Sand Filter	SQDV
T-7: Porous Pavement Detention	SQDV
T-8: Porous Landscape Detention	SQDV
T-9: Infiltration Basin	SQDV
T-10: Infiltration Trench	SQDV
T-11: Media Filter	SQDV
T-12: Proprietary Control Measures	SQDV or SQDF

Contributing Impervious Area Determination

The SQDF and SQDV are calculated by determining runoff from the impervious and pervious areas of a site that are connected to the treatment control measure. Impervious areas include sidewalks, roadways, parking areas, staging areas, storage areas, slabs, roofs, and other non-vegetated areas, including compacted soil areas. Off-site areas that could run-on to a site and contribute drainage to the treatment control measure should be included in the impervious area determination. The effective imperviousness of a site can be reduced through implementation of general site design control measures (e.g. G-5.1 and G-5.2) to reduce flow from impervious areas, as described in Section 3. Procedures for calculating effective imperviousness are presented in Section 3, Fact Sheet G-5.

Stormwater Quality Design Flow (SQDF) Calculation

Hydrologic calculations for design of flow-based stormwater treatment control measures in Ventura County shall be in accordance with latest edition of the *Hydrology Manual* produced by Ventura County Public Works Agency, Flood Control Department, together with the procedure set forth herein. The designer is specifically reminded to regard minimum subarea sizes required in the *Hydrology Manual* (p. II-3). Where jurisdictions within Ventura County have approved alternative hydrologic calculation methods, the alternative methods may be utilized if they have been approved by the jurisdiction for use in design of flow-based stormwater quality BMPs. This procedure complies with Regional Board Order No. 00-108, NPDES Permit No. CAS004002, Attachment A – Ventura Countywide Stormwater Quality Urban Impact Mitigation Plan, issued July 27, 2000.

The Stormwater Quality Design Flow (SQDF) is defined to be equal to 10 percent of the peak rate of runoff flow from the 50-year storm as determined using the procedures set forth in the *Hydrology Manual*.

Calculation Procedure

1. The Stormwater Quality Design Flow (SQDF) in Ventura County is defined as $Q_{P,\ SQDF}$.

2. Calculate the peak rate of flow from the 50-year storm ($Q_{P,\ 50\ yr.}$) using the procedures set forth in the *Hydrology Manual* or as directed by the local agency Drainage Master Plan.

3. Convert $Q_{P,\ 50yr}$ (Step 2) to $Q_{P,\ SQDF}$ (Step 1).

$$Q_{P,\ SQDF} = 0.1 \text{ x } Q_{P,\ 50yr}$$

Example Stormwater Quality Design Flow Calculation

The steps below illustrate calculation of SQDF:

Step 1: SQDF = $Q_{P,\ SQDF}$

Step 2: Calculate the peak rate of flow from a 50-year storm.

$Q_{p,\ 50\ yr.}$ = 10 cfs from the *Hydrology Manual*

Step 3: Convert $Q_{p,50\ yr}$ (Step 2) to $Q_{p,\ SQDF}$ (Step 1)

$$Q_{P,\ SQDF} = 0.1 \text{ x } 10 \text{ cfs}$$

$$Q_{P,\ SQDF} = 1.0 \text{ cfs}$$

Stormwater Quality Design Volume (SQDV) Calculation

Hydrologic calculations for design of volume-based stormwater treatment controls in Ventura County shall be in accordance with the procedures set forth herein. This procedure complies with Regional Board Order No. 00-108, NPDES Permit No. CAS004002, Attachment A – Ventura Countywide Stormwater Quality Urban Impact Mitigation Plan, issued July 27, 2000.

The Stormwater Quality Design Volume (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

1. Review the area draining to the proposed treatment control measure. Determine the effective imperviousness (I_{WQ}) of the drainage area using the procedure presented in Section 3, Fact Sheet G-5.
2. Figure 5-1 provides a direct reading of Unit Basin Storage Volumes required for 80% annual capture of runoff for values of "I_{WQ}" determined in Step 1. Enter the horizontal axis of Figure 5-1 with the "I_{WQ}" value from Step 1. 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 5-1from this point until the vertical axis is intercepted. Read the Unit Basin Storage Volume along the vertical axis.

   Figure 5-1 is based on Precipitation Gage 168, Oxnard Airport. This gage has a data record of approximately 40 years of hourly readings and is maintained by Ventura County Flood Control District. Figure 5-1 is for use only in the permit area specified in Regional Board Order No. 00-108, NPDES Permit No. CAS004002.
3. The SQDV for the proposed treatment control measure is then calculated by multiplying the Unit Basin Storage Volume by the contributing drainage area. Due to the mixed units that result (e.g., acre-inches, acre-feet) it is recommended that the resulting volume be converted to cubic feet for use during design.

Example Stormwater Quality Design Volume Calculation

1. Determine the drainage area contributing to control measure, A_t. Example: 10 acres.
2. Determine the area of impervious surfaces in the drainage area, A_i. Example: 6.4 acres.
3. Calculate the percentage of impervious, $I_A = (A_i / A_t)*100$

   Example: Percent Imperviousness = $(A_i / A_t)*100$ = (6.4 acres/10 acres)*100 = 64%
4. Determine Effective Imperviousness using Figure 3-4.

   Example: G-5.1 employed → I_{WQ} = 60%
5. Determine design drawdown period for proposed control measure.

   Example: T-3:Extended Detention Basin → Drawdown period = 40 hours
6. Determine the Unit Basin Storage Volume for 80% Annual Capture, V_u using Figure 5-1.

   Example: for $I_{WQ}/100 = 0.60$ and drawdown = 40 hrs, $V_u = 0.64$ in.
7. Calculate the volume of the basin, V_b, where $V_b = V_u * A_t$.

   Example: V_b = (0.64 in)(10 ac)(ft/12 in(43,560 ft^2 / ac) = 23,232 ft^3.
8. Solution: Size the proposed control measure for 23,232 ft^3 and 40-hour drawdown.

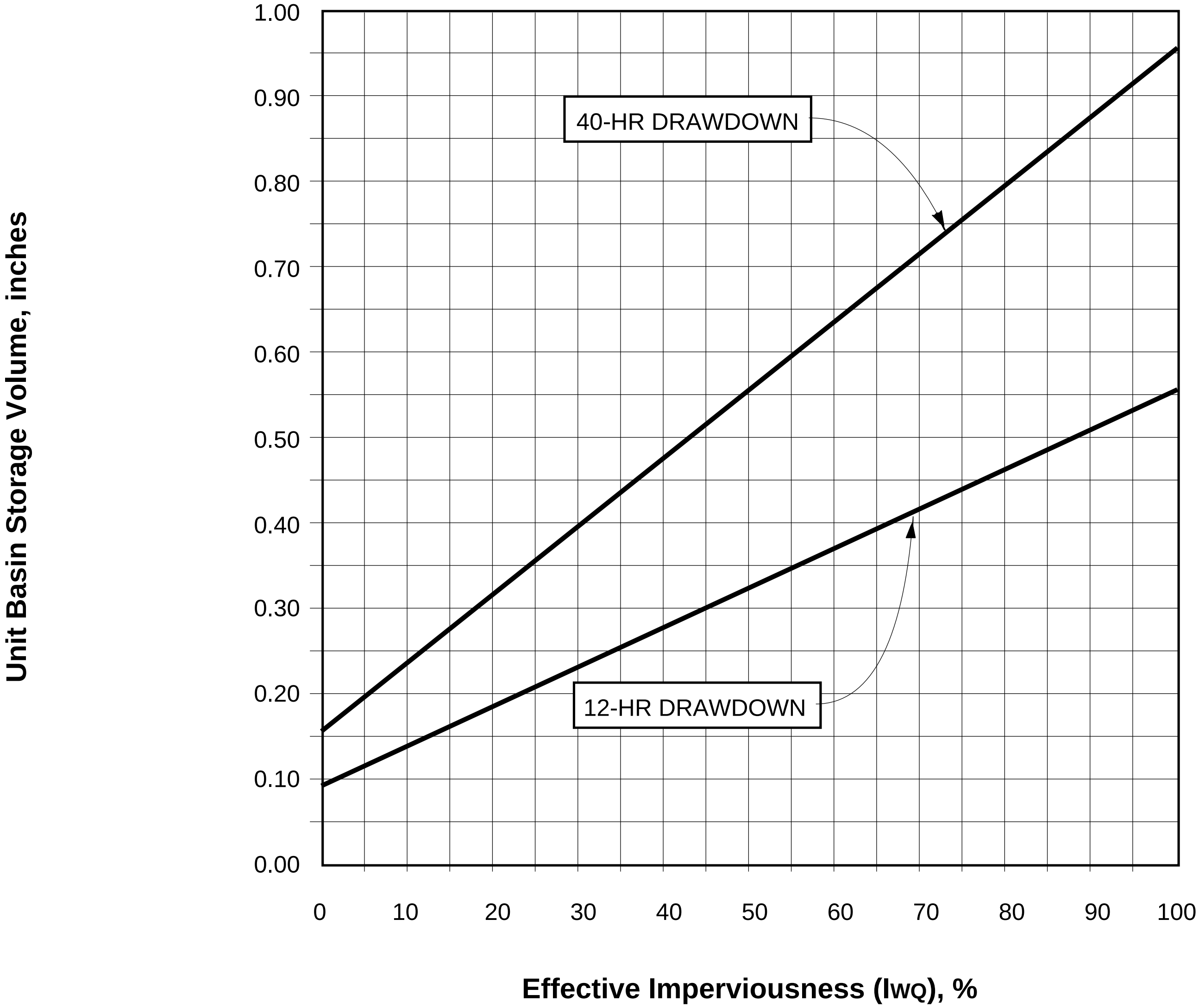


Figure 5-1. Unit Basin Storage Volume vs. Effective Imperviousness

Grass Strip Filter (GSTF)

Description

Grass Strip Filters (GSTF) are uniformly graded and densely vegetated strips of turf grass. Runoff flow to be treated is distributed uniformly across the top width of the strip to achieve sheet flow down the length of the strip. Uniform application to the top of the grass strip may be achieved by routing sheet flow from impervious areas, such as parking lots, directly to the top of the GSTF or by redistributing concentrated flow across the top of the GSTF by means of a level spreader. A GSTF is sized to treat the SQDF from the tributary area. Grass Strip Filters are essentially the same as Grass Buffers described in Fact Sheet G-5.1 in Section 3, with the only differences being design criteria for the linear rate of application along top of the strip and the length of strip in the direction of flow. Applications of GSTFs are illustrated in Figure 5-2.

General Application

Grass Strip Filters are appropriate for use in residential, commercial, industrial and institutional settings and are typically incorporated into the landscape design of the site. They are typically located adjacent to impervious areas to be mitigated. The contributing flow that can be accommodated by the GSTF will be limited according to the design criteria in this fact sheet. Tributary areas are typically less than 5 acres. Several Grass Strip Filters may be used on a single site, each sized according to the tributary area from which it receives flow. To limit the size of units when space is limited, runoff flow from pervious and off-site areas should not be routed over Grass Strip Filters. Irrigation and regular mowing are required to maintain the turf grass cover.

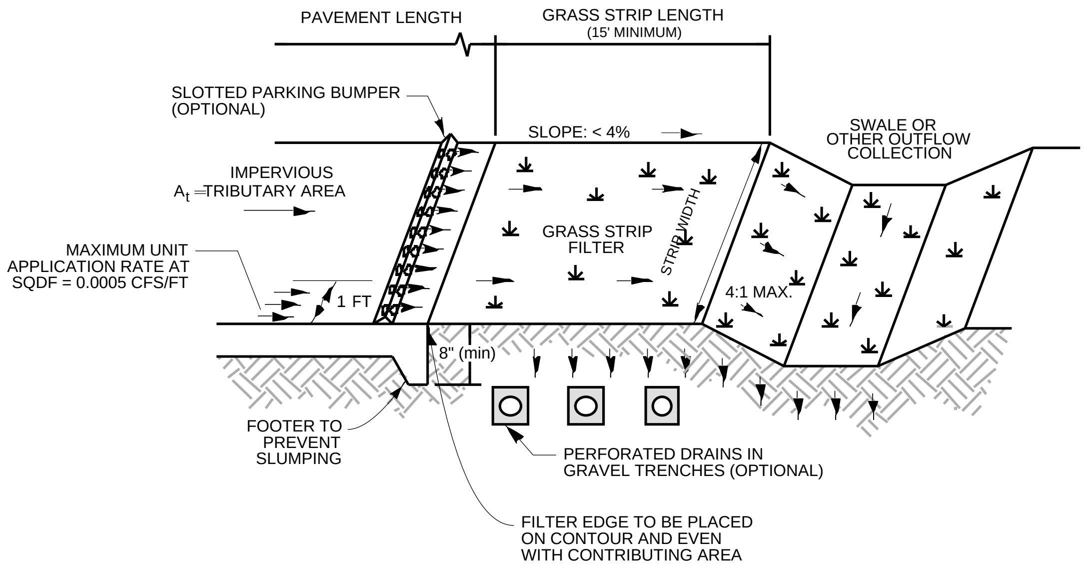
Advantages/Disadvantages

General

Grass Strip Filters are relatively easy to design, install and maintain. Vegetated areas that would normally be included in the site layout, if designed for appropriate flow patterns, may be used as Grass Strip Filters. Landscape architects can easily alter planting schemes to include appropriate turf species to meet design requirements for strips. Finally, maintaining a Grass Strip Filter often requires little more than normal landscape maintenance activities such as irrigation and mowing. Compared with some other means for improving stormwater runoff quality, GSTFs provide a relatively unobtrusive, attractive, long-term and inexpensive stormwater quality management technique. In addition to pollutant removal, GSTFs provide opportunity for infiltration of runoff and reduce peak flows.

Site Suitability

After final grading the site should have a uniform slope and be capable of maintaining sheet flow conditions. Grass Strip Filters should be located away from or protected from excessive pedestrian or vehicular traffic that can damage the grass cover and affect achievement of sheet flow over the surface.



SHEET FLOW CONTROL

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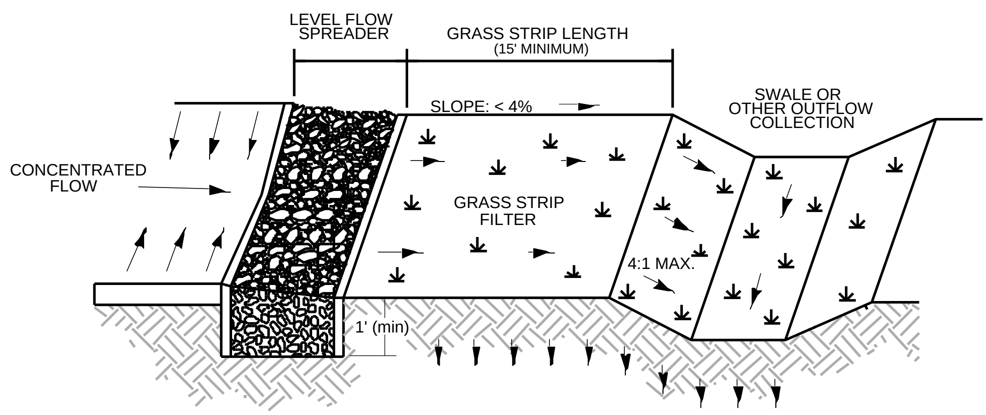

CONCENTRATED FLOW CONTROL

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Figure 5-2 GRASS STRIP FILTER

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

Pollutant Removal

Relative pollutant removal effectiveness of a GSTF is presented in Table 5-1. Removal effectiveness of GSTF for sediment and particulate forms of metals, nutrients and other pollutants is considered high to moderate. Grass Strip Filters are particularly effective when used as an upstream control measure in combination with grass swale filters, sand filters, and infiltration control measures.

Design Criteria and Procedure

Principal design criteria for GSTFs are listed in Table 5-3.

Table 5-3. Grass Strip Filter Design Criteria

Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.1 x $Q_{P,\ 50yr}$
Maximum linear unit application rate (q_a)	cfs/ft • width	0.005
Minimum width (normal to flow) (W_{GSTF})	ft	(SQDF) / (q_a)
Minimum length (flow direction) (L_{GSTF})	ft	15
Maximum slope (flow direction)	%	4
Vegetation	–	Turf grass (irrigated) or approved equal
Minimum grass height	inches	2
Maximum grass height	inches	4 (typical) or as required to prevent lodging or shading

Design procedure and application of design criteria are outlined in the following steps:

1. Design Flow — Determine Stormwater Quality Design Flow (SQDF) for impervious area to be mitigated.

   $Q_{P,\ SQDF} = 0.1 \times Q_{P,\ 50yr}$ (see Fact Sheet, Section 5)

2. Minimum Width — Calculate minimum width of the Grass Strip Filter (W_{GSTF}) normal to flow direction.

   W_{GSTF} = (SQDF) / (q_a)

   W_{GSTF} = (SQDF) / 0.005 cfs/ft (minimum)

3. Minimum Length — Length of the Grass Strip Filter (L_{GSTF}) in the direction of flow shall not be less than 15 feet.

   L_{GSTF} = 15 feet (minimum)

4. Maximum Slope — Slope of the ground in the direction of flow shall not be greater than 4 percent.

5. Flow Distribution	Incorporate a device at the upstream end of the GSTF to evenly distribute flows along the top width, such as slotted curbing, modular block porous pavement, or other spreader devices. Concentrated flow delivered to the GSTF must distributed evenly by means of a level spreader of similar concept.
6. Vegetation	Provide irrigated perennial turf grass to yield full, dense cover. (See Appendix F for suitable grasses). Note: Some local agencies have restrictions on use of irrigated turf grass; consult with local agency regarding selection of appropriate vegetation. Submit a Landscape Plan for stormwater agency review. Plan shall be prepared by a landscape or other appropriate specialist and shall include a site plan showing location and type of vegetation. Mow grass to maintain height approximately between 2 and 4 inches.
7. Outflow Collection	Provide a means for outflow collection and conveyance (e.g. grass channel/swale, storm sewer, street gutter)

Design Example

A completed design form follows as a design example. Blank design forms are provided in Appendix G.

Design Procedure Form for T-1: Grass Strip Filter (GSTF)

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Design Flow	$Q_{P, SQDF}$ = 0.5 cfs
2. Design Width W_{GSTF} = (SQDF) / 0.005 cfs/ft	W_{GSTF} = 100.0 ft.
3. Design Length (15 ft minimum)	L_{GSTF} = 15.0 ft.
4. Design Slope (4 percent maximum)	S_{GSTF} = 3.0 %
5. Flow Distribution (Check type used or describe "Other")	__X__ Slotted curbing _____ Modular Block Porous Pavement _____ Level Spreader _____ Other ____________________
6. Vegetation (describe)	Tall Fescue
7. Outflow Collection (Check type used or describe "Other")	_____ Grass Swale __X__ Street Gutter _____ Storm Sewer _____ Underdrain Used _____ Other ____________________

Notes ____

Construction Considerations

Scheduling

Grass Strip Filters should be established and operational by October 1, unless another schedule has been justified in the Landscape Plan and approved by the local agency. To meet the October 1 deadline, the following schedule must be met:

- Seeding should be conducted during the dry season, no later than September 1 to ensure sufficient vegetation by October 1. Irrigation may be required.
- Within 30 days of seeding, or by September 30, whichever is earlier, the site shall be inspected to determine adequacy of vegetation growth, and to determine if erosion or damage has occurred. Areas of damage shall be repaired, seeded, and mulched immediately.
- If vegetation growth is insufficient, or excessive damage or erosion has occurred, the site will be further stabilized with other appropriate erosion control measures such as matting, mulching, etc. If the site can not be adequately stabilized prior to October 1, temporary measures must be installed to divert storm flows around the GSTF until adequate vegetation and stabilization occurs.

During Construction

All construction activity BMPs must remain in place to prevent high sediment loads into the GSTF, if active construction is being conducted upstream of the GSTF. If necessary additional BMPs must be installed.

Post Construction

After all construction activities are complete, necessary temporary BMPs to protect the integrity of the GSTF shall be installed, if necessary, until:

- the drainage area for the GSTF is adequately stabilized,
- vegetation in the GSTF is adequately established, and
- the GSTF maintenance plan is fully implemented.

Maintenance Requirements

To provide optimum treatment, Grass Strip Filters need to be regularly maintained to ensure a dense vegetation growth, and to prevent erosion of the underlying soils.

Maintenance Agreement

Treatment controls are to be maintained by the owner/operator. Maintenance agreement between the owner/operator of the Grass Strip Filters and the local agency may be required. (See Appendix C for example maintenance agreement)

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the local agency's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format:

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

Maintenance Activities

At a minimum the following activities must occur to properly maintain a GSTF:

- Mow regularly to maintain vegetation height between 2 and approximately 4 inches, and to promote thick, dense vegetative growth. Clippings are to be removed immediately after mowing.
- Regularly maintain the GSTF to remove all litter, branches, rocks, or other debris. Damaged areas of the filter strip should be repaired immediately by reseeding and applying mulch.
- Remove all accumulated sediment that may obstruct flow through the GSTF. Replace the grass areas damaged in the process.
- Regularly maintain inlet flow spreader.
- Irrigate GSTF during dry season (April through October) when necessary to maintain the vegetation.
- After installing, inspect GSTF after seeding and after major storms. Repair all damage immediately.
- Once the GSTF is established, inspect at least three times per year. Repair all damage immediately.

Grass Swale Filter (GSWF)

Description

Grass Swale Filters (GSWF) are densely vegetated (turf grass) drainageways with gentle sideslopes and gradual slopes in the direction of flow that collect and slowly convey runoff flow to downstream points of discharge. Berms or check dams may be installed perpendicular to flow to provide grade control in steeper slopped areas. Underdrains may be installed at sites with very gradual slopes to avoid standing water. A GSWF is sized to treat the SQDF from the tributary area. Grass Swale Filters are similar to Grass-lined Channels described in Fact Sheet G-5.2 in Section 3, with the only differences being design criteria for hydraulic design parameters (e.g. flow depth, friction factor, and contact time.) Grass Swale Filters require shallower flow depths and longer contact times to provide treatment. Applications of GSWFs are illustrated in Figure 5-3.

General Application

Grass Swale Filters are appropriate for use in residential, commercial, industrial and institutional settings and are typically incorporated into the landscape design of the site. They are often used in conjunction with Turf Buffers or GSTFs to provide effluent collection and conveyance as well as treatment. The contributing flow that can be accommodated by the GSWF will be limited according to the design criteria in this fact sheet. Tributary areas are typically less than 5 acres. Several Grass Swale Filters may be used on a single site, each sized according to the tributary area from which it receives flow. To limit the size of units when space is limited, runoff flow from pervious and off-site areas should not be routed to Grass Swale Filters. Irrigation and regular mowing are required to maintain the turf grass cover.

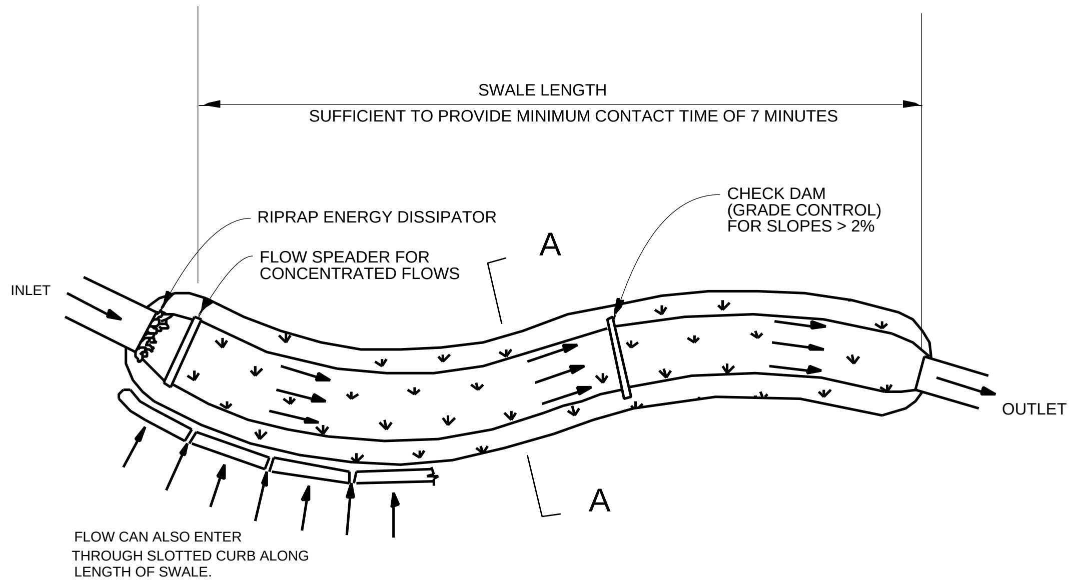
Advantages/Disadvantages

General

Like Grass Strip Filters, Grass Swale Filters are relatively easy to design, install and maintain. Vegetated areas that would normally be included in the site layout, if designed for appropriate flow patterns, may be used as Grass Swale Filters. Landscape architects can easily alter planting schemes to include appropriate turf species to meet design requirements for swales. Finally, maintaining a GSWF often requires little more than normal landscape maintenance activities such as irrigation and mowing. Compared with some other means for improving stormwater runoff quality, grass filters provide a relatively unobtrusive, attractive, long-term and inexpensive stormwater quality management technique. In addition to pollutant removal, GSWFs provide opportunity for infiltration of runoff and reduce peak flows.

Site Suitability

Grass Swale Filters are not practical for sites with slopes greater than about 4 percent. Underdrains are recommended for design slopes less than 0.5 percent when soils types C or D (see Appendix E) are present.



TRAPEZOIDAL GRASS SWALE PLAN

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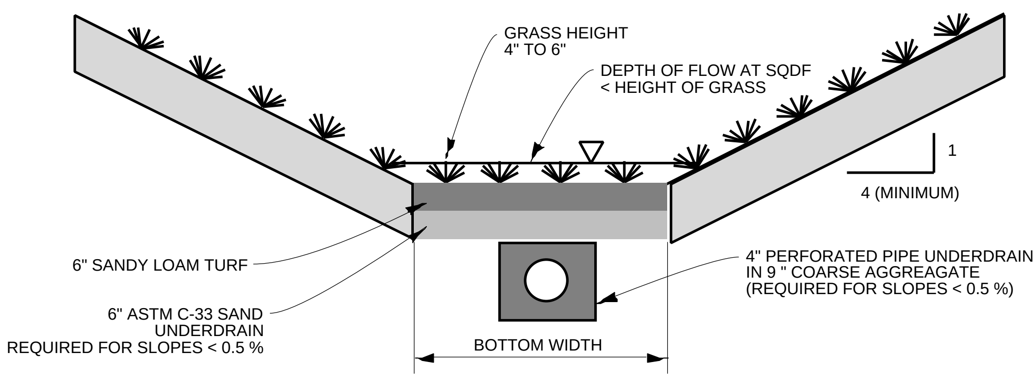

TRAPEZOIDAL GRASS SWALE SECTION

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VOL. 3 - BEST MANAGEMENT PRACTICES,
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT,11/99

Figure 5-3 GRASS SWALE FILTER

Pollutant Removal

Relative pollutant removal effectiveness of a GSWF is presented in Table 5-1. Removal effectiveness of GSWF for sediment and particulate forms of metals, nutrients and other pollutants is considered moderate to low. Grass Swale Filters are the least effective of the approved treatment control measures. Consequently, they should generally be used in conjunction with one of the other approved treatment control measures.

Design Criteria and Procedure

Principal design criteria for GSWFs are listed in Table 5-4.

Table 5-4. Grass Swale Filter Design Criteria

Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.1 x $Q_{P,\ 50yr}$
Swale geometry	–	Trapezoidal or triangular
Maximum channel side slope	H:V	4 :1
Minimum slope in flow direction	%	0.2 (provide underdrains for slopes < 0.5)
Maximum slope in flow direction	%	2.0 (provide grade-control checks for slopes >2.0)
Maximum flow velocity	ft/sec	1.0 (based on Manning n = 0.20)
Maximum depth of flow at SQDF	inches	3 to 5 (1 inch below top of grass)
Minimum contact time	minutes	7 (provide sufficient length to yield min contact time)
Minimum length	ft	sufficient length to provide minimum contact time
Vegetation	–	Turf grass or approved equal
Grass height	Inches	4 to 6 (mow to maintain height)

Design procedure and application of design criteria are outlined in the following steps:

1.	Design Flow	Determine Stormwater Quality Design Flow (SQDF) for impervious area to be mitigated. $Q_{P,\ SQDF} = 0.1 \times Q_{P,\ 50yr}$ (see Fact Sheet, Section 5)
2.	Swale Geometry	Use tapezoidal or triangular cross section.
3.	Maximum Side Slope	Side slopes shall not be steeper than 4:1 (5:1 or flatter preferred).
4.	Minimum Slope	Slope of the swale in the direction of flow shall not be less than 0.2 percent. Swales with slopes less than 0.5 percent should be provided with underdrains (see Figure 5-3).
5.	Maximum Slope	Slope of the swale in the direction of flow shall not be greater than 2 percent. Provide grade control checks for slopes greater than 2.0 percent (see Figure 5-3).
6.	Flow Velocity	Maximum flow velocity at design flow should not exceed 1.0 ft/sec. based on a Mannings n = 0.20.
7.	Flow Depth	Maximum depth of flow at design flow should not exceed 3 to 5 inches based on a Mannings n = 0.20
8.	Swale Length	Provide length in the flow direction sufficient to yield a minimum contact time of 7 minutes at SQDF. L = (7 min) x (flow velocity, ft/sec) x 60 sec/min
9.	Vegetation	Provide irrigated perennial turf grass to yield full, dense cover. (See Appendix F for suitable grasses) Note: Some local agencies have restrictions on use of irrigated turf grass; consult with local agency regarding selection of appropriate vegetation. Mow to maintain height of 4 to 6 inches.
10.	Drainage and Flood Control	Provide sufficient flow depth for flood event flows to avoid flooding of critical areas or structures

Design Example

A completed design form follows as a design example. Blank design forms are provided in Appendix G.

Design Procedure Form for T-2: Grass Swale Filter (GSWF)

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Design Flow	$Q_{P, SQDF}$ = 1.0 cfs
2. Swale Geometry a. Swale Bottom Width (b) b. Side slope (Z)	 b = 10.0 ft. Z = 4:1
3. Depth of flow at SQDF (d) (2 ft max, Manning n= 0.20)	d = 4.2 inches
4. Design Slope a. s = 4 percent maximum b. No. of grade controls required	 s = 0.5 % ________ (number)
5. Design flow velocity (Manning n= 0.20)	V = 0.25 ft/sec
6. Design Length L = (7 min) x (flow velocity, ft/sec) x 60	 L = 103 feet
6. Vegetation (describe)	Tall Fescue
7. Outflow Collection (Check type used or describe "Other")	__X__ Grated Inlet _____ Infiltration Trench _____ Underdrain Used _____ Other __________

Notes ____

Construction Considerations

Scheduling

Grass Swale Filters should be established and operational by October 1, unless another schedule has been justified in the Landscape Plan and approved by the local agency. To meet the October 1 deadline, the following schedule must be met:

- Seeding should be conducted during the dry season, no later than September 1 to ensure sufficient vegetation by October 1. Irrigation may be required.
- Within 30 days of seeding, or by September 30, whichever is earlier, the site shall be inspected to determine adequacy of vegetation growth, and to determine if erosion or damage has occurred. Areas of damage shall be repaired, seeded, and mulched immediately.
- If vegetation growth is insufficient, or excessive damage or erosion has occurred, the site should be further stabilized with other appropriate erosion control measures such as matting, mulching, etc. If the site can not be adequately stabilized prior to October 1, temporary measures must be installed to divert storm flows around the swale until adequate vegetation and stabilization occurs.

During Construction

All construction activity BMPs must remain in place to prevent high sediment loads into the GSWF, if active construction is being conducted upstream of the GSWF. If necessary additional BMPs must be installed.

Post Construction

After all construction activities are complete, temporary BMPs to protect the integrity of the GSWF shall be installed, if necessary, until:

- the drainage area for the GSWF is adequately stabilized,
- vegetation in the GSWF is adequately established, and
- the GSWF maintenance plan is fully implemented.

Maintenance Requirements

To provide optimum treatment, Grass Swale Filters need to be regularly maintained to ensure a dense vegetation growth, and to prevent erosion of the underlying soils.

Maintenance Agreement

Treatment controls are to be maintained by the owner/operator. Maintenance agreement between the owner/operator of the Grass Swale Filters and the local agency may be required. (See Appendix C for example maintenance agreement.)

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the local agency's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format:

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

Maintenance Activities

At a minimum the following activities must occur to properly maintain a GSWF:

- Mow regularly to maintain vegetation height between 4 and approximately 6 inches, and to promote thick, dense vegetative growth. Clippings are to be removed immediately after mowing.
- Regularly maintain the GSWF to remove all litter, branches, rocks, or other debris. Damaged areas of the filter strip should be repaired immediately by reseeding and applying mulch.
- Remove all accumulated sediment that may obstruct flow through the GSWF. Replace the grass areas damaged in the process.
- Regularly maintain inlet flow spreader (if applicable).
- Irrigate GSWF during dry season (April through October) when necessary to maintain the vegetation.
- After installing, inspect GSWF after seeding and after major storms. Repair all damage immediately.
- Once the GSWF is established, inspect at least three times per year. Repair all damage immediately.

Description

Extended detention basins (EDB) are permanent basins formed by excavation and/or construction of embankments to temporarily detain the Stormwater Quality Design Volume (SQDV) of stormwater runoff to allow sedimentation of particulates to occur before the runoff is discharged. Extended detention basins are typically dry between storms, although a shallow pool, 1 to 3 feet deep, can be included in the design for aesthetic purposes and to promote biological uptake and conversion of pollutants. A bottom outlet provides controlled slow release of the detained runoff over a specified time period (40 hours for SQDV). The basic elements of an extended detention basin are shown in Figure 5-4. This configuration is most appropriate for large sites.

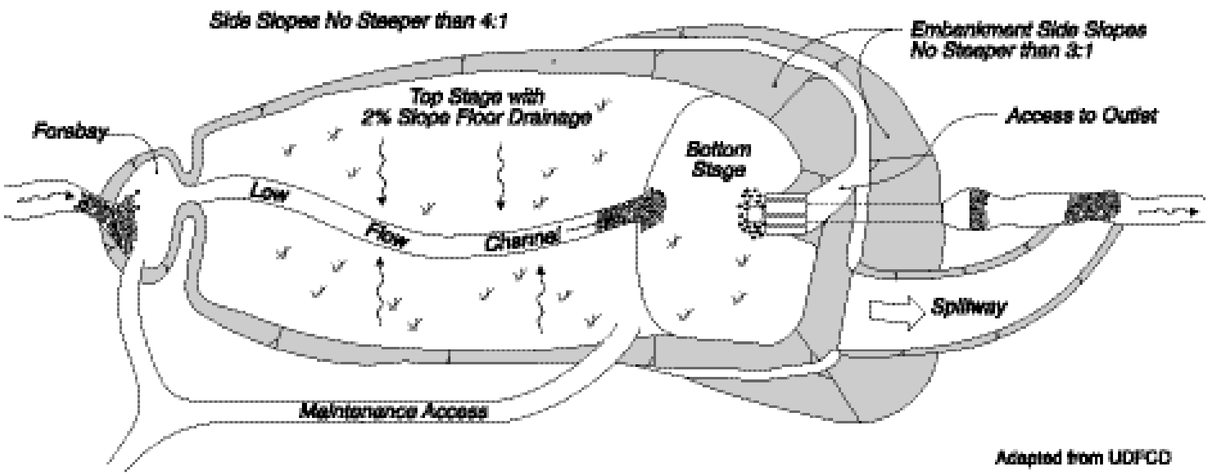
Surface basins are typical, but underground vaults may be appropriate in a small commercial development. Where irrigation water is available, basins should be vegetated to protect the basin slopes and bottom from erosion. To minimize erosion from inlet flow, basins are to be designed with an inlet energy dissipator and an inlet forebay section divided from the main basin by a secondary berm. The bottom of the basin is sloped toward the outlet end at a grade of approximately two percent. A low flow channel is provided to convey incidental flows directly to the outlet end of the basin.

EDBs are sized to detain and release the SQDV. Storm volumes greater than the SQDV are passed through the basin by means of a secondary outlet or spillway. Outlets are designed to include erosion protection.

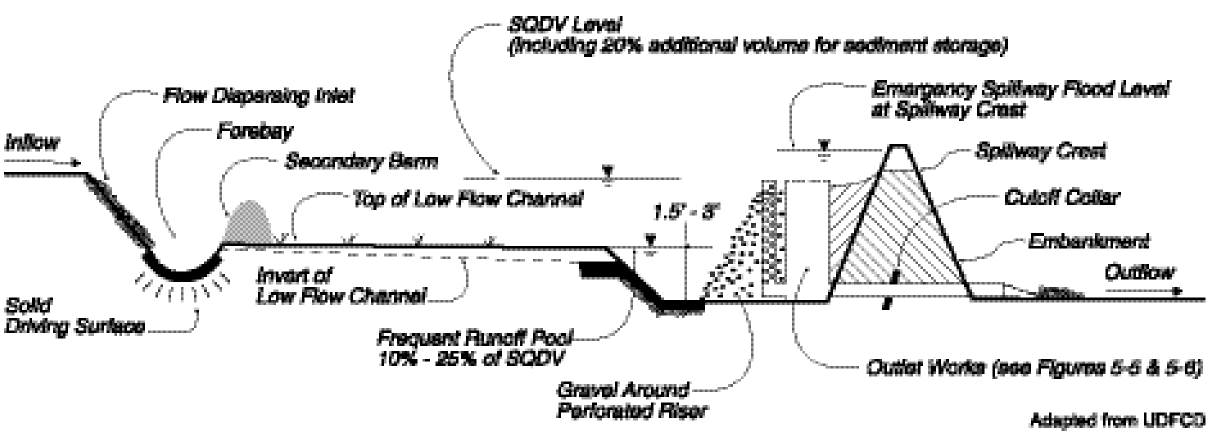
General Application

An EDB serves to reduce peak stormwater runoff rates, as well as provide treatment of stormwater runoff. If the basins are constructed early in the development cycle, they can also serve as sediment traps during construction within the tributary area. However, accumulated sediment must be removed after construction activities are complete and before the basin is placed into final long-term use as an EDB. Basins may be designed as dual-use facilities to provide recreational use during the dry season, and can be designed into flood control basins or sometimes retrofitted into existing flood control basins. EDBs that are intended to serve as a flood control basin, as well as a stormwater treatment control measure, must also be designed in accordance with applicable flood control design standards.

EDBs can serve essentially any size tributary area from an individual commercial development to a large residential or regional area, but are typically used for tributary areas greater than 10 acres. They work well in conjunction with other control measures, such as onsite source controls and downstream infiltration basins.



Plan View



Section View

Figure 5-4. Extended Detention Basin Conceptual Layout

Advantages/Disadvantages

General

EDBs may be designed to provide other benefits such as recreation, wildlife habitat, and open space. Safety issues must be address through proper design.

Site Suitability

Space requirements for EDBs are significant. Land requirements for EDBs typically range from approximately 0.5 to 2.0 percent of the of the tributary development area. Groundwater levels must be considered during site evaluation and design. Vector and vegetation control problems can develop when the seasonal high ground water level is above the basin bottom elevation.

Pollutant Removal

Relative pollutant removal effectiveness of an EDB is presented in Table 5-1. Removal effectiveness of EDBs for sediment and particulate forms of metals, nutrients and other pollutants is considered high to moderate. Removal effectiveness for dissolved pollutants is considered low. EDBs may be used upstream of control measures that are more effective at removing soluble pollutants, such as infiltration basins, filters or wetlands.

Design Criteria and Procedure

Principal design criteria for EDBs are listed in Table 5-5.

Table 5-5. Extended Detention Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV / 50% SQDV	hrs	40 / 12 (minimum)
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 40-h drawdown
Basin design volume	acre-ft	1.2 x SQDV (privide 20% sediment storage volume)
Inlet/outlet erosion control	–	Energy dissipator to reduce inlet/outlet velocity
Forebay volume/ drain time	%/min.	5 to 15 % of SQDV / Drain time < 45 minutes
Low-flow channel depth/ flow capacity	in/–	9 / 2 x forebay outlet rate
Bottom slope of upper stage	%	2.0
Length to width ratio (minimum)	–	2:1 (larger preferred)
Upper stage depth/width (minimum)	ft	2.0/30
Bottom stage volume	%	10 to 25 % of SQDV
Bottom stage depth	ft	1.5 to 3 ft deeper than top stage
Freeboard (minimum)	ft	1.0
Embankment side slope (H:V)	–	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete

Design procedure and application of design criteria are outlined in the following steps:

a) Basin Storage Volume

Provide a storage volume equal to 120 percent of the SQDV, based on a 40-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin. The additional 20 percent provides an allowance for sediment accumulation.

a. Determine the percent imperviousness of the tributary area (I_a).

b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from Step 1.b.

d. Calculate the SQDV in acre-ft as follows:

$$SQDV = (V_u / 12) \times Area$$

where

Area = Watershed area tributary to EDB in acre-ft

e. Calculate Design Volume in acre-ft as follows:

$$Design\ Volume = SQDV \times 1.2$$

where

1.2 factor = Multiplier to provide for sediment accumulation

2. Outlet Works

The Outlet Works are to be designed to release the SQDV (i.e. not Design Volume) over a 40-hour period, with no more than 50 percent released in 12 hours. Refer to Figures 5-5 and 5-6 for schematics pertaining to structure geometry; grates, trash racks, and screens; outlet type: orifice plate or perforated riser pipe.

a. For perforated pipe outlets or vertical plates with multiple orifices (see Figure 5-5), use the following equation to determine required area per row of perforations, based on the SQDV(ft^2) and depth of water above the centerline of the bottom perforation D_{BS} (ft).

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

where

$$K_{40} = 0.013D_{BS}^2 + 0.22D_{BS} - 0.10$$

Select appropriate perforation diameter and number of perforations per row (i.e. 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:

$$nr = 1 + (D_{BS} X 3)$$

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

Total orifice area = area/row x nr

b. For single orifice outlet control or single row of orifices at the basin bottom surface elevation (see Figures 5-6), use the following equation based on the SQDV (ft^3) and depth of water above orifice centerline D_{BS} (ft) to determine total orifice area (in^2):

$$\text{Total orifice area} = (SQDV) \div [(60.19)(D_{BS}^{0.5})(T)]$$

where

T = drawdown period (hrs)= 40 hrs

3. 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.

4. Basin Shape

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

5. Two-Stage Design

A two-stage design with 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 ft.

b. Bottom Stage: The active storage basin of the bottom stage should be 1.5 to 3 feet deeper than the top stage and store 10 to 25 pecent of the SQDV. A mico-pool below the active storage volume of the bottom stage, if provided, should be one-half the depth of the top stage or 2 feet, which ever is greater.

6. Forebay Design

The forebay provides a location for sedimentation of larger particles that has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The forebay volume should be 5 to 10 percent of the SQDV. A berm should separate the forebay from the upper stage of the basin. The outlet pipe from

	be 5 to 10 percent of the SQDV. A berm should separate the forebay from the upper stage of the basin. The outlet pipe from the forebay to the lowflow 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.
7. 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.
8. Inlet/Outlet Design	Basin inlet and outlet points should be provided with an energy dissipation structure and/or erosion protection.
9. 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.
10. Embankment	Design embankments to conform to requirements State of California Division of Safety of Dams, 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.
11. Access	All-weather access to the bottom, forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.
12. 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 Ventura County Flood Control District.
13. Geotextile Fabric	Non-woven geotextile fabric used in conjunction with gravel packs around perforated risers shall conform the specifications listed in Table 5-6.

Table 5-6. 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
Permitivity	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.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-3: Extended Detention Basin

Designer:____

Company:____

Date:____

Project:____

Location:____

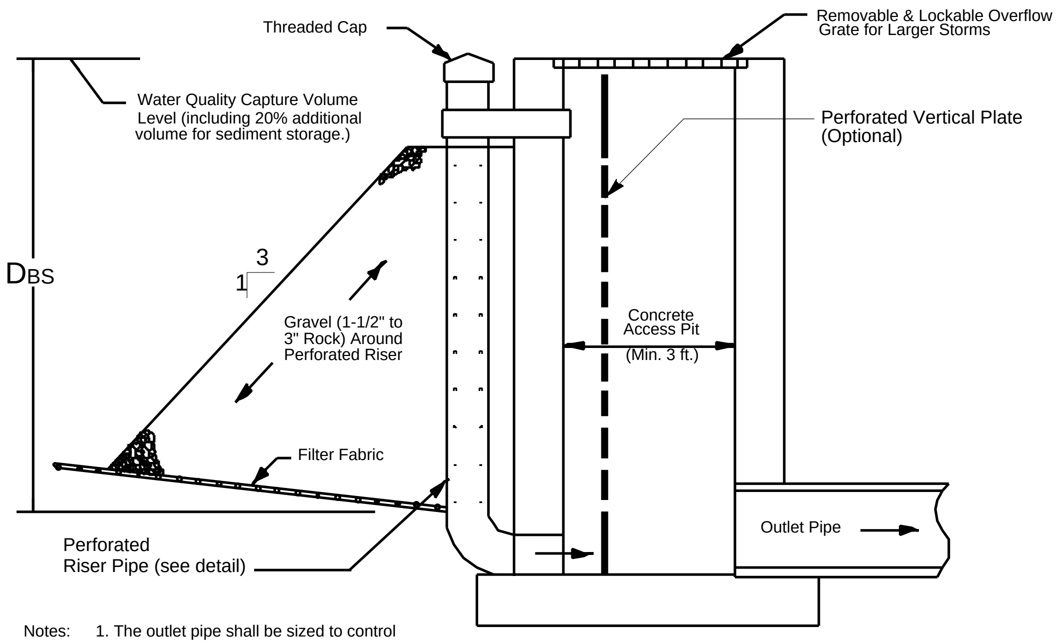
1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	64	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	60	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	0.64	in.
d. Watershed Area Tributary to EDB	Area =	10	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	0.54	acre-ft
f. Calculate Design Volume Design Volume = SQDV x 1.2	Design Volume =	0.64	acre-ft
2. Outlet Works			
a. Outlet Type (check one)	Single Orifice	X	
	Multi-orifice Plate	____	
	Perforated Pipe	____	
	Other	____	
b. Depth of water above bottom orifice	Depth =	3	feet
c. Single Orifice Outlet			
1) Total Area	A =	5.64	square inches
2) Diameter or W x L	D =	2 x 2.8	inches
d. Multiple Orifice Outlet			
1) Area per row of perforations	A =	____	
2) Perforation Diameter (2 inches max.)	D =	____	
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 =	____	

Design Procedure Form for T-3: Extended Detention Basin (Page 2 of 2)

Project:____

3. Trash Rack or Gravel Pack (check one)	Trash Rack **X**	Gravel Pack____	
4. Basin Length-Width Ratio (2:1 minimum)	Ratio =	3:1	L:W
5. Two-Stage Design			
a. Upper Stage			
1) Depth (2 feet minimum)	Depth =	3	feet
2) Width (30 feet minimum)	Width =	40	feet
3) Bottom Slope (2% to low flow channel)	Slope =	2	%
b. Bottom Stage			
1) Depth (1.5 to 3 feet deeper than Upper)	Depth =	5	feet
2) Storage Volume (5-15% of SQDV min.)	Volume =	0.12	acre-ft
6. Forebay Design			
a. Forebay Volume (5-10% of SQDV min.)	Volume =	0.03	acre-ft
b. Outlet pipe drainage time (~45 minutes)	Drainage Time	45	minutes
7. Low Flow Channel			
a. Depth (9 inches min.)	Depth =	2.0	feet
b. Flow Capacity (2 x outlet for Forebay)	Flow Capacity =	60 cfs	cfs
8. Vegetation	Native Grasses	________	
	Irrigated Turf	**X**	
	Other	________	
9. Embankment			
a. Interior Slope (4:1 max.)	Interior Slope =	4:1	H/V
b. Exterior Slope (3:1 max.)	Exterior Slope =	3:1	H/V
10. Access			
a. Slope (10% max.)	Slope =	9	%
b. Width (16 feet min.)	Width =	16	feet

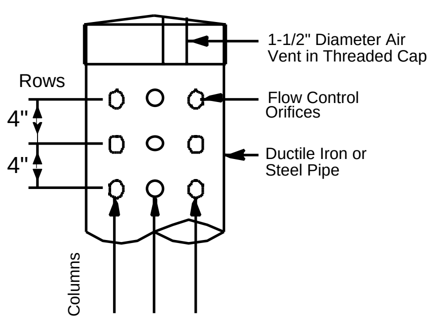
Notes: ____



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

OUTLET WORKS
NOT TO SCALE

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



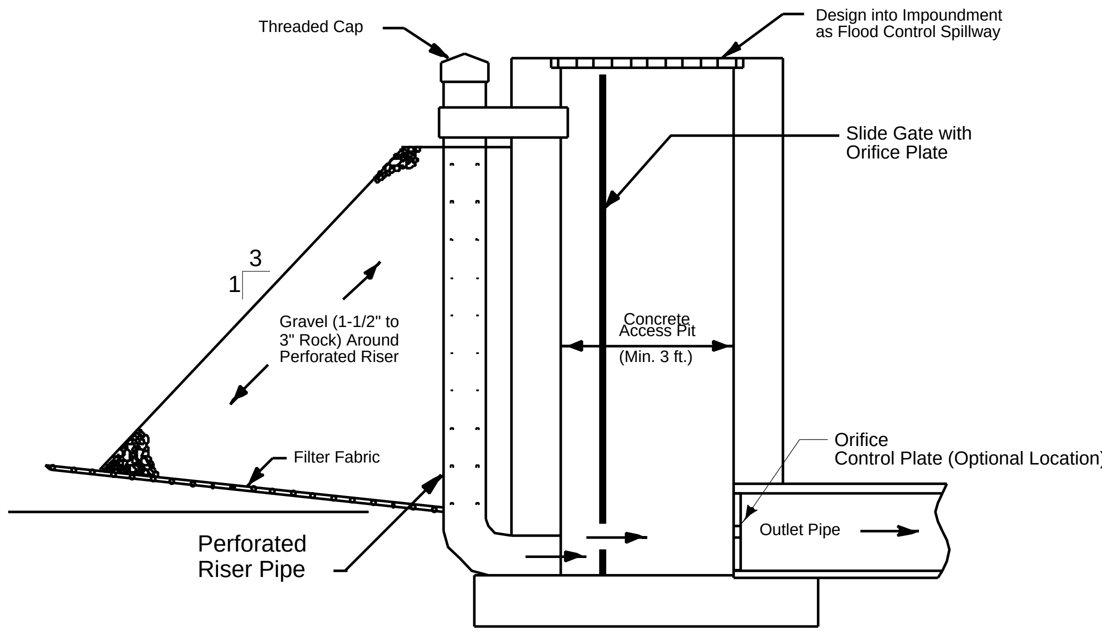
PERFORATED VERTICAL RISER PIPE
NOT TO SCALE

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

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

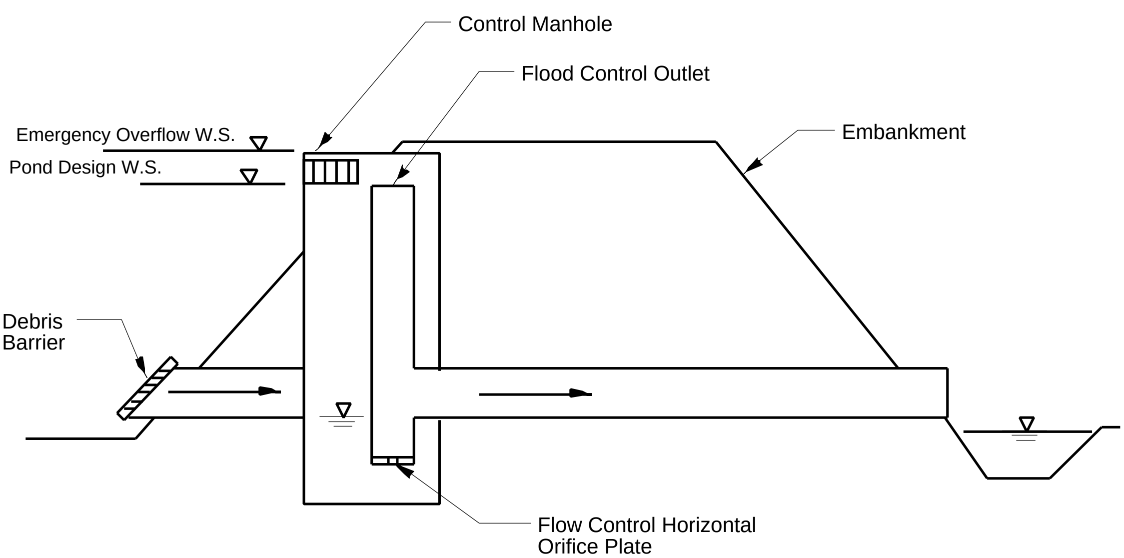
ADAPTED FROM UDFCD, 1999

Figure 5-5 . OUTLET CONFIGURATIONS USING MULTIPLE ORIFICE FLOW CONTROL



PERFORATED RISER PIPE WITH VERTICAL FLOW CONTROL ORIFICE

NOT TO SCALE



CONTROL MANHOLE WITH SUBMERGED HORIZONTAL ORIFICE PLATE

NOT TO SCALE

Figure 5-6. OUTLET CONFIGURATIONS USING SINGLE ORIFICE FLOW CONTROL

Maintenance Requirements

The following maintenance requirements apply to extended detention basins

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the governing agency may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. (See Appendix C for example maintenance agreement.)

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the governing agency's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format:

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

Maintenance Activities

- Inspect basin semiannually, after each significant storm, or more frequently, if needed.. Some important items to check for include: differential settlement, cracking; erosion, leakage, or tree growth on the embankment; the condition of the riprap in the inlet, outlet and pilot channels; sediment accumulation in the basin; and the vigor and density of the grass turf on the basin side slopes and floor. Correct observed problems as necessary.
- Remove litter and debris from banks and basin bottom as required.
- Repair erosion to banks and bottom as required.
- Remove sediment when accumulation reaches 25% of original design depth, or if resuspension is observed. Clean in early spring so vegetation damaged during cleaning has time to re-establish.

a) Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, and more frequently if needed. Correct observed problems as necessary.

b) Clean forebay frequently to reduce frequency of main basin cleaning.

a) Control mosquitoes, as necessary.

Description

Wet detention basins (WDBs) are open earthen basins that feature a permanent pool of water that is displaced by storm water flow, in part or in total, during storm runoff events. Like Extended Detention Basins (see T-3), WDBs are designed to temporarily detain the Stormwater Quality Design Volume (SQDV) of stormwater runoff and to slowly release this volume over a specified period (12 hours). WDBs differ from EDBs in that the influent runoff flow water mixes with and displaces the permanent pool as it enters the basin. The drawdown time for WDBs (12 hours) is shorter than for EDBs (40 hours), because enhanced treatment is provided in the permanent pool. A dry-weather base flow is required to maintain the permanent pool. The basic elements of a WDB are shown in Figure 5-7.

General Application

Wet Detention Basins function similarly to EDBs, serving to reduce peak stormwater runoff rates and providing treatment of runoff primarily through sedimentation. These basins can improve the quality of urban runoff from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites and are generally used as a regional or follow-up treatment because of the base-flow requirements. Because there is a permanent pool present, wet detention basins can also serve as passive recreational areas during the dry season, and can be designed into flood control basins or sometimes retrofitted into existing flood control basins.

Wet detention basins can serve essentially any size tributary area from an individual commercial development to a large residential or regional area, but are typically used for areas greater than 10 acres. These basins work well in conjunction with other BMPs, such as upstream onsite source controls and downstream filter basins or wetland channels.

Advantages/Disadvantages

General

Wet Detention Basins may be designed to provide other benefits such as passive recreation, wildlife habitat, and open space. Safety issues must be addressed through proper design.

Site Suitability

Wet Detention Basin space requirements are significant. Land requirements for WDBs typically range from approximately 0.5 to 2 percent of the tributary development area. These basins are also not suitable for dense urban areas or sites with steep and unstable slopes. Although site suitability concerns are similar to those stated for an EDB, Wet Detention Basins are not suitable for areas with long dry spells and high evaporation rates without perennial groundwater base flow or supplemental water to maintain permanent pool and aquatic vegetation. A complete water budget under the projected watershed conditions should be performed to assure that the base flow will exceed evaporation, evapotranspiration, and seepage losses. This control measure is most appropriate for sites with low-permeability soils (Type C and D).

Vegetation Maintenance

Considerable resources must be committed to properly maintain peripheral aquatic vegetation in WDBs to control mosquito propagation and to maintain effective permanent pool volume.

Pollutant Removal

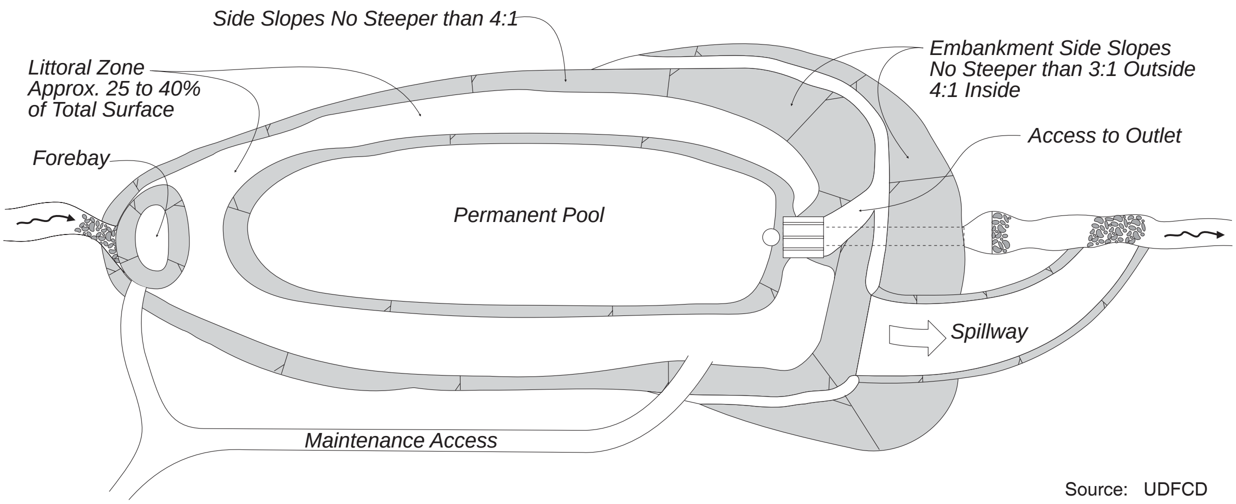
Relative pollutant removal effectiveness of a Wet Detention Basin is presented in Table 5-1. Removal effectiveness of WDBs for sediment and particulate forms of metals, nutrient and other settleable solids is considered high to moderate. WDBs also remove flotables and achieve some degree of dissolved contaminant removal, but effectiveness against dissolved contaminants is low. WDBs may be used upstream of control measures that are more effective at removing soluble pollutants, such as infiltration basins, filters or wetlands.

Design Criteria and Procedure

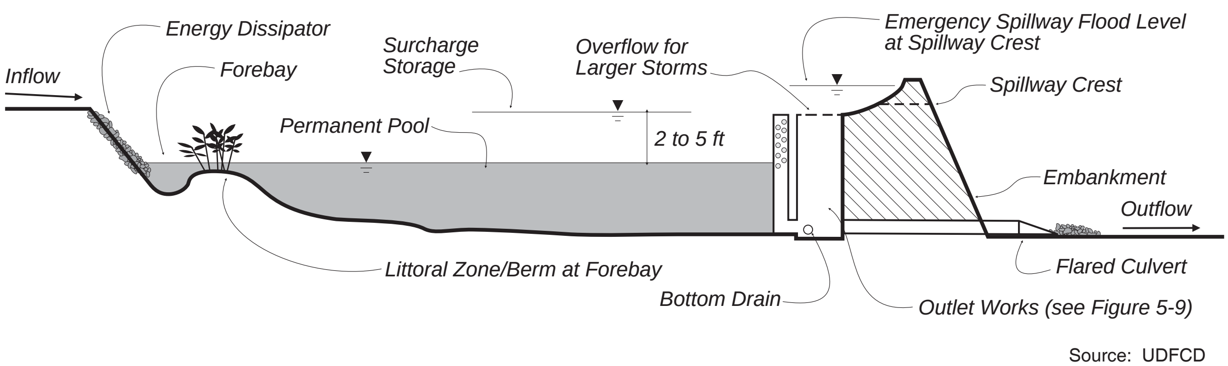
Principal design criteria for WDBs are listed in Table 5-7.

Table 5-7. Wet Detention Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV / 50% SQDV	hrs	12
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 12-h drawdown
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Permanent Pool volume	–	1.0 to 1.5 x SQDV
2 Depth Zones Required	–	Littoral Zone (6-12 inches deep, 25-40% of permanent pool surface area) Deeper Zone (4-8 feet average depth of remaining pond area, 12 feet max. depth)
Forebay volume/ drain time	%/min	5 to 10% of SQDV. Drain time < 45 minutes
Length to width ratio (minimum)	–	2:1 (larger preferred)
Minimum bottom width	ft	30
Freeboard (minimum)	ft	1.0
Embankment side slope (H:V)	–	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete



Plan View



Section View

Figure 5-7. Conceptual Layout of Wet Detention Basin

Design procedure and application of design criteria for WDBs are outlined in the following steps:

1. Basin Surcharge Volume

   Provide a surcharge volume equal to the SQDV, based on a 12-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 12-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u / 12) \times Area$$

   where Area = Watershed area tributary to WDB (acres)

2. Permanent Pool

   The permanent pool provides stormwater quality enhancement between storm runoff events through biochemical processes and continuing sedimentation.

   a. Determine the volume of the permanent pool (V_p), which is 1.0 to 1.5 times the SQDV.

   b. Depth Zones (see Figure 5-8)

   Littoral Zone should be between 6 to 12 inches deep that is between 25 to 40 percent of the permanent pool surface for aquatic plant growth along the perimeter of the pool.

   Deeper Zone should be 4 to 8 feet average depth with a maximum depth of 12 feet. This zone should cover the remaining pond area and promote sedimentation and nutrient uptake by phytoplankton.

3. Base Flow

   A net influx of water must be available through a perennial base flow and must exceed the losses. The following equation and parameters can be used to estimate the net quantity of base flow available at the time.

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

Q_{net} = Net quantity of base flow (acre-ft/year)

Q_{inflow} = Estimated base flow (acre-ft/year). (Estimate by seasonal measurements and/or comparison to similar watersheds.)

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

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

Q_{ET} = Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface)

4. Outlet Works

The Outlet Works are to be designed to release the SQDV (i.e. not Design Volume) over a 12-hour period. Refer to Figure 5-9 for schematics pertaining to structure geometry; grates, trash racks, and outlet.

a. 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 the centerline of the bottom perforation D (ft).

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

where

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

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

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

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

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

b. For single orifice outlet control or single row of orifices at the basin bottom surface elevation use the following equation based on the SQDV (ft^3) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

$$\text{Total orifice area} = (SQDV) \div [(60.19)(D^{0.5})(T)]$$

where

$$T = \text{drawdown period (hrs)} = 12 \text{ hrs}$$

5. Basin Side Slopes

Side slopes should be stable and sufficiently gentle to limit rill erosion and to facilitate maintenance. Side slopes above the permanent pool should be no steeper than 4:1, preferable 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.
6. Forebay Design	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 volume should be 5 to 10 percent of the SQDV. 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.
9. Inlet/Outlet Design	Basin inlet and outlet points should provided with an energy dissipation structure and/or erosion protection.
10. 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.
11. Embankment	Design embankments to conform to requirements State of California Division of Safety of Dams, 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.
12. Access	All-weather access to the bottom, forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.
13. 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 of Woodland Storm Drainage Guidance and Criteria.
14. 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.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

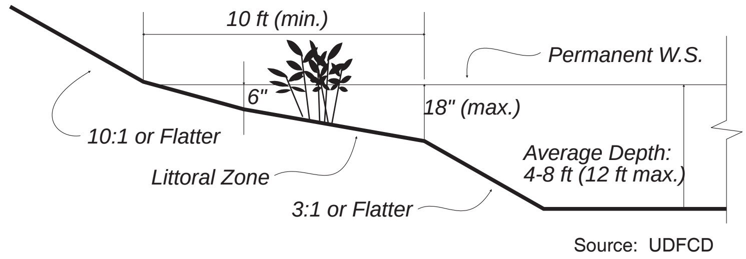


Figure 5-8. Depth Zones for Wet Detention Basin

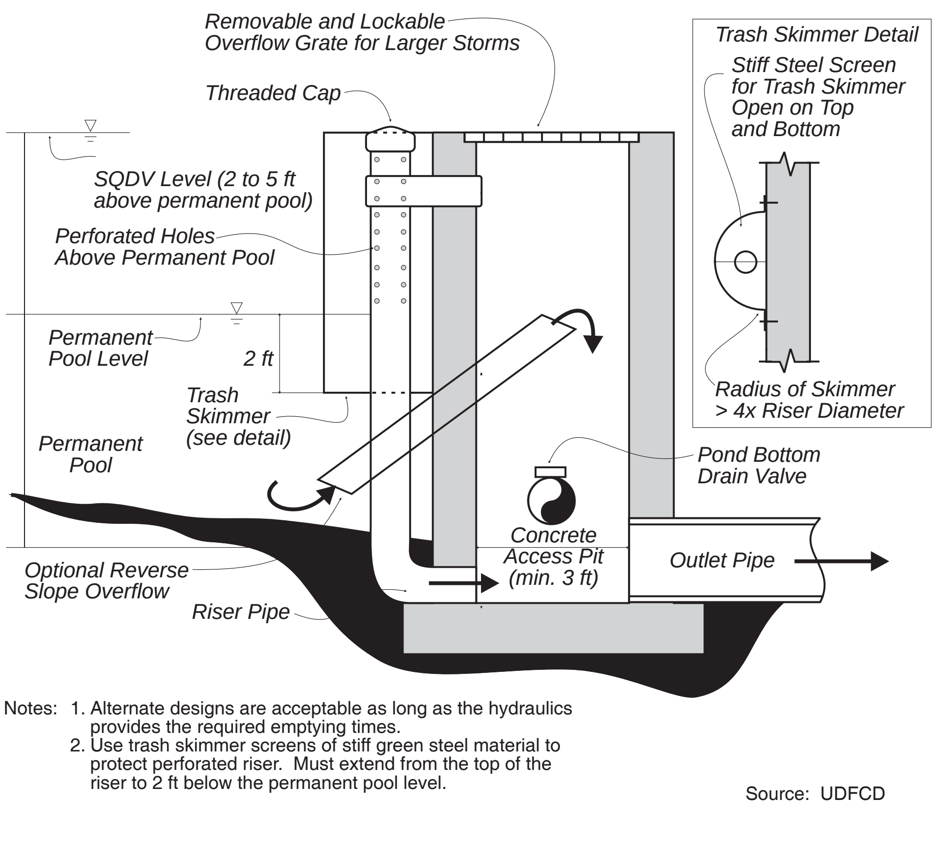


Figure 5-9. Outlet Works for Wet Detention Basin

Design Procedure Form for T-4: Wet Detention Basin

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	64	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	60	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12 hr drawdown and I_{wq}	V_u=	0.28	in.
d. Watershed Area Tributary to EDB	Area =	100.0	acres
Calculate SQDV = (V_u / 12) x Area	SQDV =	2.33	acre-ft
2. Permanent Pool			
a. Volume of Permanent Pool (1.0 to 1.5 times SQDV minimum)	V_p =	2.33	acre-ft
b. Depth			
1) Littoral Zone Depth (6 to 12 inches)	Depth =	1.0	feet
2) Deeper Zone Depth (4 to 8 ft average, 10 ft max)	Average Depth =	6.0	feet
	Max Depth =	9.0	feet
c, Permanent Pool Surface Area			
1) Littoral Zone Area (25%-40% Permanent Pool Surface)	Area =	0.175	acres
	% of total	30.0	%
2) Deeper Zone Area (60%- 40% Permanent Pool Surface)	Area =	0.408	acres
	% of total	70.0	%
3) Total Area	Total area =	0.583	acres
3. Estimated Net Base Flow (must be > 0)			
$Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} =	2.33	acre-ft
	Q_{evap} =	0.3	acre-ft
	$Q_{seepage}$ =	0.8	acre-ft
	$Q_{evapotranspiration}$	0.8	acre-ft
	Q_{net} =	0.43	acre-ft

Design Procedure Form for T-4: Wet Detention Basin (Page 2 of 3)

Project:____

4. Outlet Works			
a. Outlet Type (check one)	Single Orifice	X (1 row)	
	Multi-orifice Plate	________	
	Perforated Pipe	________	
	Other	________	
b. Depth of water above bottom orifice	Depth =	3.0	feet
c. Single Orifice Outlet			
1) Total Area	A =	81.13	square inches
2) Diameter or L x W	D =	4 @ 5.08	inches
d. Multiple Orifice Outlet			
1) Area per row of perforations	A =	________	
2) Perforation Diameter (2 inches max.)	D =	________	
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 =	________	
5. Trash Rack or Gravel Pack Present?	Yes/No	Yes	
6. Basin Shape			
a. Length-Width Ratio	Ratio =	3:1	L/W
7. Forebay Design			
a. Forebay Volume (5-10% of SQDV min.)	Volume =	0.12	acre-ft
b. Outlet pipe drainage time (< 45 minutes)	Drainage Time	45	mins.
8. Embankment Slope			
a. Interior Slope (4:1 max.)	Interior Slope =	4:1	L/W
b, Exterior Slope (3:1 max.)	Exterior Slope =	3:1	L/W

Design Procedure Form for T-4: Wet Detention Basin (Page 3 of 3)

Project:____

9. Vegetation (Check type used or describe "Other")	__X__ Native Grasses _____ Irrigated Turf Grass _____ Emergent Aquatic Plants (specify type / density) _____ Other ____________________________
10. Underdrains Provided?	Yes /No ____No____

Notes:

Maintenance Requirements

The following maintenance requirements apply to wet detention basins

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. (See Appendix C for example maintenance agreement.)

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format:

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

Maintenance Activities

- Inspect basin semiannually, after each significant storm, or more frequently, if needed.. Some important items to check for include: differential settlement, cracking; erosion, leakage, or tree growth on the embankment; the condition of the riprap in the inlet, outlet and pilot channels; sediment accumulation in the basin; and the vigor and density of the grass turf on the basin side slopes and floor. Correct observed problems as necessary.
- Remove litter and debris from banks and basin bottom as required.
- Repair erosion to banks and bottom as required.
- Remove sediment when accumulation reaches 25% of original design depth, or if resuspension is observed. Clean in early spring so vegetation damaged during cleaning has time to re-establish.
- Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, and more frequently if needed. Correct observed problems as necessary.
- Clean forebay frequently to reduce frequency of main basin cleaning.
- Control mosquitoes, as necessary. Mosquito control is an important issue for WDBs and may require extensive and frequent control of peripheral vegetation.

Description

A Constructed Wetland Basin (CWBs) is a single-stage treatment system consisting of a forebay and a permanent micropool with aquatic plants. CWBs funtion in a similar manner to Wet Detention Basins (WDBs) in that the influent runoff flow water mixes with and displaces a permanent pool as it enters the basin. The surcharge volume above the permanent pool is slowly released over a specified period (40 hours for SQDV). A base flow is required to maintain the permanent water pool. CDBs differ from WDBs primarily in terms of depth and volume of the permanent pool and the extensive presence of aquatic plants (rushes, willows, cattails, and reeds). Plants provide energy dissipation and enhance pollutant removal by sedimentation and biological uptake. A conceptual layout of a CWB is shown in Figure 5-10.

Constructed Wetlands differ from "natural" wetlands in that they are man-made and are designed to enhance stormwater quality. Sometimes natural wetlands can be incorporated into the constructed wetland system. Such action, however, requires the approval of federal and state regulators. Constructed wetlands are generally not allowed to be used to mitigate the loss of natural wetlands, but are allowed to be disturbed by maintenance activities. Nevertheless, any activity that disturbs a constructed wetland should be first cleared through the U.S. Army Corps of Engineers to ensure some form of an individual, general, or nationwide 404 permit coverage.

General Application

Constructed wetlands are ideal for large, regional tributary areas where space is available to provide shallow water conditions. Land uses for which this BMP is appropriate include large residential developments, and commercial, institutional and industrial areas where incorporation of a green space and a wetland into the landscape is desirable and feasible. CWBs can be used effectively in combination with upstream treatment controls sucha s Grass Strip Filters and Grass Swale Filters. A base flow of water is required to maintain aquatic conditions.

Advantages/Disadvantages

General

CWBs offer an attractive, effective means for improving stormwater quality. As part of a landscape design, a constructed wetland can offer the beauty of water and vegetation in a predominantly dry area, if base flow is available or provisions are made to maintain the permanent pool. CWBs offer the potential for wildlife habitat and passive recreation. For example, a constructed wetland can be used in a park-like area where people can picnic, stroll or bird watch.

The primary drawback to wetlands is the need for a continuous base flow to maintain aquatic plants. In addition, salts and scum can accumulate and, unless properly designed and managed, can be flushed out during larger storms.

Site Suitability

Adequate space of around 1 to 2 percent of the tributary watershed is usually required. Constructed wetlands, however, require more land space than WDBs for similar drainage areas because part of the constructed wetland must be shallower than a wet detention basin. A perennial base flow is needed to sustain a wetland, and should be determined using a complete water budget analysis.

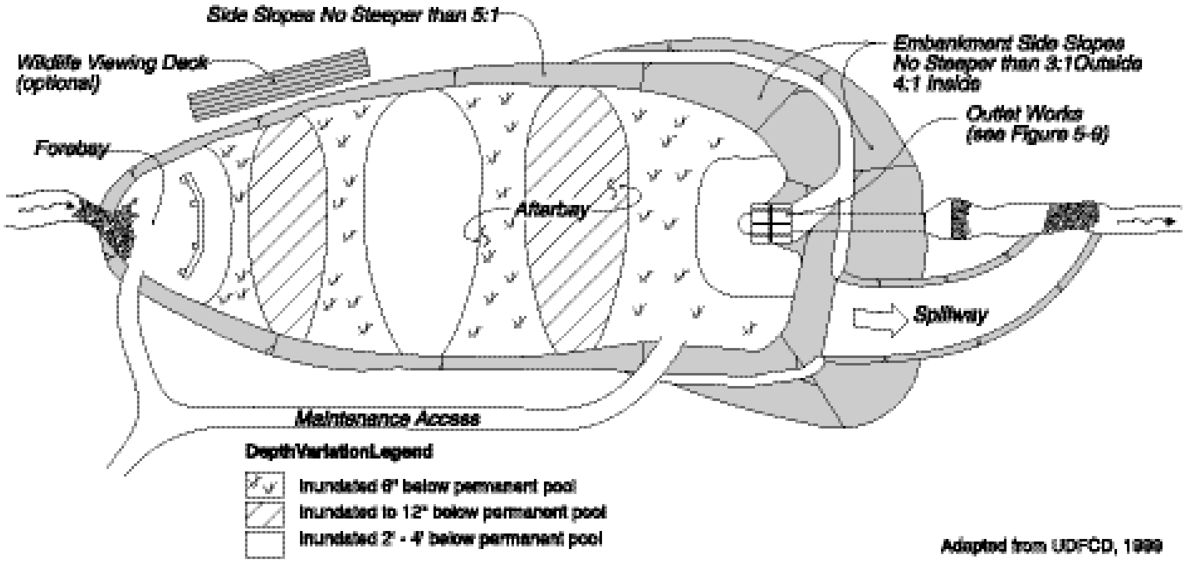
This control measure is most appropriate for sites with low-permeability soils (Type C and D) that will support aquatic plant growth. Infiltration through a wetland bottom cannot be relied upon because the bottom is either covered by soils of low permeability or because the groundwater is higher than the wetland's bottom. Wetland bottom channels also require a near-zero longitudinal slope; drop structures are used to create and maintain a flat grade.

Vegetation Maintenance

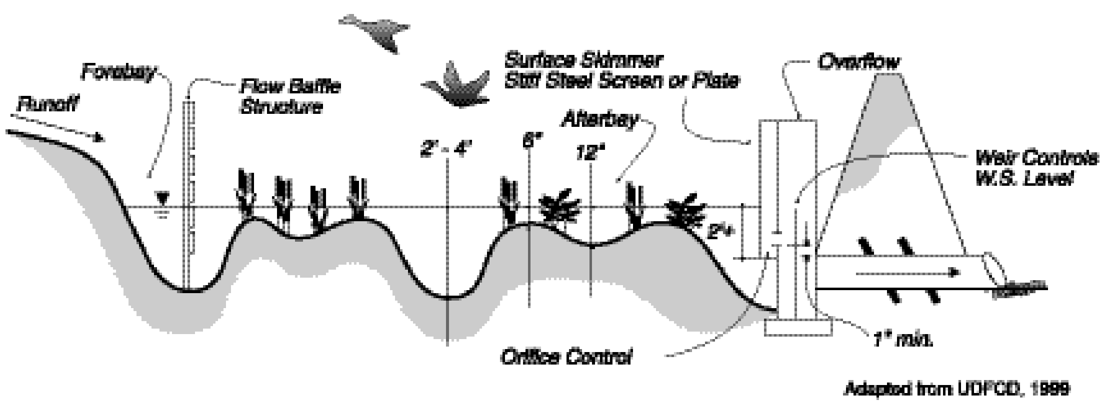
Considerable resources must be committed to provide nutrient removal and to maintain desirable mix and density of vegetation. Regular harvesting and removal of aquatic plants is required if the removal of nutrients is assured. Sediment removal is also necessary to maintain the proper distribution of growth zones and of water movement within the wetland. Water and plant management to avoid mosquito propagation is also essential.

Pollutant Removal

Wetlands remove a variety of constituents but their effectiveness varies significantly. Relative pollutant removal effectiveness of a CWB is presented in Table 5-1. With periodic sediment removal and plant harvesting, expected removal efficiencies for sediments, organic matter, and metals can be moderate to high; for phosphorus and nitrogen, low to moderate. Pollutants are removed primarily through sedimentation and entrapment, with some of the removal occurring through biological uptake by vegetation and microorganisms. Without a continuous dry-weather base flow, salts and algae can concentrate in the water column and can be released into the receiving water in higher levels at the beginning of a storm event as they are displaced. Harvesting aquatic plants and periodic removal of sediment also removes nutrients and pollutants associated with the sediment.



Plan View



Section View

Figure 5-10 . Conceptual Layout of Constructed Wetland Basin

Design Criteria and Procedure

Principal design criteria for CWBs are listed in Table 5-8.

Table 5-8. Constructed Wetland Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV / 50% SQDV	hrs	40 / 12 (minimum)
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 40-h drawdown
Permanent pool volume (minimum)	%	75% of SQDV
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Permanent Pool Area / Depth		
Forebay, free water surface, and outlet areas	% / ft	30% to 50% of the permanent pool surface area / 2 to 4ft
Wetland zones with emergent vegetation	% / ft	50% to 70% of the permanent pool surface area / 0.5 to 1.0 ft (30% to 50 % should be 0.5 ft deep)
Forebay volume	%	5 to 10 % of SQDV
Surcharge depth above permanent pool	ft	2.0 ft maximum
Length to width ratio (minimum)	–	2:1 (larger preferred)
Freeboard (minimum)	ft	1.0
Wetland (Littoral) zone bottom slope	%	10.0 maximum
Embankment side slope	(H:V)	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $SQDV = (V_u /12) \text{ x Area}$

   where Area = Watershed area tributary to CWB

2. Basin Depth/Volume

The volume of the permanent wetland pool shall be not less than 75% of the SQDV. Distribution of wetland area is needed for a diverse ecology. Distribute component areas as follows:

Components	Percent of Permanent Pool Surface Area	Water Design Depth
Forebay, outlet and free water surface areas	30-50%	2 to 4 feet
Wetland zones with emergent vegetation	50-70%	6 to 12 inches (1/3 to 1/2 of this area should be 6 inches deep with bottom slope ≤ 10%)

3. Depth of Surcharge

The surcharge depth of the SQDV above the permanent pool's water surface should not exceed 2.0 feet.

4. Outlet Works

Provide outlet works that limit the SQDV depth to 2 feet or less. The Outlet Works are to be designed to release the SQDV over at least a 40 hour period. A single orifice outlet control is depicted in Figure 5-10.

For single orifice outlet control or single row of orifices at the basin bottom surface elevation (see Figures 5-6), use the following equation based on the SQDV (ft^3) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

$$\text{Total orifice area} = (\text{SQDV}) \div [(60.19)(D^{0.5})(T)]$$

where

$$T = \text{drawdown period (hrs)} = 40 \text{ hrs}$$

For perforated pipe outlets or vertical plates with multiple orifices (see Figure 5-5), use the following equation to determine required area per row of perforations, based on the SQDV(ft^2) and depth of water above the centerline of the bottom perforation D (ft).

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

where

$$K_{40} = 0.13D^2 + 0.22D - 0.10$$

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:

$$nr = 1 + (D_{BS}/3)$$

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

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

5. Basin Use

Determine if flood storage or other uses will be provided for above the wetland surcharge storage or in an upstream facility. Design for combined uses when they are provided for.

6. 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 a 3:1 recommended. Internal baffling with berms or modification of inlet and outlet points may be necessary to achieve this ratio.

7. 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 less than 3:1.

8. Base Flow

A net influx of water must be available through a perennial base flow and must exceed the losses. The following equation and parameters can be used to estimate the net quantity of base flow available at the time.

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

Q_{net} = Net quantity of base flow (acre-ft/year)

Q_{inflow} = Estimated base flow (acre-ft/year). (Estimate by seasonal measurements and/or comparison to similar watersheds.)

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

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

Q_{ET} = Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface)

9. Inlet/Outlet Design

Basin inlet and outlet points should provided with an energy dissipation structure and/or erosion protection. Outlets should be placed in an offbay that is at least 3 feet deep. The outlet should be protected from clogging by a skimmer shield that starts at the bottom of the permanent pool and extends above the maximum SQDV depth. Also, provide for a trash rack.

11. Forebay/Afterbay

The forebay provides a location for sedimentation of larger

	particles that has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The after bay is optional. The forebay volume should be 5% to 10 % of the SQDV. Depth should be 2.0 to 4.0 ft.
12. Vegetation	Selected wetland plants and grasses should be planted in the wetland bottom. 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 controlled as necessary to establish wetland plants and raised to final operating level after plants are established.
12. Access	All-weather access to the forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.
13. 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 Ventura County Flood Control District.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-5: Constructed Wetlands Basin

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	50	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	50	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	0.56	in.
d. Watershed Area Tributary to EDB	Area =	50	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	2.33	acre-ft
2. Wetland Pond Volume, Depth, and Water Surface Area		**Minimums**	
a. Calculated Requirements, Minimum Permanent Pool: $Vol_{pool} \geq 0.75 \times SQDV$	Vol_{pool} >	1.75	acre-ft
	Water Area>	0.70	acres, estimated
		Actual Design	
	Vol_{pool} =	1.80	acre-ft, actual
	Water Area =	1.20	acres, actual
b. Forebay Depth Range = 2.0' – 4.0'	Depth =	3.0	ft
Volume Range = 5%to 10 % of SQDV	Volume =	0.09	acre-ft,% = 5.0
c. Outlet Pool Depth Range = 2.0' – 4.0'	Depth =	3.0	ft
Volume Range = 6%to 10% of SQDV	Volume =	0.18	acre-ft,% = 10.0

Continued on next page

Design Procedure Form for T-5: Constructed Wetlands Basin (Page 2 of 3)

Project:____

3. Wetland Pond Volume, Depth, and Water Surface Area (Continued)			
d. Free Water Surface Areas (Area = 30-50% combined) (Depth Range = 2.0' – 4.0')	Depth =	2.0	ft
	Area =	0.60	acres, % = 50
	Volume =	1.20	acre-ft
e. Wetland Zones with Emergent Vegetation (Depth Range = 6" – 12") (Area = 50-70%)	Depth =	1.0	ft
	Area =	0.60	acres, % = 50
	Volume =	0.60	acre-ft
4. Estimated Net Base Flow (must be > 0)			
$Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} =	362.0	acre-ft
	Q_{evap} =	1.40	acre-ft
	$Q_{seepage}$ =	2.80	acre-ft
	$Q_{evapotranspiration}$	1.50	acre-ft
	Q_{net} =	356.30	acre-ft
5. Outlet Works			
a. Outlet Type (check one)	Single Orifice	X	
	Multi-orifice Plate	______	
	Perforated Pipe	______	
	Other	______	
b. Depth of water above bottom orifice	Depth =	3.0	feet
c. Single Orifice Outlet			
1) Total Area	A =	24.34	square inches
2) Diameter (or L x W)	D =	3 x 8.11	inches
d. Multiple Orifice Outlet			
1) Area per row of perforations	A =	______	
2) Perforation Diameter (2 inches max.)	D =	______	
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 =	______	

Design Procedure Form for T-5: Constructed Wetlands Basin (Page 3 of 3)

Project:____

6. Trash Rack or Gravel Pack Present?	Yes/No ____Yes___
7. Basin Shape a. Length-Width Ratio	Ratio = ______3:1______ L:W
8. Embankment Side Slope a. Interior Side Slope (4:1 max.) b, Exterior Side Slope (3:1 max.)	Int. Side Slope = ______4:1______ L:W Ext. Side Slope = ______3:1______ L:W
9. Vegetation (Check type used or describe "Other")	__X__ Native Grasses _____ Irrigated Turf Grass __X__ Emergent Aquatic Plants (specify type / density)* _____ Other ______________________________ *Describe Species Density and Mix: _____See attached specification_______________ ____ ____ ____ _____

Notes:

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Maintenance Requirements

The following maintenance requirements apply to Constructed Wetland Basins

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the governing agency may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the governing agency'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
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Inspect constructed wetlands a minimum of twice a year, before and after the rainy season, after large storm events, or more frequently if needed. Some important items to check for include: differential settlement, cracking; erosion, leakage, or tree growth on the embankment; the condition of the riprap in the inlet, outlet and pilot channels; sediment accumulation in the basin; and the vigor and density of the vegetation on the basin side slopes and floor. Correct observed problems as necessary.
- Remove litter and debris from banks and basin bottom as required.
- Repair erosion to banks and bottom as required.
- Clean forebay every two years at a minimum, to avoid accumulation in main wetland area. Environmental regulations and permits may be involved with the removal of wetland deposits. When the main wetland area needs to be cleaned, it is suggested that the main area be cleaned one half at a time with at least one growing season in between cleanings. This will help to preserve the vegetation and enable the wetland to recover more quickly from the cleaning.
- Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, and more frequently if needed. Correct observed problems as necessary.
- Control mosquitoes, as necessary. The forebay (deep water only) can be stocked with Gambusia fish (mosquito fish), if approved by the Department of Fish and Game and other appropriate agencies.

Detention Basin/Sand Filter

Description

A detention basin/sand filter (DBSF) consists of a runoff storage zone underlain by a sand bed filter with an underdrain system constructed in an earthen basin. The basin is divided into a forebay settling basin to remove large sediment followed by sand filter basin. During storm events, runoff accumulates in the surcharge zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to downstream conveyance. Schematic plan and section views of a typical DBSF are shown in Figure 5-11.

General Application

A DBSF is generally suited to offline, onsite configurations where there is no base flow and the sediment load is relatively low. Drainage areas of up to 100 acres are appropriate for DBSFs.

Advantages/Disadvantages

General

Primary advantages of DBSFs include effective water quality enhancement through settling and filtering.

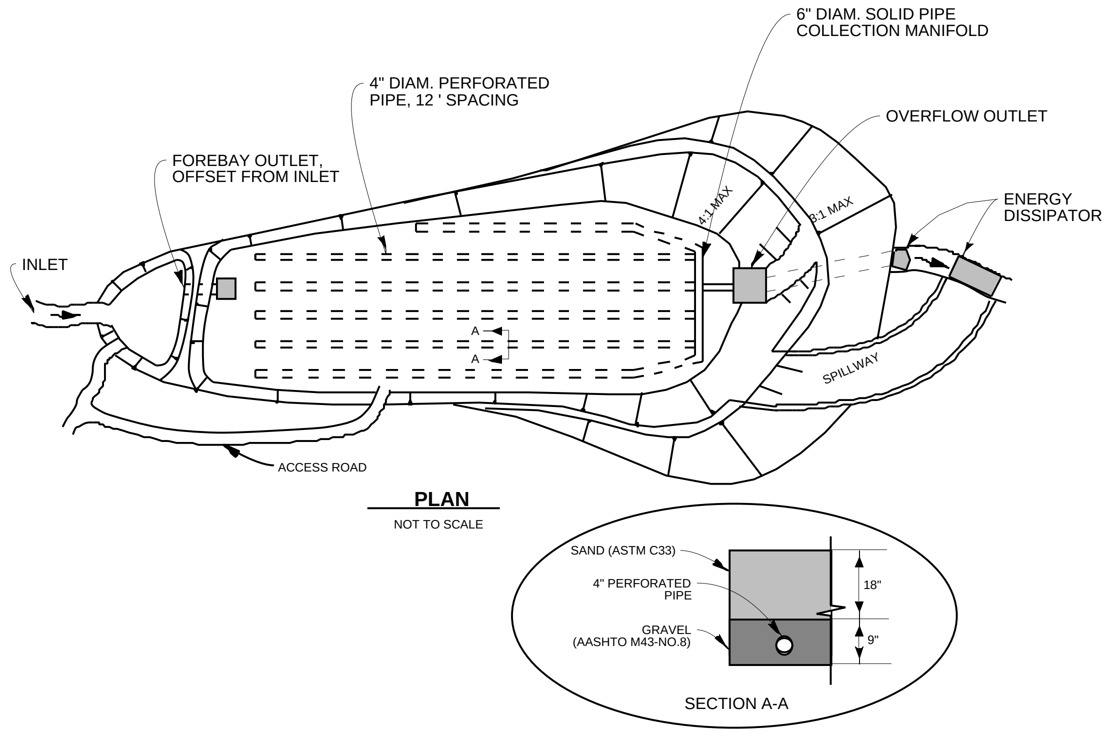
The primary disadvantage is the potential for clogging of the filter media. For this reason, systems should not be put into operation while construction activities are taking place in the tributary catchment. Maintenance requirements to maintain permeability of the filter media can be high if sediment loads are excessive.

Site Suitability

Because an underdrain system is incorporated into this control measure, DBSFs are suited to most soil types; presence of sandy soils is not a requirement. DBSFs are best suited to flat or gently sloping terrain , because of the need to construct zero-slope filter beds.

Pollutant Removal

Relative pollutant removal effectiveness of a DBSF is presented in Table 5-1. Removal effectiveness of DBSFs for sediment and particulate forms of metals, nutrients and other pollutants is considered high to moderate. Removal effectiveness for dissolved pollutants is considered low.



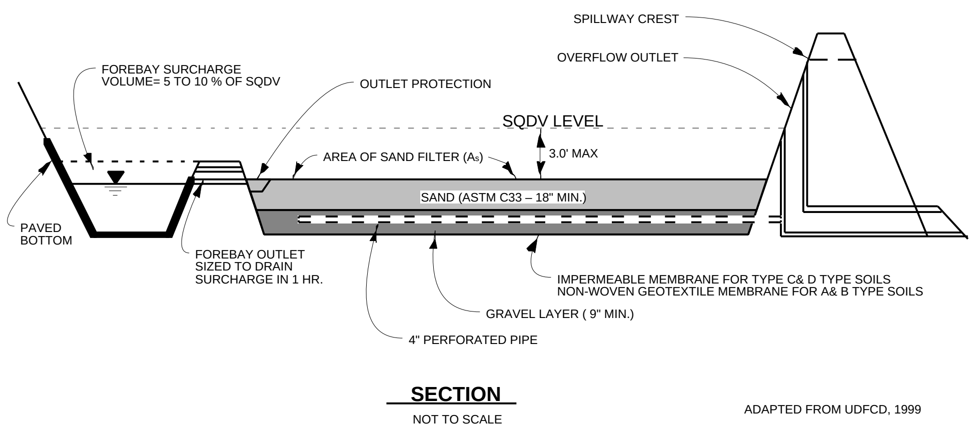


FIGURE 5-11. DETENTION BASIN/SAND FILTER

Design Criteria and Procedure

Principal design criteria for DBSFs are listed in Table 5-9.

Table 5-9. Detention Basin /Sand Filter Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV / 50% SQDV	hrs	40 / 12 (minimum)
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 40-h drawdown
Forebay surcharge volume	%	5 to 10% of SQDV
Max depth at SQDV	ft	3 feet
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Length to width ratio (minimum)	–	2:1 (larger preferred)
Freeboard (minimum)	ft	1.0
Filter bed media	--	Sand: 18 inches, Gravel: 9 inches.
Embankment side slope (H:V)	–	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of

   the SQDV, based on a 40-hr drawdown time, above the san bed of the basin.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u /12) \times Area$$

   where

   Area = Watershed area tributary to DBSF

2. Basin Depth — Maximum design volume depth should be 3 feet.

3. Filter Surface Area — Calculate the minimum sand filter area (A_s at the basin's bottom with the following equation:

$$A_s = \text{Design Volume} / (3 \times 43{,}560\ ft^2)$$

4. Filter Bed — An 18-inch layer of sand (ASTM C 33) over a 9-inch gravel layer (ASSHTO M43-No. 8) shall line the entire DBSF for purposes of filtering and draining the SQDV.

   If expansive soils are a concern or if the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the gravel layer.

5. Outlet Works — A grated outlet structure with overflow should be provided to convey flows in excess of the SQDV out of the basin.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-6: Detention Basin / Sand Filter

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	64	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	60	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	0.64	in.
d. Watershed Area Tributary to DBSF	Area =	10.0	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	0.54	acre-ft
2. Filter Surface Area (A_s)			
a. A_s (min) = (SQDV / 3) x 43,560 ft^2)	A_s (min) =	7,840.80	ft^3
b. Design A_s	A_s =	7,850.0	ft^2
3. Design basin depth, based on design filter area			
D = Design Volume/ Design A_s	D =	3.0	ft
4. Filter Bed			
a) ASTM C33 Sand Layer (18 in. minimum)		18	inches
b) ASSHTO M43-No.8 Gravel Layer (9 in. min.)		9	inches

Notes:

Maintenance Requirements

The following maintenance requirements apply to Detention Basin/Sand Filters.

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the governing agency may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the governing agency'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
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Inspect basin a minimum of twice a year, before and after the rainy season, after large storm events, or more frequently if needed. Some important items to check for include: differential settlement, cracking; erosion, leakage, or tree growth on the embankment; the condition of the riprap in the inlet, outlet and pilot channels; sediment accumulation in the basin; and the vigor and density of the vegetation on the basin side slopes and floor. Correct observed problems as necessary.
- Remove litter and debris from banks and basin bottom as required.
- Repair erosion to banks and bottom as required.
- Check infiltration rate of sand bed twice annually, once after significant rainfall.
- Scarify top 3 to 5 inches of filters surface by raking once annually or as required to restore infiltration rate of the filter.
- Clean forebay every two years at a minimum, to avoid accumulation in main basin.
- Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, and more frequently if needed. Correct observed problems as necessary.

Description

A Porous Pavement Detention Basin (PPD) consists of an installation of Modular Block Porous (MBP) pavement that is flat (i.e., S_o = 0.00% in all directions) and is provided with a 2-inch deep surcharge zone to temporarily store the WQCV draining from an adjacent area. Runoff will infiltrate the porous pavement and sublayers of sand a gravel and will slowly exit through an underdrain.

Modular Block Porous Pavement consists of open void concrete block units laid on a two-layer sand and gravel subgrade. The surface pavement voids are filled with sand. A typical cross section of a PPD system is shown in Figure 5-12. An alternate approach is to use stabilized-grass porous pavement, consisting of grass turf reinforced with plastic rings and filter fabric underlain by gravel.

General Application

A PPD may be used in low vehicle-movement zones such as residential driveways and is often used as a parking pad surface. Although PPDs are typically used as parking pads in a parking lot, there are other potential applications such as:

- Low vehicle movement airport zones such as parking aprons and maintenance roads
- Crossover/emergency stopping/parking lanes on divided highways.
- Residential street parking lanes
- Residential driveways
- Maintenance roads and trails
- 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; however it may require irrigation and lawn care.

Advantages/Disadvantages

General

In addition to relatively high pollutant removal effectiveness, PPD can reduce flooding potential by infiltrating or slowing down runoff. Modular Block patterns, colors and materials can serve functional and aesthetic purposes. An additional advantage is to provide a means to provide storm water capture for sites that have little available open area for detention.

The primary disadvantage for use of PPD is cost. Also, uneven driving surfaces and potential traps for the high heels of women's shoes may be a problem. The cost of restorative maintenance can be somewhat high when the system seals with sediment and no longer functions properly as a permeable pavement.

Site Suitability

PPDs may be installed without free draining subsoils when provided with underdrains. An underdrain ensures the drainage of the gravel subgrade whenever the subsoils are not free draining. In cases when the subsoils are not free draining, an impermeable liner should be provided to drain the water in the gravel pack and to mitigate concerns about expansive soils.

The PPD should also be located far enough from foundations in expansive soils so as to limit damage to potential structures. In addition, 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.

Pollutant Removal

Removal rates for both suspended sediment and associated constituents are projected to be high to moderate. Runoff through the sand and gravel of the modular block voids and entrapment in the gravel media are the primary removal mechanisms of pollutants. Removal rates for dissolved constituents are expected to be low to moderate. Relative pollutant removal effectiveness of a DBSF is presented in Table 5-1.

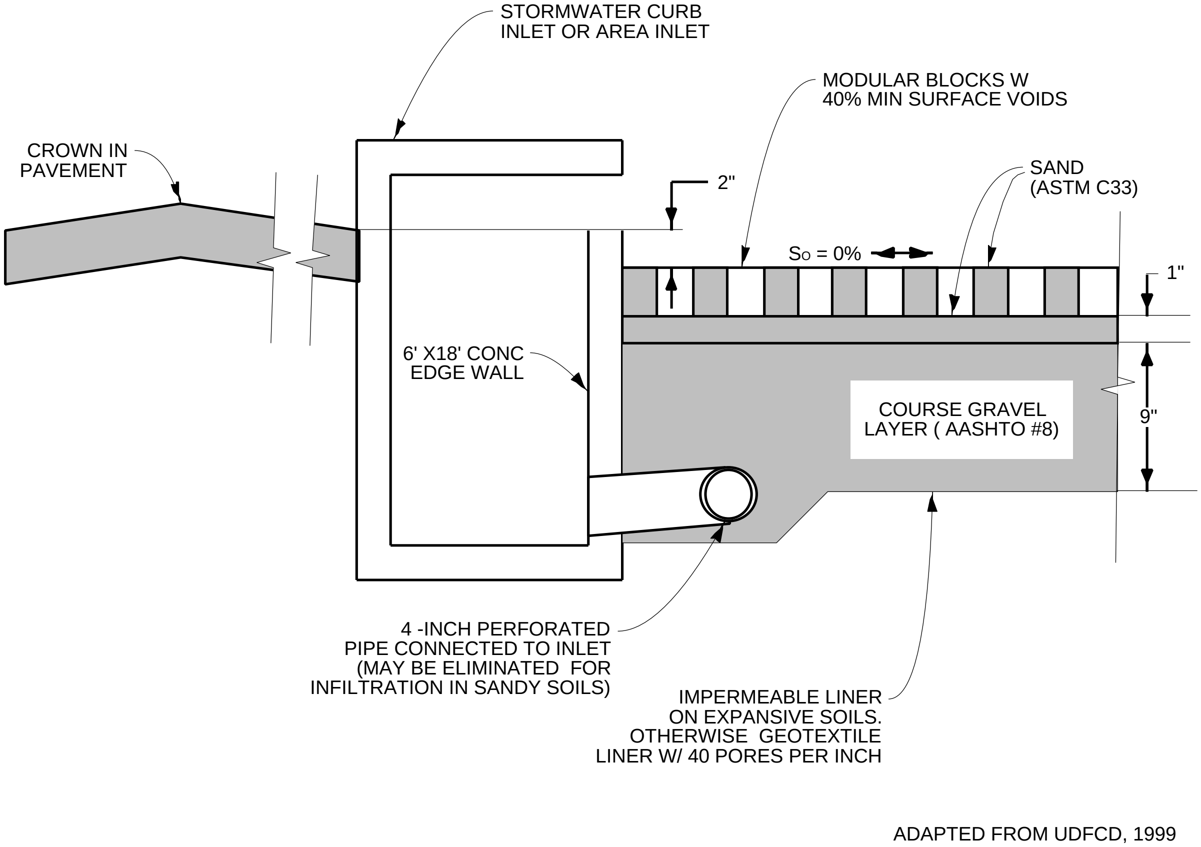


Figure 5-12. Porous Pavement Detention

Design Criteria and Procedure

Principal design criteria for PPDs are listed in Table 5-10.

Table 5-10. Porous Pavement Detetnion Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	12 (minimum)
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 12-h drawdown
Modular Porous Block Type	%	40% surface area open
Porous Pavement Infill	--	ASTM C-33 Sand or equivalent
Base courses	–	1-inch sand (ASTM C-33) over 9-inch gravel
Perimeter Wall Width	in	6

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume Provide a storage volume equal to 100 percent of the QDV, based on a 12-hr drawdown time.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 12-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u /12) \times Area$$

   where Area = Watershed area tributary to PPD

2. Basin Surface Area Calculate minimum required surface area based on surcharge depth of 2 inches as follows:

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

3. 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.

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

5. Base Courses	Provide 1-inch sand over 9-inch gravel base courses as shown in Figure 5-12.
6. Perimeter Wall	Provide a concrete perimeter wall to confine the edges of the PPD area. The wall should be minimum 6-inch wide and at least 6 inches deeper than all the porous media and modular block depth combined.
7. 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.
8. 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.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-7: Porous Pavement Detention

Designer:______________________________

Company:______________________________

Date:______________________________

Project:______________________________

Location:______________________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12 hr drawdown and I_{wq}	V_u=	0.65	in.
d. Watershed Area Tributary to DBSF	Area =	0.1	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	0.0054	acre-ft
1. Basin Surface Area			
a. Design Volume (SQDV)	SQDV =	236	ft^3
b. A_s = Design Volume / (0.17 ft) (based on surcharge depth of 2 inches)	A_s	1,388	ft^2
2. Block Type	Block name:	Uni-Green	
	Manufacturer:	Pavestone	
a. Minimum open area = 40%	Open Area =	40	%
b. Minimum thickness = 4 inches	Thickness	4.0	inches
3. Base Course (Check)			
a. ASTM C33 Sand Layer (1 inch)	Sand Layer	X	
b. ASSHTO M43-No.8 Gravel Layer (9 inches)	Gravel Layer	X	

Notes:

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Maintenance Requirements

The following maintenance requirements apply to Porous Pavement Detention.

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the governing agency may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the governing agency'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
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Inspect PPD a minimum of twice a year during storm events to determine if runoff is infiltrating properly.
- If infiltration is significantly reduced, remove surface sand by vacuuming. Dispose and replace sand with fresh ASTM C-33 sand.
- Remove litter and debris from PPD area as required.

Description

A Porous Landscape Detention (PLD) basin functions similarly to Porous Pavement Detention (PPD) except vegetation is used instead of porous blocks. A PLD consists of a low-lying vegetated area underlain by a sand bed with an underdrain pipe. A shallow surcharge zone is provided above the PLD for temporary storage of the SQDV. During runoff events, runoff accumulates in the vegetated zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to downstream conveyance. Like the PPD, a PLD allows detention of the SQDV to be provided on sites with limited open area available for stormwater detention. A typical cross section of a PLD is shown in Figure 5-13.

General Application

A PLD can be located in just about any of the open areas of a site. It is ideally suited for small installations such as:

- Parking lot islands
- Street medians
- Roadside swale features
- Site entrance or buffer features

A PLD can be implemented on a larger scale, serving as an infiltration basin/sand filter for an entire site, if desired, provided the stormwater quality capture volume and average depth requirements are met.

Advantages/Disadvantages

General

PLDs provide storm water capture on a site while reducing the impact on developable land. Aside from the relatively high degree of pollutant removal provided, PLDs can reduce flooding potential by infiltrating or slowing down runoff. A PLD provides a natural moisture source for vegetation, enabling “green areas” to exist with reduced irrigation.

The primary disadvantage of a PLD is the potential for clogging if sediment loading is excessive. The cost of restorative maintenance can be high when the system seals with sediment and no longer functions as a storm water basin. A PLD should be placed away from building foundations or other areas where expansive soils are present, although underdrain and impermeable liner can ameliorate some of these concerns.

Site Suitability

If an underdrain system is incorporated into the design, PLDs are suited for almost any site regardless of soil type. An underdrain ensures the drainage of the subgrade whenever the subsoils are not free draining. If sandy soils (type A or B) are present, the facility can be installed without an underdrain. However, sandy subsoils are not a requirement. In cases when the subsoils are not free draining, an impermeable liner should be provided to drain the water in the subgrade and to mitigate concerns about expansive soils. This BMP has a relatively flat surface area and may be more difficult to incorporate it into steeply sloping terrain.

The PLD should be located far enough from foundations in expansive soils so as to limit damage to potential structures. In addition, 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.

Pollutant Removal

The degree of pollutant removal by a PLD should be significant and should equal or exceed the removal effectiveness provided by sand filters. In addition to removal by settling, PLDs provides filtering, adsorption, and biological uptake of constituents in stormwater. Relative pollutant removal effectiveness is indicated in Table 5-1.

Design Criteria and Procedure

Principal design criteria for SFBs are listed in Table 5-11.

Table 5-11. Extended Detention Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	12 hrs
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 12-h drawdown
Average surcharge depth	in	6-12
Sand-peat layer	in	18" (minimum)– 75% ASTM C-3 Sand + 25% peat
Gravel layer	in	9" – ASSHTO #8 Coarse Aggregate
Vegetative (sandy loam turf) layer	in	6"

When implementing multiple small PLDs on a site, it is increasingly important to accurately account for each upstream drainage area tributary to each PLD site to make sure that each facility is properly sized, and that all portions of the development site are directed to a PLD.

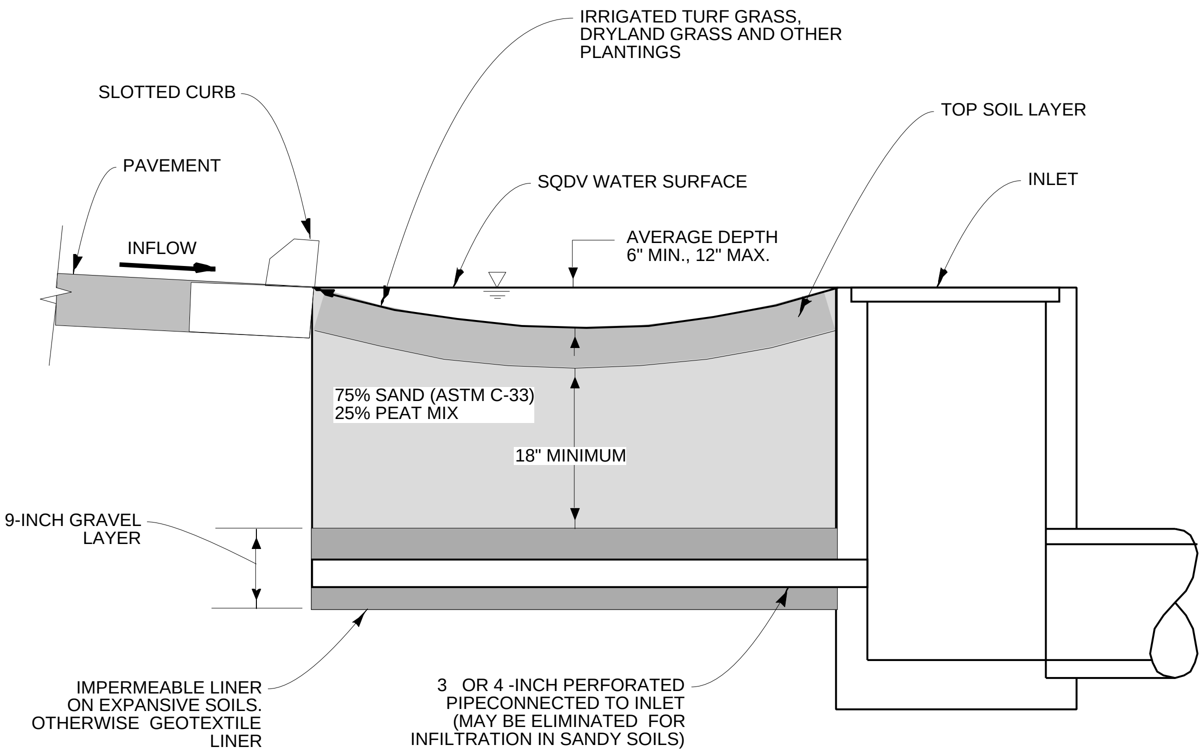

Figure 5-13. POROUS LANDSCAPE DETENTION

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume	Provide a storage volume equal to 100 percent of the SQDV, based on a 12-hr drawdown time. a. Determine the percent imperviousness of the tributary area (I_a). b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate. c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 12-hr drawdown and I_{wq} value from step 1.b. d. Calculate the SQDV in acre-ft as follows: SQDV = (V_u /12) x Area where Area = Watershed area tributary to PLD
2. Basin Surface Area	Calculate minimum required surface area as follows: Surface Area = SQDV / average surcharge depth
3. Base Courses	Provide 18-inch sand + peat layer over 9-inch gravel layer as shown in Figure 5-13. Thoroughly mix 75% sand (ASTM C-33) with 25% peat for filtration and adsorption of contaminants.
4. 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.
5. Surcharge Depth	Maintain the average SQDV depth between 6 and 12 inches. Average depth is defined as water volume divided by the water surface area.
6. Vegetative Layer	Provide a sandy loam turf layer above the sand-peat mix layer. This layer shall be no less than 6 inches thick, but a thicker layer is recommended to promote healthier vegetation.
7. Overflow	Provide an overflow, possibly with an inlet to a storm sewer, set above the SQDV surcharge water level

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-8: Porous Landscape Detention Basin

Designer:______________________________

Company:______________________________

Date:______________________________

Project:______________________________

Location:______________________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12 hr drawdown and I_{wq}	V_u=	0.65	in.
d. Watershed Area Tributary to DBSF	Area =	0.25	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	0.0135	acre-ft
2. Basin Surface Area			
a. Design Volume (SQDV)	SQDV =	590	ft^3
b. Average Depth	Average Depth =	1.0	ft
c. A_s = Design Volume / Average Depth	A_s =	590	ft^2
3. Base Course Layers (check)	Sandy Loam Turf	X	in. (6" min)
	Sand/peat mix	X	in. (18" min)
	Gravel	X	in. (9" min)
4. Subsurface Drainage (check)	X	Infiltration to subgrade with permeable geotextile membrane	
	______	Underdrain with impermeable membrane	
	______	Underdrain with permeable goetextile membrane	

Notes:

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Maintenance Requirements

The following maintenance requirements apply to Porous Landscape Detention.

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the governing agency may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the governing agency'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
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Mow grass and remove weeds to limit unwanted vegetation as required. Maintain irrigated turf grass height at 2 to 4 inches and non-irrigated native grasses at 4 to 6 inches.
- Remove litter and debris from PPD area as required.
- Inspect PLD a minimum of twice a year during storm events to determine if runoff is infiltrating properly.
- If infiltration is significantly reduced, remove and replace sandy loam turf and landscaping layer. May be required every 5 to 10 years or more frequently depending on sediment loads to the PLD.

Description

An Infiltration Basin (INB) consists of an earthen basin constructed in naturally pervious soils (Type A or B soils) with a flat bottom and provided with inlet structure to dissipate energy of incoming flow and an emergency spillway to control excess flows. An optional relief underdrain may be provided to drain the basin if standing water conditions occur. A forebay settling basin as described for EDBs should be provided if high sediment loads are anticipated. An INB functions by retaining the SQDV in the basin and allowing the retained runoff to percolate into the underlying native soils over a specified period of time (40 hours). The bottoms of basins are typically vegetated with dry-land grasses or irrigated turf grass. . A typical layout of an INB system is shown in Figure 5-14.

General Application

Infiltration basins can serve drainage areas up to 50 acres. Infiltration basins can be sized to pass storm volumes greater than the storm quality capture volume (SQDV). However, treatment efficiencies are reduced and the threat of system failure increases as the volume of runoff directed to the infiltration basin increases above the SQDV. It is recommended that the basin be sized to treat the storm quality capture volume only and divert all other flows around the treatment control measure.

Advantages/Disadvantages

General

In addition to removing pollutants effectively, infiltration basins also control runoff volume, which may serve to reduce downstream bank erosion in watercourses. INBs, are empty when not in use and can be dual-purpose facilities. A grass-covered area in a park, for example, could function as an infiltration basin during the wet season, and as a park during the dry season .

The primary disadvantage of an infiltration basin is the potential for clogging if excessive sediment is allowed to flow into the facility. Basins cannot be put into operation until the upstream tributary area is stabilized. The cost of restorative maintenance can be high if soil infiltration rates are significantly reduced due sediment deposition.

Also, there is a risk of groundwater contamination in very coarse soils since coarse soils do not effectively remove dissolved pollutants. This may require groundwater monitoring

Site Suitability

An infiltration basin requires significant space and is suitable for large drainage areas (10 to 50 acres. INBs infiltration basins cannot be placed on fill or unstable sites. Also, INBs should not be placed in high-risk areas such as service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk.

Before exploring the use of infiltration BMPs, preliminary soil investigations, including a percolation test, shall be performed to assess whether the soils on site have an extended infiltration rate of at least 0.5 inches per hour. Separate on-site infiltration systems from the groundwater table (or bedrock) by a minimum of 10 feet vertically to provide sufficient infiltration volume within the soil. Tributary area should have a low potential for erosion. Other suitability considerations include the soil makeup (Appendix E), site topography, and the location of other facilities. Prior to the use of infiltration basins consultation with local agencies is recommended to identify the location of unconfined groundwater basins and vulnerable unconfined aquifers to determine the appropriateness of this BMP. In an area identified as an unconfined groundwater basin or a vulnerable unconfined aquifer the application of infiltration BMPs should be limited to those that provide pre-treatment to ensure groundwater is protected for pollutants of concern.

The site must further provide a relatively flat area in which to construct the facility. Infiltration facilities shall be sited at least 50 feet away from slopes steeper than 15 percent. Adequate spacing (100 feet or more) shall be provided between infiltration facilities and non-potable wells, tanks, drain fields and springs. For separation between infiltration BMPs and potable water supply wells, follow Department of Health Services requirements in the Guidelines for Location of Water Wells. INBs shall also be sited at least 20 feet down slope or 100 feet up slope from building foundations. A geotechnical expert shall be consulted when necessary to verify appropriate placement on site.

An important consideration for all infiltration facility configurations is that, during construction, great care must be taken not to reduce the infiltration capacity of the soil in the facility through compaction or by using the infiltration area as a sediment trap. Infiltration facilities shall be constructed late in the site development after soils (that might erode and clog the units) have been stabilized, or shall be protected until the site is stabilized.

Pollutant Removal

The amount of pollutant removed by INBs should be significant and should equal or exceed the removal rates provided by sand filters. In addition to settling, infiltration basins provide filtering, adsorption, and biological uptake of constituents in stormwater. Relative pollutant removal effectiveness is indicated in Table 5-1.

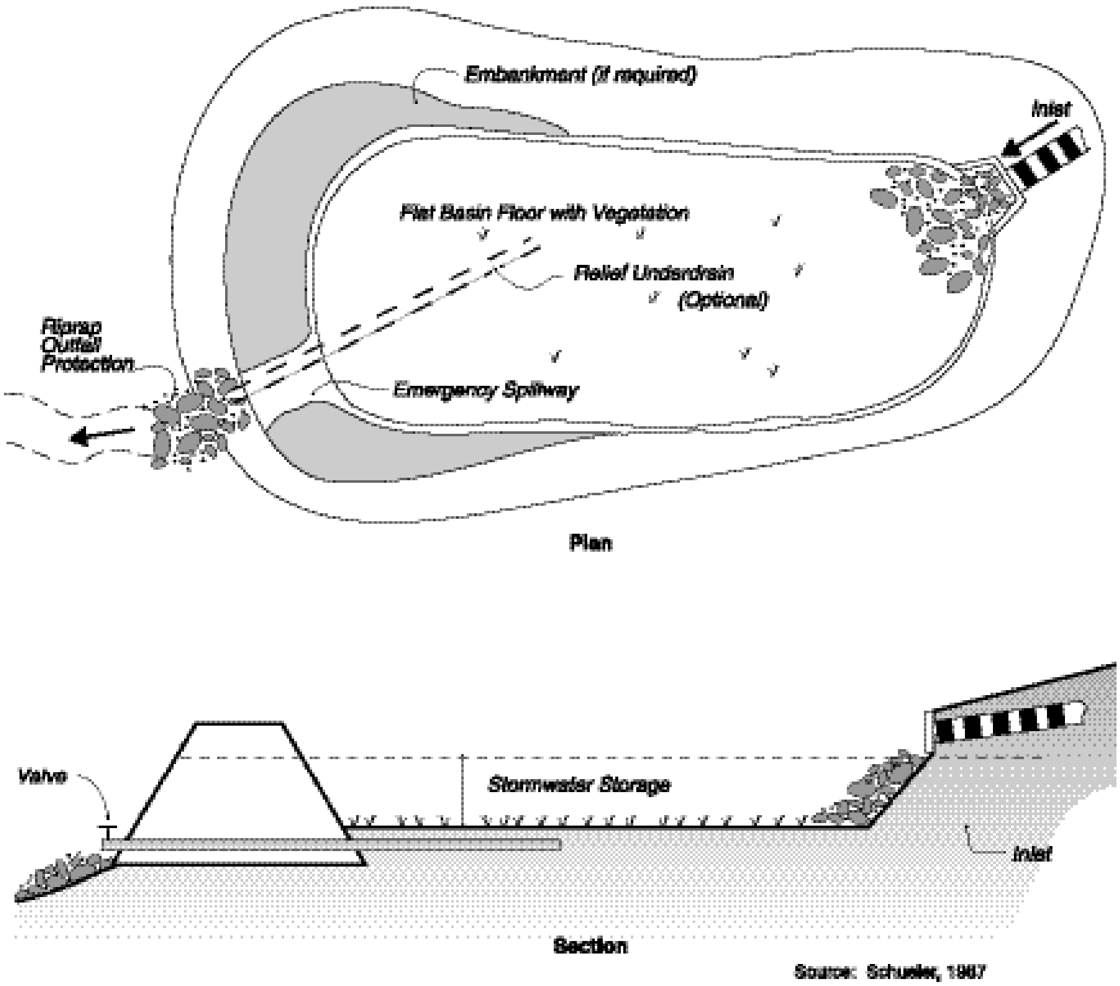

Figure 5-14. INFILTRATION BASIN

Design Criteria and Procedure

Principal design criteria for INBs are listed in Table 5-12.

Table 5-12. Infiltration Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	40
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 40-h drawdown
Bottom Basin Elevation	ft	5 feet above seasonally high groundwater table minimum.
Freeboard (minimum)	ft	1.0
Setbacks	ft ft.	100 feet from wells, tanks, fields, springs 20 feet down slope or 100 feet up slope from foundations
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Embankment side slope (H:V)	–	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete
Vegetation	–	Side slopes and bottom (may require irrigation during summer)

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u /12) \times Area$$

   where

   Area = Watershed area tributary to INB

2. Basin Surface Area — Calculate the minimum surface area of the infiltration system:

   $$A_m = V/D_m$$

where:

A_m = minimum area required (ft^2)

V = volume of the infiltration basin (ft^3)

D_m= maximum allowable depth (ft)

where:

D_m= tI/12s

and: I = site infiltration rate in (in/hr)

s = safety factor

t = minimum drawdown time = 40 hours

In the formula for maximum allowable depth, the safety factor accounts for the possibility of inaccuracy in the infiltration rate measurement. The less certain the infiltration rate the higher the safety factor shall be. Minimum safety factors shall be as follows:

- Without site-specific borings and percolation tests, use s=10
- With borings (but no percolation test), use s=6
- With percolation test (but no borings), use s=5
- With borings and percolation test, use s=3

3. Inline/Offline — Basins may be on-line or off-line with flood control facilities. For on-line basins, the water quality outlet may be superimposed on the flood control outlet or may be constructed as a separate outlet.

4. 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.

5. Embankments — Design embankments to conform to requirements State of California Division of Safety of Dams, 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.

6. Access — All-weather access to the bottom, forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete. Provide security fencing, except when used as a recreation area.

7. 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 Ventura County Flood Control District.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-9: Infiltration Basin

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = 100 %
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} = 100 %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u= 0.95 in.
d. Watershed Area Tributary to DBSF	Area = 0.2 acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV = 0.0158 acre-ft
2. Maximum Allowable Depth ($D_m = tI/12s$)	
a. Site infiltration rate (I)	I = 2.0 in/hr
b. minimum drawdown time (t = 40 hours)	t = 40 hrs
c. safety factor (s)	s = 3
d. $D_m = tI/12s$	D_m = 2.22 ft.
3. Basin Surface Area A_m = SQDV / D_m	A_m = 310 ft^2
4. Vegetation (Check type used or describe "Other")	_X_ Native Grasses ____ Irrigated Turf Grass ____ Other

Notes:

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Maintenance Requirements

The following maintenance requirements apply to Infiltration Basins.

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the governing agency may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the governing agency'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
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Inspect a minimum of twice a year, before and after the rainy season, after large storms, or more frequently if needed.
- Clean when loss of infiltrative capacity is observed. If drawdown time is observed to have increased significantly over the design drawdown time, removal of sediment may be necessary. This is an expensive maintenance activity and the need for it can be minimized through prevention of upstream erosion.
- Mow, as appropriate for vegetative cover species.
- Monitor health of vegetation and replace as necessary.
- Control mosquitoes as necessary.
- Remove litter and debris from INB area as required.

Description

An Infiltration Trench (INT) consists of subsurface gravel and sand bed constructed in naturally pervious soils (Type A or B soils) where runoff is stored until it infiltrates into the soil profile. Upstream control measures such as Turf Buffers (see G-5.1), Grass-lined Channels(see G-5.2), Grass Strip Filters (see T-1, or Grass Swales Filters (see T-2), are typically combined with INTs to provide sediment removal upstream of the INT. The trench is designed to retain and infiltrate the SQDV over a specified period of time (40 hours). A screened overflow pipe or outlet should be provided to convey runoff in excess of the SQDV to downstream drainage. An observation well constructed of perforated PVC pipe should be provided to allow the depth of water in the trench to be monitored. Typical elements of an INT system are shown in Figure 5-15. Infiltration vaults and leach fields are variations of the infiltration trench concept in which runoff is distributed to upper zone of the subsurface gravel bed by means of perforated pipes. Illustrations of infiltration vaults and leach fields are shown in Figure 5-16 and 5-17, respectively.

General Application

Infiltration trenches are typically used to serve areas less than 10 acres and are usually combined with upstream treatment control measures to reduce sediment load to the INT. For example, INTs are commonly used in combination with Turf Buffers to treat runoff from parking lots or other paved areas as illustrated in Figure 5-15. Infiltration trenches are easily incorporated into the landscape features of development sites.

Advantages/Disadvantages

General

In addition to removing pollutants effectively, infiltration trenches, like infiltration basins, also control runoff volume, which may serve to reduce downstream bank erosion in watercourses.

The primary disadvantage of an infiltration trench, as for any infiltration device, is the potential for clogging if excessive sediment is allowed to flow into the facility. The cost of restorative maintenance can be high if soil infiltration rates are significantly reduced due sediment deposition.

Also, there is a risk of groundwater contamination in very coarse soils since coarse soils do not effectively remove dissolved pollutants. This may require groundwater monitoring. INTs cannot be put into operation until the upstream tributary area is stabilized.

Site Suitability

INBs cannot be placed on fill or unstable sites. Also, INBs should not be placed in high-risk areas such as service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk.

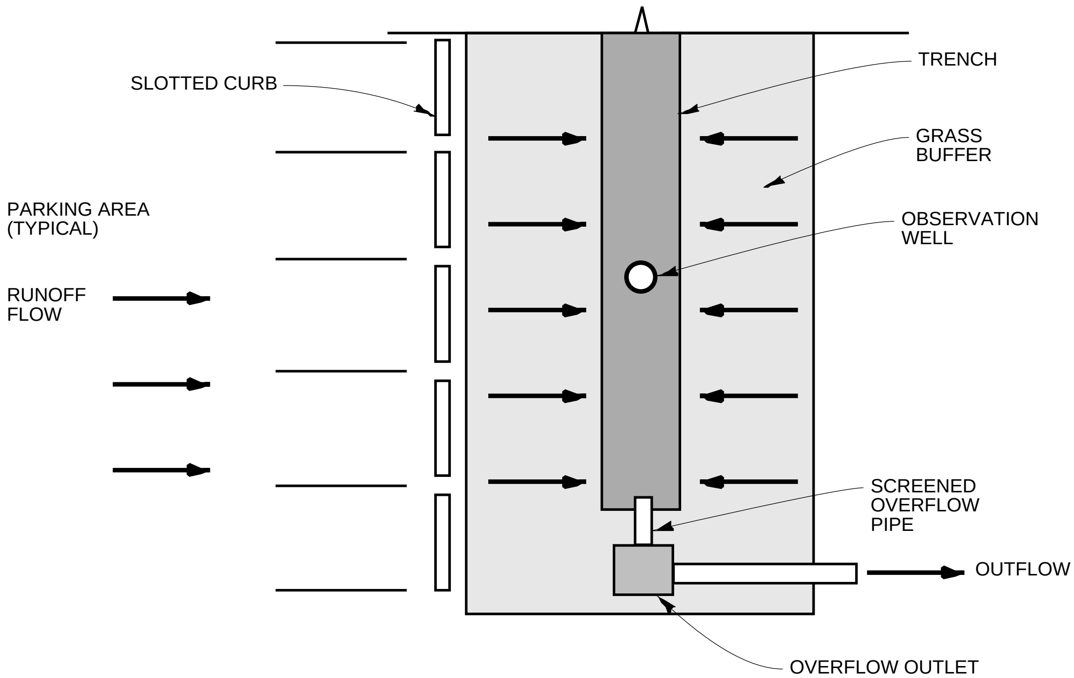
Before exploring the use of infiltration treatment control measures preliminary soil investigations, including a percolation test, shall be performed to assess whether the soils on site have an extended infiltration rate of at least 0.5 inches per hour. Separate on-site infiltration systems from the groundwater table (or bedrock) by a minimum of 5 feet vertically to provide sufficient infiltration volume within the soil. Tributary area should have a low potential for erosion. Other suitability considerations include the soil makeup (Appendix E), site topography, and the location of other facilities.

Infiltration facilities shall be sited at least 50 feet away from slopes steeper than 15 percent. Adequate spacing (100 feet or more) shall be provided between infiltration facilities and non-potable wells, tanks, drain fields and springs. For separation between infiltration BMPs and potable water supply wells, follow Department of Health Services requirements in the Guidelines for Location of Water Wells. INTs shall also be sited at least 20 feet down slope or 100 feet up slope from building foundations. A geotechnical expert shall be consulted when necessary to verify appropriate placement on site.

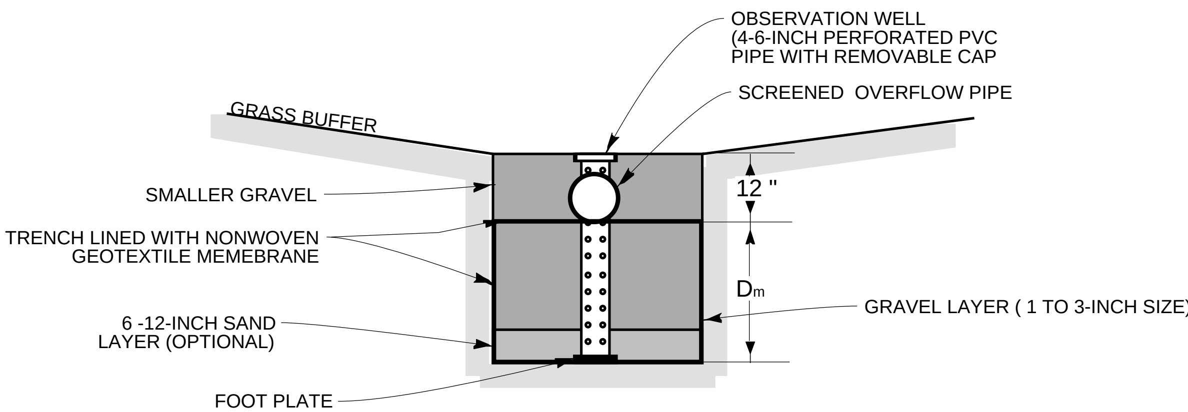
An important consideration for all infiltration facility configurations is that, during construction, great care must be taken not to reduce the infiltration capacity of the soil in the facility through compaction or by using the infiltration area as a sediment trap. Infiltration facilities shall be constructed late in the site development after soils (that might erode and clog the units) have been stabilized, or shall be protected until the site is stabilized.

Pollutant Removal

The amount of pollutant removed by INTs should be significant and should equal or exceed the removal rates provided by sand filters. In addition to settling, infiltration basins provide filtering, adsorption, and biological uptake of constituents in stormwater. Relative pollutant removal effectiveness is indicated in Table 5-1.



PLAN VIEW



SECTION VIEW

Figure 5-15. IINFILTRATION TRENCH

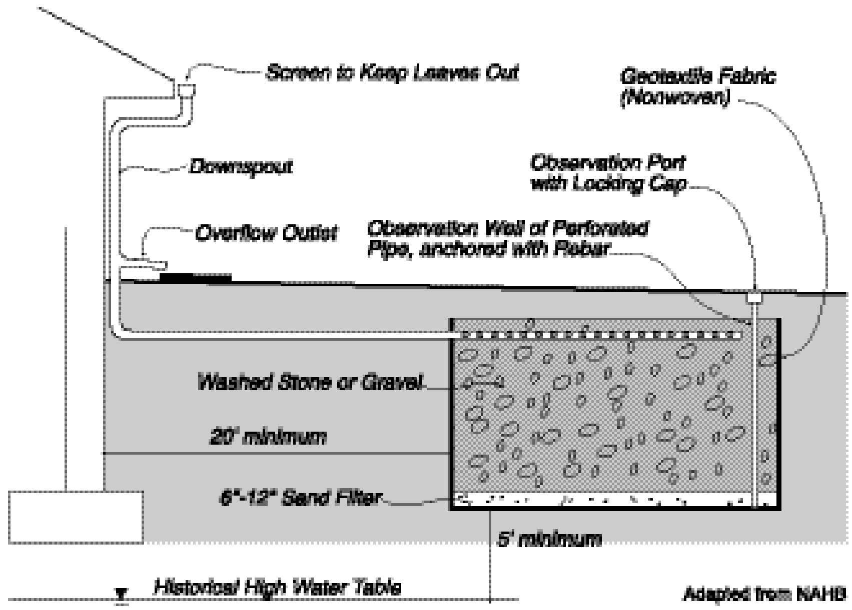


FIGURE 5-16. INFILTRATION VAULT

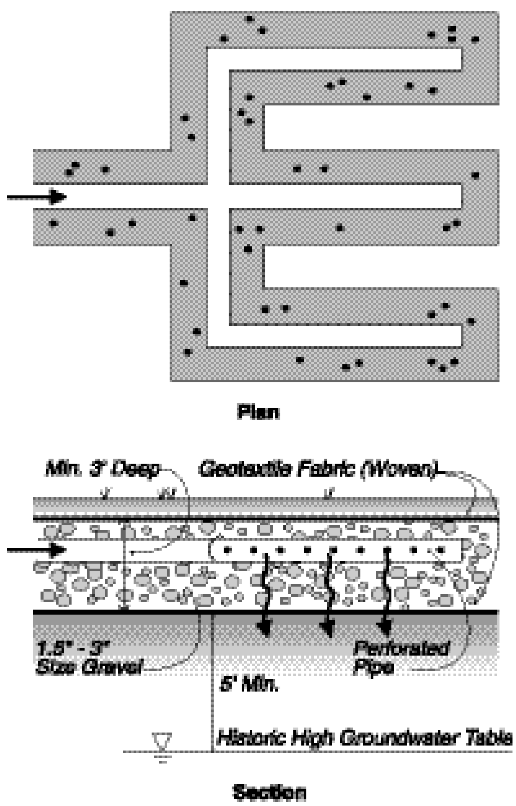


FIGURE 5--17. LEACH FIELD

Design Criteria and Procedure

Principal design criteria for INTs are listed in Table 5-13. These criteria also apply to vaults and leach fields

Table 5-13. Infiltration Trench Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	40
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 40-h drawdown
Trench bottom elevation	ft	5 feet above seasonally high groundwater table minimum.
Trench surcharge depth (D_m)	ft	D_m = ≤ 8.0 ft
Gravel bed material	ft	Clean, washed aggregate 1 to 3 inches in diameter
Trench lining material	–	Geotextile fabric (see Table 5-7)
Setbacks	ft ft.	100 feet from wells, tanks, fields, springs 20 feet down slope or 100 feet up slope from foundations Do not locate under tree drip-lines

Design procedure and application of design criteria are outlined in the following steps:

1. Trench Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u / 12) \times Area$$

   where

   Area = Watershed area tributary to INB

2. Trench Water Depth — Calculate the maximum allowable depth of water surcharge in the trench. Maximum depth should not exceed 8 feet.:

   $$D_m = tI/12s$$

   where I = site infiltration rate in (in/hr)

   s = safety factor

   t = minimum drawdown time = 40 hours

In the formula for maximum allowable depth, the safety factor accounts for the possibility of inaccuracy in the infiltration rate measurement. The less certain the infiltration rate the higher the safety factor shall be. Minimum safety factors shall be as follows:

- Without site-specific borings and percolation tests, use s=10
- With borings (but no percolation test), use s=6
- With percolation test (but no borings), use s=5
- With borings and percolation test, use s=3

3. Trench Surface Area — Calculate the minimum surface area of the trench bottom:

$$A_m = V/D_m$$

where:

A_m = minimum area required (ft^2)

V = SQDV (ft^3)

D_m = maximum allowable depth (ft)

4. Observation Well — Provide a vertical section of perforated PVC pipe, 4 to 6 inches in diameter, installed flush with top of trench on a foot plate and with a locking, removable cap.

5. 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 grated overflow outlet.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-10: Infiltration Trench

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	70	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	66	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	0.68	in.
d. Watershed Area Tributary to DBSF	Area =	0.5	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	0.028	acre-ft
2. Maximum Allowable Depth ($D_m = tI/12s$)			
a. Site infiltration rate (I)	I =	3.0	in/hr
b. minimum drawdown time (t = 40 hours)	t =	40	hrs
c. safety factor (s)	s =	3	
d. $D_m = tI/12s$	D_m =	3.33	ft.
3. Trench Bottom Surface Area			
A_s = SQDV / D_m	A_s =	366	ft^2

Notes:

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Maintenance Requirements

The following maintenance requirements apply to Infiltration Trenches.

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the governing agency may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the governing agency'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
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

- Inspect a minimum of twice a year, before and after the rainy season, after large storms, or more frequently if needed.
- Clean when loss of infiltrative capacity is observed. If drawdown time is observed to have increased significantly over the design drawdown time, removal of sediment may be necessary. This is an expensive maintenance activity and the need for it can be minimized through prevention of upstream erosion.
- Mow, as appropriate for vegetative cover species.
- Monitor health of vegetation and replace as necessary.
- Control mosquitoes as necessary.
- Remove litter and debris from INT area as required.

Description

A media filter (MF) is a two-stage constructed treatment system, including a pretreatment settling basin and a filter bed containing sand or other filter media. Media filters are typically concrete vault structures with a solid wall or baffle wall separating the sediment chamber from the filter bed. The filter bed is supported by a gravel base course and is underdrained with perforated pipe.

This section provides design information for three types of media filters that are named after the area of the country where they were developed:

- T11.1: Austin Sand Filter System – large units, above or below surface, used in large drainage areas (up to 50 acres).
- T-11.2: DC Underground Sand Filter – underground line system used for small drainage areas (up to 1.5 acres); receives concentrated flows.
- T-11.3: Delaware (Linear) Sand Filter - situated along perimeter of small drainage area (up to 5 acres); receives sheet or concentration flows; can be used in areas of high ground water.

Due to size constraints, media filters are designed to only treat the SQDV. Diversion structures are used to route storm volumes in excess of the SQDV around the filter (see Appendix B).

General Application

Media Filters are generally suited to offline, onsite configurations where there is no base flow and the sediment load is relatively low. Media Filters remove particulate and floatable materials and are appropriate for drainage areas of up to 100 acres. Media filters are well suited to Southern California because they do not require vegetation and require less space than other treatment control measures with similar removal efficiencies when a partial treatment sedimentation basin is used. The effectiveness of the MF was proven in the City of Austin, where they are widely used today.

Selection of a unit configuration for a MF depends on the size of the drainage area and the facility location. Land uses for which MF are appropriate include residential, commercial, institutional, and industrial, except for extractive, chemical/petroleum, food and printing. A MF is not appropriate for agricultural sites or other areas with expanses of erosive soil upstream of the unit.

For large watersheds, i.e., 50 to 100 acres, an Austin sand filter is recommended. For small catchments requiring underground facilities, a DC sand filter is recommended. Delaware sand filters are especially suitable for paved sites and industrial sites because they can be situated to accept sheet flow from adjacent pavement.

To operate effectively, the filter media must be protected against clogging caused by excessive sediment or highly turbid waters. Placing a settling basin upstream of the filter provides this protection. For this reason, filters should not be put into operation while construction activities are taking place in the tributary catchment.

Advantages/Disadvantages

General

Primary advantages of MFs include effective water quality enhancement through settling and filtering. They also require less space than other treatment practices and can be located underground. Media Filters may be used when there is a lack of water for irrigation or base flow and it is infeasible to use a wet detention basin, wetlands or biofilter, which could be advantageous for Southern California.

The primary disadvantage of MFs is the potential for clogging. Although settling basins or other control measures effective for sediment removal, such as Grass Strip Filters or Grass Swale Filters, placed upstream of the filter will reduce this potential. Other disadvantages include significant head loss that may limit use on flat sites.

Site Suitability

Media Filter systems are designed to function by gravity. For systems located at sites without sufficient vertical relief to operate the filter by gravity, the design must be augmented to include a clear well and pumps to lift the stormwater from the settling basin to the filter. Note, costs for maintenance increase significantly when pumping is employed.

Because an underdrain system is incorporated into its design, MFs are suited for most soil conditions ; presence of sandy soils is not a requirement. This BMP has a relatively flat surface area, so it may be more challenging to incorporate it into the steeply sloping terrain. MFs should not be located close to construction sites or close to building foundations or areas where expansive soils are a concern.

Pollutant Removal

Media Filters effectively remove sediment and pollutants associated with sediment. Relative pollutant removal effectiveness of MFs is presented in Table 5-1.

Design Criteria and Procedure

T-11.1: Austin Sand Filter

There are two possible filter configurations used by Austin that may be considered.

- Full Sedimentation

  In this configuration, sedimentation occurs in a settling basin designed to hold the entire SQDV and release it to the filter over an extended draw-down time (40 hours). (See Figure 5-18 for typical configuration).

- Partial Sedimentation

  In this configuration, the settling basin holds a minimum of 20% of the water quality volume and does not incorporate an extended draw-down period. This removes the heavier sediment and large trash only and requires more intensive maintenance than the full sedimentation system. A larger filter surface area will be required to compensate for the more rapid clogging of the filter.

Design criteria for partial sedimentation are not included in this manual due to the increased maintenance required for this type of control measure. This configuration will only be considered when it is adequately shown that space limitations will not allow full sedimentation, and other control measures recommended in this manual are not viable alternatives.

<u>Settling Basin Design</u>

Settling basin design criteria for Austin Sand Filters are summarized in Table 5-14.

Table 5-14. Austin Sand Filter Sedimentation Basin Design Criteria

Design Parameter	Unit	Design Criteria
Maximum drainage area	acres	100
Minimum basin depth	ft	3.0
Minimum surface area (A_s)	ft^2	SQDV ÷ 10 ft
Length to width ratio, L:W	–	2:1 or greater
Minimum draw-down time	hrs	40
Freeboard	ft	1.0 ft above maximum water surface elevation
Minimum basin volume	ft^3	SQDV + freeboard volume
Maximum inlet velocity	fps	3.0
Minimum particle sized removed	micron	20 (specific gravity = 2.65)

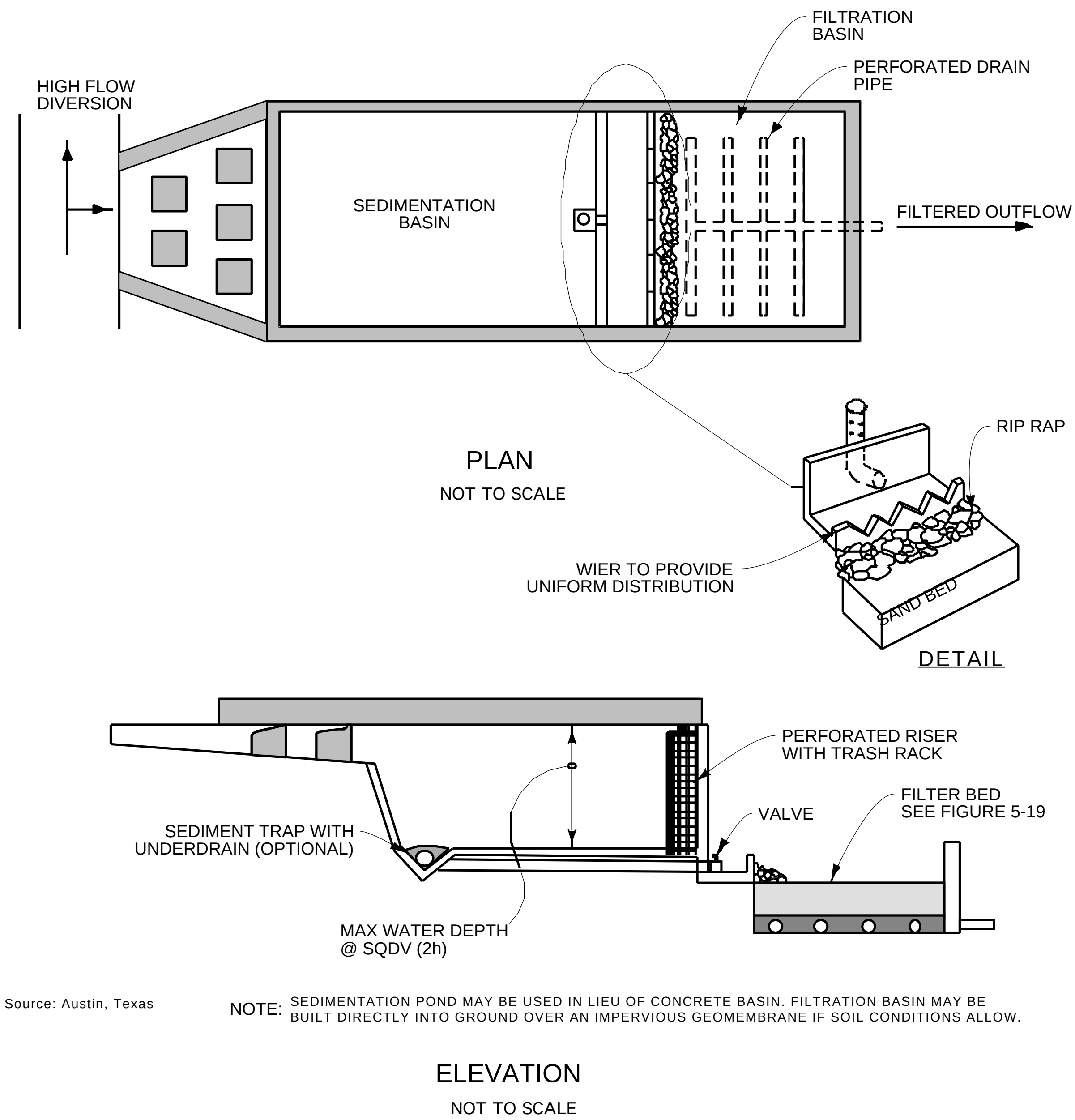

FIGURE 5-18. AUSTIN SAND FILTER

Design procedure and application of design criteria for Austin Filter Sedimentation Basin are outlined in the following steps:

1.Basin Storage Volume

Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin.

a. Determine the percent imperviousness of the tributary area (I_a).

b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

d. Calculate the SQDV in acre-ft as follows:

$$SQDV = (V_u / 12) \times Area$$

where

Area = Watershed area tributary to Media Filter

2. Inlet/Outlet Design

Basin inlet and outlet points should provided with an energy dissipation structure and/or erosion protection. Energy dissipation devices may be necessary in order to reduce inlet velocities that exceed three (3) feet per second.

3. Basin Shape

Whenever possible, 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 will improve basin performance and reduce maintenance requirements.

Short circuiting (i.e., flow reaching the outlet structure before it passes through the sedimentation basin volume) flow should be avoided. Dead storage areas (areas within the basin which are by-passed by the flow regime and are, therefore, ineffective in the settling process) should be minimized. The length to width ratio should be a minimum of 2:1. Internal baffling with berms may be necessary to achieve this ratio and could be used to mitigate short-circuiting and/or dead storage problems.

4. 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 to use of 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 controls orifices.

5. Sediment Trap (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 filtration basin. The minimum grading of the piping to the filtration basin should be 1/4 inch per foot (two percent slope). Access for cleaning the sediment trap drain system is necessary.
6. Settling Basin Liner	If an impermeable liner is required to protect ground water quality it shall meet the specifications for clay liner given in Table 5-20. The clay liner should have a minimum thickness of 12 inches. If an impermeable liner is not required then a geotextile fabric liner shall be installed that meets the specifications listed in Table 5-17 unless the basin has been excavated to bedrock. If a geotextile liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant.

Filter Basin Design

Filter basin design criteria for Austin Sand Filters are summarized in Table 5-15.

Table 5-15. Austin Sand Filter Basin Design Criteria

Design Parameter	Unit	Design Criteria
Minimum gravel depth over sand filter	inches	2.0
Minimum water depth over filter, h	ft	3.0
Minimum sand depth, d_f	inches	18.0
Minimum filtration rate of filter, k	ft/d	3.5
Slope of sand filter surface	%	0
Minimum gravel cover over underdrain	inches	2
Sand size, diameter	inches	0.02 – 0.04
Under drain gravel size, diameter	inches	0.5 – 2.0
Minimum inside diameter underdrain	inches	6.0
Underdrain pipe type	–	PVC schedule 40 (or thicker)
Minimum slope of underdrain	%	1.0
Minimum underdrain peroration, diameter	inches	0.375
Minimum perorations per row	–	6
Minimum space between perforation rows	inches	6
Maximum drawdown time, t_f	hr	40.0
Minimum gravel bed depth, d_g	inches	16

Design procedure and application of design criteria for Austin Filter Sedimentation Basin are outlined in the following steps:

1. Maximum Water Depth — Determine maximum allowable depth of water (2h) in the sedimentation basin considering elevation differences between inlet and outlet invert elevations of sedimentation basin and filter surface elevation. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices.)

2. Filter Surface Area — Surface area is the primary design parameter, and is a function of sand permeability, bed depth, hydraulic head and sediment loading. The required filter surface area (A_f) can be calculated using the following equation and design criteria provided in Table 5-16

$$A_{fm} = \frac{(SQDV)(d_f)}{k(h + d_f)(t_f)}$$

Where: WQV = SQDV, cf

A_{fm} = filter surface area, ft^2

d_f = sand bed depth, ft

k = coefficient of permeability for sand filter (ft./hr.)

h = one-half of maximum allowable water depth (2h) over filter, ft.

t_f =t ime required for runoff volume to pass through filter, hrs.

2. Filter Basin 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.

3. 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.

4. Filter Bed — The sand bed may be a choice of one of the two configurations given below. Note: Sand bed depths are final, consolidated depths. Consolidated effects must be taken into account.

1) Sand Bed with Gravel Layer (Figure 5-19A)

The sand layer is a minimum depth of 18 inches consisting of 0.02-0.04 inch diameter sand. Under the sand is a layer of 0.5 to 2.0-inch diameter gravel which provides a minimum of two 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 5-16 must separate the sand and gravel and must be used to be wrap around the lateral pipes.

Drainage matting meeting the specifications in table 5-17 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 5-18.

2) Sand Bed - Trench Design (Figure 5-19B)

The top layer shall be 12-18 inches of 0.02-0.04 inch diameter sand. Laterals shall be placed in trenches with a covering of 0.5 to 2.0-inch gravel and geotextile fabric (see Table 5-16). The laterals shall be underlain by a layer of drainage matting (see Table 5-17).

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 5-18.

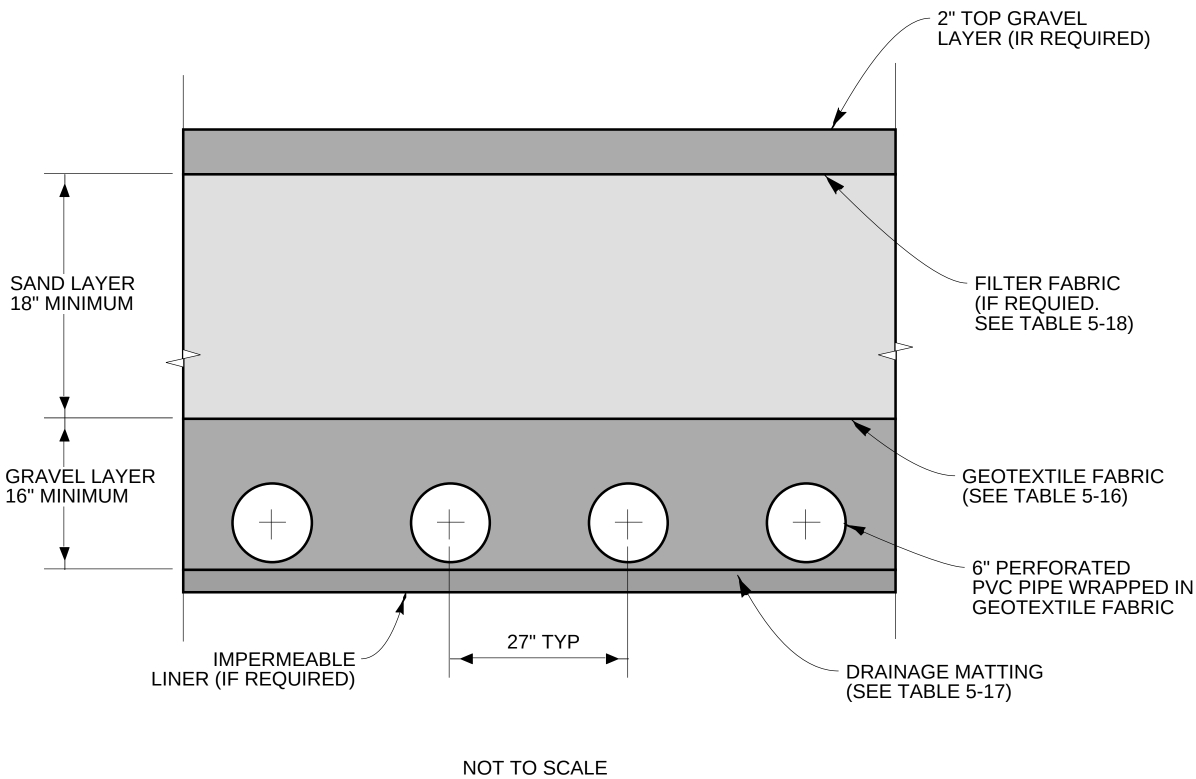

FIGURE 5-19A. FILTER BED WITH GRAVEL UNDERDRAIN

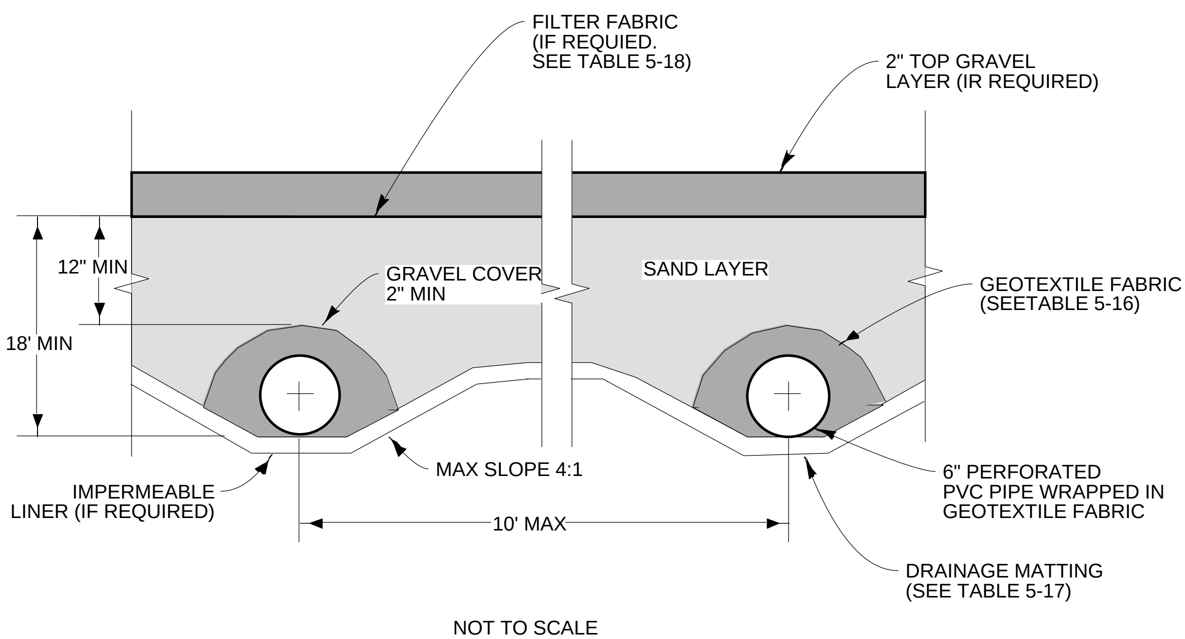

FIGURE 5-19B. FILTER BED WITH TRENCH UNDERDRAIN

Table 5-16. Geotextile Fabric Specifications

Property	Test Method	Unit	Specification
Material			Nonwoven geotextile fabric
Unit Weight		Oz./Sq.yd.	8 (min.)
Filtration Weight		In/Sec	0.08 (min.)
Puncture Strength	ASTM D-751 (Modified)	Lb.	125 (min.)
Mullen Burst Strength	ASTM D-751	PSI	400 (min.)
Tensile Strength	ASTM-D-1682	Lb.	300 (min.)
Equiv. Opening Size	US Standard Sieve	No.	80 (min.)

Table 5-17. Drainage Matting Specifications

Property	Test Method	Unit	Specification
Material			Nonwoven geotextile fabric
Unit Weight		Oz/Sq.yd.	20
Flow Rate (fabric)		GPM/ft.	180 (min.)
Permeability	ASTM D-2434	Cm/Sec.	12.4×10^{-2}
Grab strength (fabric)	ASTM D-1682	Lb.	Dry Lg. 90 Dry Wd:70 Wet Lg.95 Wet Wd: 70
Puncture strength (fabric)	COE CW-02215	Lb.	42 (min.)
Mullen burst strength	ASTM D-1117	Psi	140 (min.)
Equiv. opening size	US Standard Sieve	No.	100 (70-120)
Flow rate (drainage core)	Drexel Univ. Test Method	GPM/ft. width	14

Source: City of Austin

Table 5-18. Filter Fabric Specifications

Property	Test Method	Unit	Specification
Material			Non-woven geotextile fabric
Unit Weight		Oz./Sq.yd.	4.3 (min.)
Flow rate		gpm/ft^2	120 (min.)
Puncture Strength	ASTM D-751 (Modified)	Lb.	60 (min.)
Thickness		in.	0.8 (min.)

5. 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 .5% are acceptable with prior approval). Access for cleaning all underdrain piping is needed.

Note: No draw-down time is to be associated with sand filtration basins, only with sedimentation basins. Thus, it is not necessary to have a specifically designed orifice for the filtration outlet structure.

6. Filter Basin Liner

If an impermeable liner is required to protect ground water quality it shall meet the specifications for clay liner given in Table 5-19. The clay liner should have a minimum thickness of 12 inches. If an impermeable liner is not required then a geotextile fabric liner shall be installed that meets the specifications listed in Table 5-16 unless the basin has been excavated to bedrock. If a geotextile liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant.

Table 5-19. Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm./sec.	1×10^{-6}
Plasticity Index of Clay	ASTM D-423 & D-424	%	Not less than 15
Liquid Limit of Clay	ASTM D-2216	%	Not less than 30
Clay Particles Passing	ASTM D-422	%	Not less than 30
Clay Compaction	ASTM D-2216	%	95% of Standard Proctor Density

Source: City of Austin

<u>Design Example</u>

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-11.1: Austin Sand Filter

Designer:______________________________

Company:______________________________

Date:______________________________

Project:______________________________

Location:______________________________

Step			
1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	68	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	60	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	0.64	in.
d. Watershed Area Tributary to DBSF	Area =	2.31	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	0.123	acre-ft
2. Maximum Water Depth			
a. Storm drainage system invert elevation at proposed connection to storm drain	Inlet Elevation	90	ft
b. Minimum control measure outlet invert elevation of sand filter at minimum grade:	Outlet Elevation	90.75 @ 1%	ft
c, Estimate filter depth or use minimum depth of filter media and determine the difference in elevation between inverts of filter inlet and outlet:	Filter Depth	97.5	ft
d. Site plan surface elevation at control measure location	Surface Elvation	103.0	ft
e. Determine inlet invert elevation into sedimentation basin	Inlet Elevation (Sed. Basin)	100.0	ft
f. Determine maximum allowable depth of water (2h) in the sedimentation basin considering elevation differences between inlet and outlet invert elevations of sedimentation basin and filterand surface elevation. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices.)	Maximum Allowable Depth	3.0	ft

Design Procedure Form for T-11.1: Austin Sand Filter (Page 2 of 2)

Project:____

3. Filter Surface Area			
a. Sand Bed Depth	d_f =	1.5	ft
b. Coefficient of permeability for sand filter	k =	0.1458	ft. / hr.
c. One half of maximum allowable depth over filter. (h)	h =	1.5	ft
d. Time required for runoff to pass through filter.	t_f =	40	hrs.
e. Filter Surface Area (minimum)	A_{fm} =	459	ft^2
$A_{fm} = \frac{(SQDV)(d_f)}{k(h + d_f)(t_f)}$			
4. Filter Basin Volume			
Filter Basin Volume = 0.2 x SQDV	FBV =	1,072	ft^3

Notes:

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T-11.2: DC Filter

The District of Columbia (D.C.) Environmental Regulation Administration developed an underground stormwater sand filter (referred to as the D.C. Sand Filter) contained in a structural shell with three chambers (see Figure 5-20). The shell may consist of precast or cast-in-place concrete.

The plunge pool in the first chamber and the throat of the second chamber, which are hydraulically connected by an underwater rectangular opening, absorbs energy and provides pretreatment, trapping grit and floating organic material such as oil, grease, and tree leaves. The second chamber contains a typical sand filter with a subsurface drainage system consisting of perforated PVC pipe in a stone bed. The third chamber, or clearwell, collects the flow from the underdrain pipes, and overflow pipes when installed, and directs the waters to the storm drainage system. A hooded large storm bypass pipe directly connecting the first chamber with the clearwell is illustrated in Figure 5-21. When storm flows are diverted upstream of the sediment chamber, an in-system overflow or bypass is neither necessary nor desired.

A major advantage of the D.C. sand filter is that it does not take up any space on the surface. It can be placed under on-site roadways (e.g., not public rights of way), parking lots, or sidewalks, and under planting spaces adjacent to buildings. The system works best for watersheds of approximately one acre of impervious surface. For larger watersheds, two or more DC sand filters will be required.

The load-carrying capacity of the filter structure must be considered when it is located under parking lots, driveways, roadways, and certain sidewalks (such as those adjacent to State highways). Traffic intensity may also be a factor. The structure must be designed by a licensed structural engineer. The effects of buoyancy must be considered in the design of an underground vault in areas with high ground water.

For cost, reliability, and maintenance considerations, it is preferable that the filter work by gravity flow. This requires sufficient vertical clearance between the invert of the prospective inflow storm piping and the invert of the storm drain which will receive the outflow.

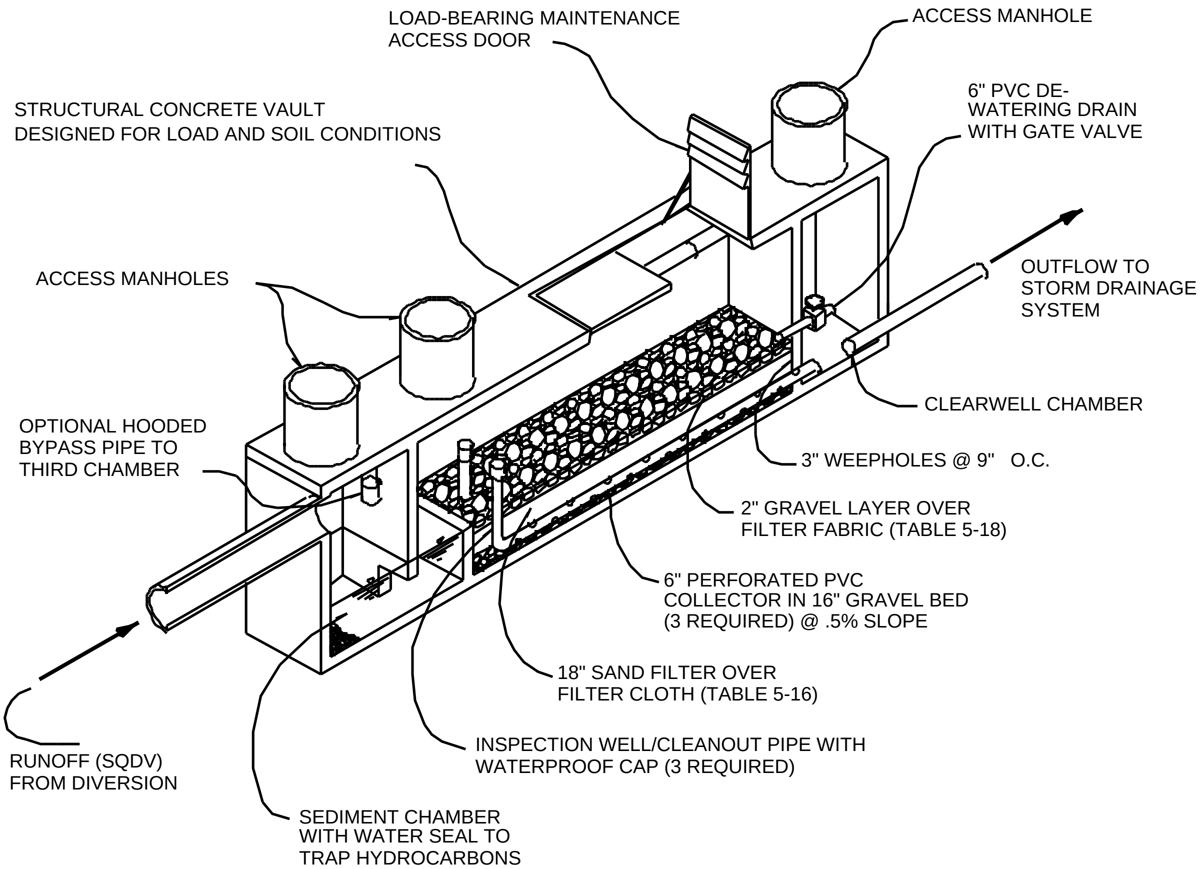
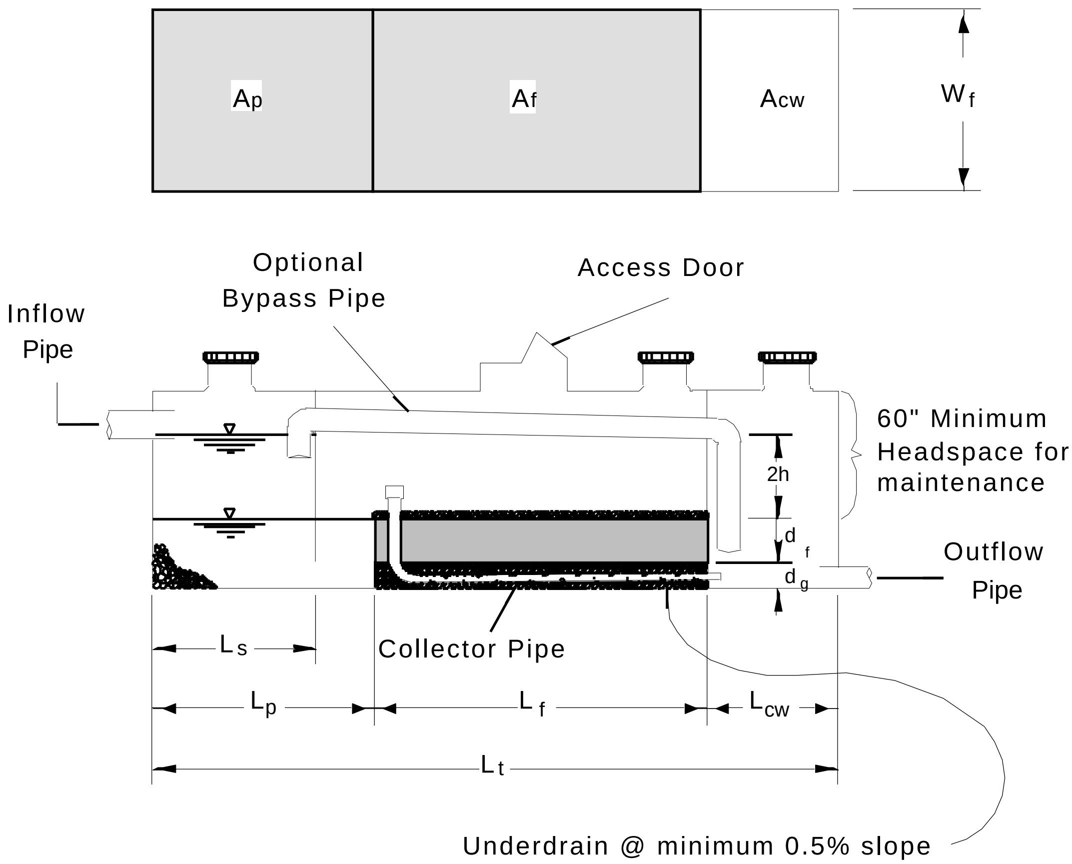


FIGURE 5-20. DC SAND FILTER



Where:

- A_p = Area of sediment chamber
- A_f = Area of sand filter
- A_{cw} = Area of clearwell
- W_f = Width of filter
- L_s = Minimum length of sediment chamber
- L_p = Final length of permanent pool
- L_f = Filter length
- L_{cw} = Length of clearwell
- L_t = Total length, sum of $L_p + L_f + L_{cw}$
- 2h = Maximum achievable ponding depth over filter
- d_f = sand bed depth
- d_g = gravel depth

Figure 5-21. DIMENSIONAL RELATIONSHIPS FOR DC SAND FILTER

Design Criteria

Principal design criteria for DC Sand Filters are summarized in Table 5-20.

Table 5-20. DC Sand Filter Design Criteria

Design Parameter	Unit	Criteria Value
Maximum drainage area	acres	1.5
Maximum draw down time in filter, t_f	hrs	40
Minimum gravel depth over filter media	in.	2.0
Minimum sand filter depth, d_f	in.	18
Minimum gravel depth below filter, d_g	in.	16
Minimum cover of gravel over underdrain pipe	in.	2
Filter coefficient, k	ft/day	2
Minimum volume of SQDV to be contained in sediment chamber	%	20
Minimum slope of underdrain	%	1
Maximum diameter of upper level gravel cover	in.	1
Minimum length of clearwell, L_{cw}	ft.	3.0
Filter sand sizing	—	ASTM C 33 concrete sand
Minimum size diameter gravel in underdrain	in.	0.5 to 2
Minimum size underdrain pipe	—	6" Sch 40 reinforced PVC pipe
Minimum size diameter perforation in drainage pipe	in.	3/8
Minimum number of perforation holes per underdrain pipe	—	6
Maximum spacing between perforation holes	in.	6
Maximum spacing of underdrain pipes	in.	27 (center to center)

Design Procedure

Design procedure and application of design criteria for DC Sand Filter are outlined in the following steps (see Figure 5-21 for dimensional relationships):

1. Maximum Water Depth — Determine maximum allowable depth of water (2h) in the filter basin considering elevation differences between inlet and outlet invert elevations. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices).
2. Sand Filter Area — Determine the minimum area of the DC Filter using the Austin Filter Formula for partial sedimentation treatment.

$$A_{fm} = \frac{(SQDV)(d_f)}{k(h + d_f)(t_f)}$$

where:

A_{fm} = filter surface area, ft^2

d_f = sand bed depth, ft

k = filter coefficient @ 0.0833 ft./hr.

h = one-half of maximum allowable water depth (2h), ft.

t_f = 40 h draw-down time

3. Filter Width / Length — Considering site constraints, select a Filter Width (W_f). Then compute the Filter Length (L_f) using the minimum area required (A_{fm}).

$L_f = A_{fm}/W_f$

Round the length and determine adjusted area, Af.

$A_f = W_f \times L_f$

(After Note: From this point, formulas assume rectangular cross section of filter shell.)

4. Storage Volume
   a. above filter (V_{tf}) — $V_{tf} = A_f \times 2h$
   b. in filter voids (Vv) — $V_v = A_f \times (d_f + d_g) \times (0.4)$ {assume 40% voids}

5. Flow Through Filter During Filling (V_Q) — $V_Q = k \times A_f \times (d_f + d_g) \times t_f / d_f$

   Use: k = 2 ft/day = 0.0833 ft/hr.

   t_f = 1 hr. to fill voids

6. Net Volume to be Stored in Sediment Chamber Awaiting Filtration (Vst) — $V_{st} = SQDV - V_{tf} - V_v - V_Q$

7. Minimum Length of Permanent Pool (L_{pm}) — $L_{pm} = V_{st} /(2h)(W_f)$ {See Figure 5-21 for dimensional relationships}

8. Minimum Length of Sediment Chamber (L_s)
   a. If $V_{st} > (0.2SQDV)$ — use: $L_s = V_{st} /(2h)(W_f)$
   b. If $V_{st} < (0.2SQDV)$ — use: $L_s = 0.2SQDV /(2h)(W_f)$

   Note: It may be economical to adjust final dimensions to correspond with standard precast structures or to round off to simplify measurements during construction.

9. Final Length of Permanent Pool (L_p)
   a. If L_{pm} , < (L_s + 2) — use: $L_p = L_{pm}$
   b. If L_{pm} , > (L_s + 2) — use: $L_p = (L_s + 2)$

10. Length of Clearwell (L_{cw})	Set the length of the clearwell (L_{cw}) for adequate maintenance and/or access for monitoring flow rate and chemical composition of effluent (minimum 3 ft.).
11. Filter Bed	
a. Top Gravel Layer	The washed gravel layer at the top of the filter should be two inches thick composed of stone 0.5 inch to 2.0 inch diameter in size. In areas with high sediment load (TSS concentration >200 mg/L), the two-inch layer of stone on top of the sand filter should be underlain with filter fabric meeting the specifications in Table 5-19.
b. Sand Layer	The sand layer should be a minimum depth of 18 inches consisting of ASTM C33 concrete sand. A layer of geotextile fabric meeting the specifications in Table 5-16 must separate the sand and gravel layer below.
c. Gravel Layer	The gravel layer surrounding the collector pipes should be at least 16 inches thick and be composed of 0.5 to 2-inch diameter stone and provide at least two inches of cover over the tops of the drainage pipes.
12. 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)(Note: slopes down to 0.5% are acceptable with prior approval). Access for cleaning all underdrain piping is needed.
13. Weep Holes	In addition to the underdrain pipes, weepholes should be installed between the filter chamber and the clearwell to provide relief in case of pipe clogging. The weepholes should be three (3) inches in diameter. Minimum spacing should be nine (9) inches center to center. The openings on the filter side of the dividing wall should be covered to the width of the trench with 12 inch high plastic hardware cloth of 1/4 inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, number 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded a minimum of six (6) inches back under the bottom stone.
14. Dewatering Drain	A six (6) inch diameter DIP or PVC dewatering drain with a gate valve is to be installed at the top of the stone/sand filter bed through the partition separating the filtration chamber from the clearwell chamber.

15. Bypass Pipe — Where a bypass pipe is needed, it shall be DIP or PVC with supports every 18 inches minimum.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-11.2:: DC Sand Filter

Designer: ____________________

Company: ____________________

Date: ____________________

Project: ____________________

Location: ____________________

1. Determine Basin Storage Volume

a. Percent Imperviousness of Tributary Area	I_a =	68	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	60	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	0.64	in.
d. Watershed Area Tributary to DBSF	Area =	1.0	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	0.053	acre-ft

1. Minimum Filter Area

$$A_{fm} = \frac{(SQDV)(d_f)}{k\,(h + d_f)(t_f)}$$

a. SQDV	SQDV =	2,323	ft^3
b. Sand bed depth (d_f)	d_f =	1.5	ft
c. Filter Coefficient (k)	k =	0.0833	ft. / hr.
d. Draw-down time (t_f= 40 hour)	t =	40	hr
e. one half maximum allowable water depth over filter (h)	h =	1.67	ft
f. Minimum filter area	A_{fm} =	482	ft^2

2. Select Filter Width, Compute Filter Length

a. Select a Filter Width (W_f)	W_f =	12.0	ft.
b. Compute filter length $L_f = A_{fm}/W_f$	L_f =	40.1	ft.
c. Determine adjusted filter area (Round L_f to closest whole number) $A_f = W_f \times L_f$	A_f =	480	ft^2

(From this point, formula assume rectangular cross section of filter shell.)

Design Procedure Form for T-11.2: DC Filter (Page 2 of 2)

Project:____

3. Compute the Storage Volume of Top of the Filter (V_{tf}) $V_{tf} = A_f \times 2h$	V_{tf} = 1,603 ft^3
4. Compute the Storage in the Filter Voids (Vv) (Assume 40% voids in the filter media) $V_v = A_f \times (d_f + d_g) \times 0.40$	V_v = 544 ft^3
5. Flow Through Filter During Filling (V_Q) (Assume 1-hour to fill) $V_Q = k \times A_f \times (d_f + d_g) \times t_f / d_f$ Use: k = 2 ft/day = 0.0833 ft/hr. t_f = 1 hr. to fill voids	V_O = 75.5 ft^3
6. Compute Net Volume to be Stored in Permanent Pool Awaiting Filtration (Vst) $V_{st} = SQDV - V_{tf} - V_v - V_Q$	V_{st} = 100.5 ft^3
7. Compute Minimum Length of Permanent Pool (Lpm) $L_{pm} = V_{st} /(2h)(W_f)$	L_{pm} = 2.5 ft
8. Compute Minimum Length of Sediment Chamber (L_s) (to contain 20% of SQDV) If $V_{st} < (0.2SQDV)$, use: $L_s = 0.2SQDV /(2h)(W_f)$ If $V_{st} > (0.2SQDV)$, use: $L_s = V_{st} /(2h)(W_f)$	L_s = 11.6 ft
9. Set Final Length of Permanent Pool (Lp) If $L_{pm} \geq (L_s + 2$ ft), use: $L_p = L_m$ If $L_{pm} < (L_s + 2$ ft), use: $L_p = (L_s + 2$ ft)	L_p = 13.6 ft
10. Set Final Length of Clear Well (Lcw) L_{cw} = 3 ft minimum	L_{cw} = 4.0 ft

Notes:

T-11.3: Delaware (Linear) Sand Filter

A schematic drawing of the modified Delaware Sand Filter (DSF) is shown in Figure 5-22. The system consists of two parallel concrete trenches divided by a close-spaced wall. The first trench serves as the sedimentation chamber. When accepting sheet flow, it is fitted with a grated cover. Concentrated stormwater may also be conveyed to the chamber in enclosed storm drain pipes. The second chamber, which contains the sand filter, is always fitted with a solid cover.

Storm flows enter the sedimentation chamber through the grates, causing the sedimentation pool to rise and overflow into the filter chamber through the weir notches at the top of the dividing wall. This provides assurance that the water to be treated arrives at the filter as sheet flow. This is essential to prevent scouring of the sand. The permanent pool in the sedimentation chamber is dead storage, which inhibits resuspension of particles that were deposited in earlier storms and prevents the heavier sediments from being washed into the filter chamber. Floatable materials and hydrocarbon films, however, may reach the filter media through the surface outflow.

The second trench contains the top 2 inches stone filter layer, the middle 18 inches of sand, and the bottom 16 inch stone layer. Six inch diameter PVC underdrains are provided in this stone layer to carry the filtered water to the clearwell and ultimately to the storm drain. For smaller units, less than 20 feet in length, a gravel underdrain bed with the weep holes may be used in place of PVC pipe.

For systems where storm flows in excess of the SQDV are not diverted upstream of the filter, an overflow weir into the clearwell from the sedimentation chamber will convey the runoff greater than the SQDV directly to the storm sewer. The overflow weir shall be sized to pass volume of water that exceeds the SQDV. Where retention of hydrocarbons is a concern, the weir should be fitted with a metal hood or commercial catch basin trap.

To ensure the filter can be drained if plugged, a 6-inch dewatering drain with gate valve is included in the design of the filter.

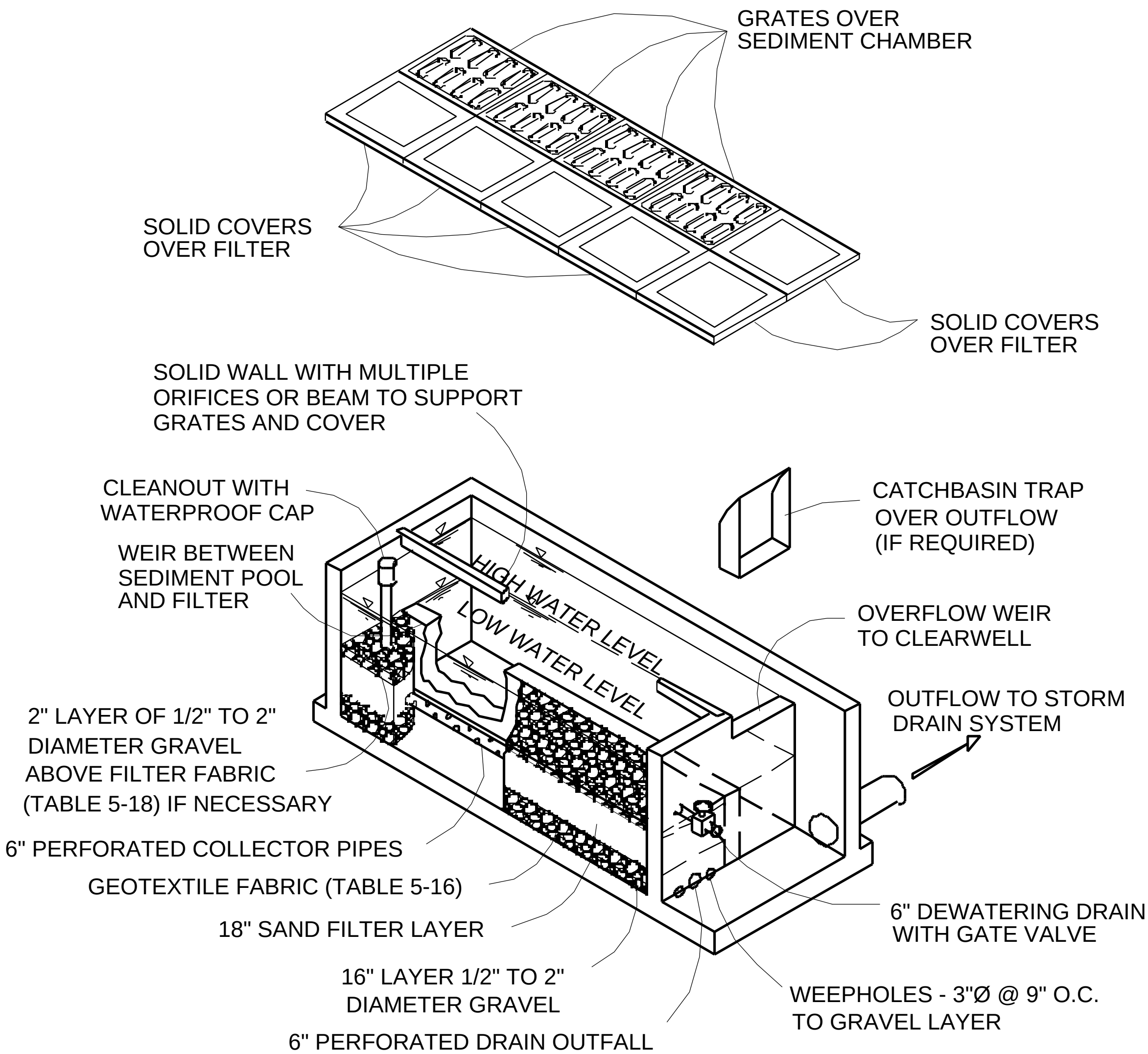


FIGURE 5-22. DELAWARE SAND FILTER

Design Criteria

Principal design criteria for the Delaware Sand Filter are summarized in Table 5-21

Table 5-21. Delaware Sand Filter Design Criteria

Design Parameter	Unit	Criteria
Maximum drainage area	acres	5
SQDV	acre-ft	80% annual capture. Use Figure 5-1 @ 40-h drawdown
Weir height between sedimentation chamber and sand filter	in.	Set weir height 2" above sand filter bed
Minimum draw down time, t_f	hrs	40
Minimum gravel depth over sand	in.	2
Minimum sand depth, d_f	in.	18
Minimum gravel underdrain depth, d_g	in.	16
Filter coefficient, k	ft/day	2
Top layer and underdrain gravel size	in.	0.5 to 2-inch diameter stone
Sand size	—	ASTM C33 concrete sand
Slope of top layer	%	0 (horizontal)
Minimum slope of underdrain or bottom of filter	%	0.5%
Minimum size underdrain	—	6" PVC schedule 40
Minimum size diameter perforation	in.	3/8
Minimum number of holes per row	—	6
Minimum spacing between rows	in.	6
Minimum weephole diameter	in.	3
Minimum spacing between weepholes	in.	9 (center to center)
Sedimentation chamber and sand filter width	in.	18 to 30

Design Procedure

Design procedure and application of design criteria for Delaware Sand Filter are outlined in the following steps:

1. Maximum Water Depth — Based on site constraints determine the maximum ponding depth over filter (2h). If an overflow device is built into the DSF shell, size the overflow weir in procedures in Appendix B.

2. Sand Filter / Sediment Chamber Surface Area — The DSF shell must have the capacity to accept and store the SQDV. The dimensions are sized to provide a filter area which processes the SQDV in the desired time frame (40 hrs.). The areas of the sedimentation chamber and filter bed are typically set equal. The required areas are calculated as follows depending on the maximum depth of water above the

	filter bed:
a. If 2h < 2.67 ft	Use: $A_{sm} = A_{fm} = SQDV/ (4.1h + 0.9)$
b. If 2h > 2.67 ft	Use: $A_{sm} = A_{fm} = \frac{(SQDV)(d_f)}{(k)(h + d_f)(t_f)}$

Where:

- SQDV = Stomwater Quality Design Volume, ft^3
- A_{fm} = filter surface area, ft^2
- A_{sm} = sediment chamber area, ft^2
- d_f = sand bed depth, ft
- k = filter coefficient @ 0.0833 ft./hr.
- h = one-half of max allowable water depth (2h), ft.
- t_f = 40 h draw-down time

3. Select sediment chamber and filter width ($W_s = W_f$)	Site considerations usually dictate the final dimensions of the facility. Sediment chambers and filter chambers are normally 18-30 inches wide. Use of standard grates requires a width of 26 inches.
4. Sediment Chamber/ Filter Length	$L_s = L_f = A_{fm} / W_f$ Round length upward as appropriate. Compute adjusted Area $A_s = A_f = W_f \times L_f$
5. Storage Volume in filter voids (Vv)	$V_v = A_f \times (d_f + d_g) \times (0.4)$ {assume 40% voids}
6. Flow Through Filter During Filling (V_Q)	$V_Q = k \times A_f \times (d_f + d_g) \times t_f / d_f$ Use: k = 2 ft/day = 0.0833 ft/hr. t_f = 1 hr. to fill voids
7. Net Volume Required to be Stored in Chambers Awaiting Filtration (V_{st})	$V_{st} = SQDV - V_v - V_Q$
8. Available Storage in Chambers (V_{sf})	$V_{sf} = 2h(A_f + A_s)$ If $V_{sf} \geq V_{st}$, proceed with design If $V_{sf} < V_{st}$, adjust width and/or length and repeat steps 3 –8.
9. Filter Bed	
a. Top Gravel Layer	The washed gravel layer at the top of the filter should be two

	inches thick composed of stone 0.5 to 2.0 inches in diameter. In areas with high sediment load (TSS concentration >200 mg/L), the two-inch layer of stone on top of the sand filter should be underlain with filter fabric meeting the specifications in Table 5-18.
b. Sand Layer	The sand layer should be a minimum depth of 18 inches consisting of ASTM C33 concrete sand. A layer of geotextile fabric meeting the specifications in Table 5-16 must separate the sand and gravel layer below.
c. Gravel Layer	The gravel layer surrounding the collector pipes should be at least 16 inches thick and be composed of 0.5 to 2-inch diameter stone and provide at least two inches of cover over the tops of the drainage pipes.
10. Underdrain Piping	The underdrain piping should follow the same criteria and design as the Austin Sand Filter. Shallow rectangular drain tiles may be fabricated from such materials as fiberglass structural channels, saving several inches of filter depth. Drain tiles should be in two-foot lengths and spaced to provide gaps 1/8-inch less than the smallest gravel sizes on all four sides. Sections of tile may be cast in the dividing wall between the filter and the clearwell to provide shallow outflow orifices.
11. Weep Holes	Weephole configuration should follow the same criteria as the DC Sand Filter.
12. Grates and Covers	Grates and cast steel covers are designed to take the same wheel loads as the adjacent pavement. Where possible, use standard grates to reduce costs. Grates and covers should be supported by a galvanized steel perimeter frame
13. Hoods / Traps	In applications where trapping of hydrocarbons and other floating pollutants is required, large-storm overflow weirs should be equipped with a 10-gauge aluminum hood or commercially available catch basin trap. The hood or trap should extend a minimum of one foot into the permanent pool.
14. Dewatering Drain	A six inch diameter dewatering drain with gate valve is to be installed at the top of the stone/sand filter bed through the partition separating the filter chamber from the clearwell chamber.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-11.3: Delaware Sand Filter

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Minimum Surface Areas of the Chambers

If 2h < 2.67 feet (2'-8")

$A_{sm} = A_{fm} = SQDV / (4.1h + 0.9)$

If 2h > 2.67 feet (2'-8")

$$A_{sm} = A_{fm} = \frac{(SQDV)(d_f)}{k(h + d_f)t_f}$$

a. SQDV	SQDV = 1300	ft^3
b. Sand bed depth (d_f)	d_f = 1.5	ft
c. Filter Coefficient (k)	k = 0.0833	ft. / hr.
d. Draw-down time (t_r)	t = 40	hr
e. One half maximum allowable water depth over filter (h)	h = 1.67	ft
f. A_{sm} (Sediment Chamber Area) and A_{fm} (Filter Surface Area)	A_{sm} and A_{fm} = 185	ft^2

2. Sediment Chamber and Filter Width / Length

a. Select width ($W_s = W_f$ = 18 to 30 inches)	$W_s = W_f$ = 2.167	ft.
b. Filter length ($L_s = L_f = A_{fm} / W_f$)	$L_s = L_f$ = 85.2	ft.
c. Adjusted length (rounded)	$L_s = L_f$ = 86.0	ft.
d. Adjusted area ($A_s = A_f = W_f \times L_f$)	$A_s = A_f$ = 186.4	ft^2

3. System Storage Volume

a. Storage in filter voids ($V_v = A_f \times (d_f + d_f) \times 0.4$)	V_v = 211.2	ft.
b. Flow through filter ($V_Q = k A_f (d_f + h)$ 1hr/ d_f)	V_Q = 32.8	ft.
c. Required net storage ($V_{st} = SQDV – V_v – V_Q$)	V_{st} = 1,056	ft.
d. Available storage ($V_{sf} = 2h(A_f + A_s)$)	V_{sf} = 1,245	ft^2

If $V_{sf} \geq V_{st}$, sizing is complete

If $V_{sf} < V_{st}$, repeat steps 2 and 3

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 be 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 also 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 under-drains are used, the minimum slope of the pipe shall be 0.5%. Where only gravel filtered water conveyance is provided, the filter floor must be sloped towards the weepholes at a minimum slope of 0.5%.

Maintenance Requirements

Maintenance Agreement

On-site treatment control measures are to be maintained by the owner/operator. Maintenance agreements between the City and the owner/operator may be required. A Maintenance Agreement with the City must be executed by the owner/operator before the improvement plans are approved.

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;
- Responsible party for operation and maintenance.

Additional guidelines for Maintenance Plans are provided in Appendix D.

Maintenance Activities

- During the first year of operation, the cover grates or precast lids on the chambers must be removed quarterly and an inspection made to assure that the system is functioning. Once the system is functioning properly, this inspection may be made on a semiannual basis.

- When the filter takes 36 hours or more to drain or when deposition of sediments in the filtration chamber indicate that the filter media is clogging and not performing properly, sediments and sand must be removed. The coloration of the sand will provide a good indication of what depth of removal is required. Clean sand must then be placed in the filter to restore the design depth. Where a layer of geotextile fabric and gravel overlay the filter, the fabric and gravel shall be rolled up and removed and a similar layer of clean fabric and gravel installed. Any discolored sand shall also be removed and replaced.
- Grass must be prevented from washing into the filter.
- Disposal of petroleum hydrocarbon contaminated sand, gravel or filter cloth must be done in accordance with all applicable laws.
- Trash collected on the grates protecting the inlets should be removed no less frequently than weekly to assure preserving the inflow capacity of the control measures.
- Monitoring manholes, flumes, and other facilities should be kept clean and ready for use.

Monitoring Agreement

The owner/operator may be required to enter into a monitoring agreement with the City to establish pollutant removal efficiencies of the sand filter.

Sand filters may be required to be designed to accommodate the installation, operation and maintenance of automatic sampling equipment to measure the input and output flow rates and the chemical composition of the inflow and outflow.

At a minimum, the sand filter system will be equipped with monitoring manholes in the inflow and outflow pipes. The City and its consultants will conduct the monitoring program unless otherwise agreed to by the agency. The type and length of monitoring program will be determined on a case-by-case basis.

Alternative and Proprietary Control Measures

This manual provides guidance for the selection and design of some of the more common on-site stormwater treatment control measures for new development. The standard treatment control measures (T-1 through T-11) included in this section are non-proprietary designs that have been reviewed and evaluated by the Permittees and determined to be generally acceptable. Because the performance of these measures has already been demonstrated and reviewed by the Permittees, the plan check review and approval process will be routine for development projects that have selected one of the control measures from this guidance manual.

The Permittees recognize, however, that these pre-accepted treatment control measures may not be appropriate for all projects due to physical site constraints. Thus, the Permittees will consider the use of alternative or proprietary control measures under the follow conditions:

1. If design guidelines for standard treatment control measures cannot be met due to physical site constraints, Permittees retain the discretion of using a lesser performance or design standard prior to accepting proprietary devices. For example: a grass swale filter with 1.5 feet/sec velocity would be considered preferable to installation of a proprietary fabric filter.
2. Alternative or proprietary treatment control devices will only be considered for approval after standard treatment control measures in the guidance manual have been rejected.
3. If, for a specific development, the average cost of installation and operation of standard treatment controls is substantially greater than the average costs for similar installations, alternative or proprietary treatment technologies may be considered for approval.
4. Alternative or proprietary treatment technologies may be approved for redevelopment projects where existing site constraints preclude installation of standard treatment controls.

Alternative control measures may include landscape-type features or proprietary devices. Site designers should contact the local agency stormwater staff early on in the planning process in order to adequately demonstrate that the level and reliability of treatment provided by an alternative control measure is equivalent to that of the pre-accepted designs. Each Permittee shall review the design and construction method of the proposed technology to determine if the device is suitable for the specific land use and pollutant to be removed.

In general, any alternative measure must be designed to treat the stormwater quality design volume, SQDV or the water quality flow, SQDF. Procedures to calculate the SQDV and SQDF are provided in the Calculation Fact Sheets. Site runoff in excess of the SQDV and SQDF may be diverted around or through the treatment device. In addition, the project applicant must demonstrate that the pollutant removal of the proposed alternative control measure will be comparable to the pre-accepted control measures. Performance data and sound engineering principles must be provided to demonstrate effective reliable treatment. Any proposed alternative must include all maintenance, operation, and construction requirements.

There are numerous manufactured proprietary devices available on the market. When proprietary control measures have been determined by the Permittees to be pre-accepted, an Appendix may be added to this guidance manual and updated periodically to provide a list and description of acceptable proprietary devices.

The Permittees encourages the development of innovative stormwater control measures and may consider a limited number of promising alternative control measures, including proprietary devices, on a 'pilot basis'. In order for a pilot project to be considered for proprietary devices, the manufacturer and/or property owner must commit to participate and fund a monitoring program to verify the device's performance. Site designers should anticipate additional review time and contact the local agency stormwater staff early in the process to request consideration of pilot installation projects.

Glossary of Terms

100,000 Square Foot Commercial Development : Any commercial development that creates at least 100,000 square feet of impermeable area, including parking areas.

Automotive Repair Shop: A facility that is categorized in any one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, or 7536-7539.

Backfill: Earth or engineered material used to refill a trench or an excavation.

Berm: An earthen mound used to direct the flow of runoff around or through a structure.

Best Management Practice (BMP): Any program, technology, process, siting criteria, operational methods or measures, or engineered systems, which when implemented prevent, control, remove, or reduce pollution.

Best Management Practices (BMPs): Includes schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent 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.

Buffer Strip or Zone: Strip of erosion-resistant vegetation over which stormwater runoff is directed.

Catch Basin: Box-like underground concrete structure with openings in curbs and gutters designed to collect runoff from streets and pavements.

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

Commercial Development: Any development on private land that is not heavy industrial or residential. The category includes, but is not limited to: hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, multi-apartment buildings, car wash facilities, mini-malls and other business complexes, shopping malls, hotels, office buildings, public warehouses and other light industrial complexes.

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

Construction General Permit: A NPDES permit issued by the State Water Resources Control Board (SWRCB) for the discharge of stormwater associated with construction activity from soil disturbance of five (5) acres or more.

Conveyance System: Any channel or pipe for collecting and directing the Stormwater.

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

Dead-end Sump: A below surface collection chamber for small drainage areas that is not connected to the public storm drainage system. Accumulated water in the chamber must be pumped and disposed in accordance with all applicable laws.

Designated Public Access Points: Any pedestrian, bicycle, equestrian, or vehicular point of access to jurisdictional channels in the area of Ventura County subject to permit requirements.

Detention: The temporary storage of stormwater runoff to allow treatment by sedimentation and metered discharge of runoff at reduced peak flow rates.

Directly Adjacent: Situated within 200 feet of the contiguous zone required for the continued maintenance, function, and structural stability of the environmentally sensitive area.

Directly Connected Impervious Area (DCIA): The area covered by a building, impermeable pavement, and/ or other impervious surfaces, which drains directly into the storm drain without first flowing across permeable land area (e.g. turf buffers).

Directly Discharging: Outflow from a drainage conveyance system that is composed entirely or predominantly of flows from the subject, property, development, subdivision, or industrial facility, and not commingled with the flows from adjacent lands.

Discharge: A release or flow of Stormwater or other substance from a conveyance system or storage container.

Environmentally Sensitive Area (ESA): An area "in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which would be easily disturbed or degraded by human activities and developments" (California Public Resources Code § 30107.5). Areas subject to stormwater mitigation requirements are: 303d listed water bodies in all reaches that are unimproved and soft-bottomed and all California Coastal Commission's *Environmentally Sensitive Habitat Areas* as delineated on maps in Local Coastal Plans. The California Department of Fish and Game's (CDFG) *Significant Natural Areas* map will be considered for inclusion as the department field verifies the designated locations.

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: Is a collection of industrial process 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 Substance: (1) Any material that poses a threat to human health and/or the environment. Typical hazardous substances are toxic, corrosive, ignitable, explosive, or chemically reactive; (2) Any substance named by EPA to be reported if a designated quantity of the substance is spilled in the waters of the United States or if otherwise emitted into the environment.

Hazardous Waste: By-products of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possesses at least one of four characteristics (flammable, corrosivity, reactivity, or toxicity), or appears on special EPA lists.

Hillside: Property located in an area with known erosive soil conditions, where the development contemplates grading on any natural slope that is 25 percent or greater.

Illegal Discharges: Any discharge to a municipal separate storm sewer 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 fire fighting activities.

Industrial General Permit: A NPDES permit issued by the State Water Resources Control Board for the discharge of Stormwater associated with industrial activity.

Infiltration: The downward entry of water into the surface of the soil.

Inlet: An entrance into a ditch, storm sewer, or other waterway.

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

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

Non-Stormwater Discharge: Any discharge to municipal separate storm drain that is not composed entirely of stormwater. Discharges containing process wastewater, non-contact cooling water, or sanitary wastewater are non-stormwater discharges.

Non-Structural Source Control Measure: Low technology, low cost activities, procedures or management practices designed to prevent pollutants associated with site functions and activities from being discharged with Stormwater runoff. Examples include good housekeeping practices, employee training, standard operating practices, inventory control measures, etc.

Notice of Intent (NOI): A formal notice to State Water Resources Control Board submitted by the owner/developer that a construction project is about to begin. The NOI provides information on the owner, location, type of project, and certifies that the permittee will comply with the conditions of the construction general permit.

NPDES Permit: An authorization, license, or equivalent control document issued by EPA or an approved State agency to implement the requirements of the NPDES program.

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

Parking Lot: Land area or facility for the temporary parking or storage of motor vehicles used personally, for business or for commerce with an impervious surface area of 5,000 square feet or more, or with 25 or more parking spaces.

Permeability: A property of soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

Pollutant: A substance introduced into the environment that adversely affects the usefulness of a resource.

Precipitation: Any form of rain or snow.

Pretreatment: Treatment of wastewater before it is discharged to a wastewater collection system.

Process Wastewater: Wastewater that has been used in one or more industrial processes.

Receiving Stream: (for purposes of this Manual only) any natural or man-made surface water body that receives and conveys stormwater runoff.

Redevelopment: Development that includes, but is not limited to the following: the 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; land disturbing activities related with structural or impervious surfaces. Redevelopment that results in the creation or addition of 5,000 square feet or more of impervious surfaces is subject to the requirements for stormwater mitigation. If the creation or addition of impervious surfaces is fifty percent or more of the existing impervious surface area, then stormwater runoff from the entire area (existing and changes) must be considered for purposes of stormwater mitigation. If the creation or changed area is less than fifty percent of the existing impervious area, then Stormwater runoff from only the changed area needs mitigation.

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).

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 and other precipitations (e.g., sprinkler irrigation) that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes, wetlands, and shallow groundwater.

Runon: Stormwater surface flow or other surface flow which enters property other than that where it originated.

Secondary Containment: Structures, usually dikes or berms, surrounding tanks or other storage containers and designed to catch spilled material from the storage containers.

Sedimentation: The process of depositing soil particles, clays, sands, or other sediments that were 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 so that adequate sunlight might not reach aquatic plants.

Source Control BMP or Measure: 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 Control BMPs: Operational practices or design features that prevent pollution by reducing potential pollutants at the source.

Spill Guard: A device used to prevent spills of liquid materials from storage containers.

Spill Prevention Control and Countermeasures Plan (SPCC): Plan consisting of structures, such as curbing, and action plans to prevent and respond to spills of hazardous substances as defined in the Clean Water Act.

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

Storm Drain System: Network of above and below-ground structures for transporting stormwater to streams or outfalls.

Storm Event: A rainfall event that produces more than 0.1 inch of precipitation and is separated from the previous storm event by at least 72 hours of dry weather.

Stormwater Discharge Associated with Industrial Activity: Discharge from any conveyance which is used for collecting and conveying stormwater which is related to manufacturing processing or raw materials storage areas at an industrial plant [see 40 CFR 122.26(b)(14)].

Stormwater: Stormwater runoff, snow-melt runoff, surface runoff, and drainage, excluding infiltration and irrigation tailwater.

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 UV radiation.

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 governing agency and is not the same as the stormwater quality design flow or volume. The drainage design storm is used to design the conveyance system, i.e. pipes, swales, etc. of the site without regard for treatment. The design engineer must ensure sufficient head room in the on-site system above the diversion to accommodate overflows.

Diverting Flows at the Inlet or Upstream of the Treatment Control Device

Diverting flow at the inlet to the treatment control is the more common approach to divert excess runoff. Figure B-1 illustrates the more commonly used diversion structures. The height of the weir to divert the flow is determined a follows:

<u>Treatment Control Measures Designed Based on the SQDV</u>

1. Determine the SQDV (see Section 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

$$Q_d = CLh^{1.5}$$ *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]

H/h	Head (h) over weir, ft						
	0.2	**0.4**	**0.6**	**0.8**	**1.0**	**2.0**	**5.0**
0.5	4.18	4.13	4.12	4.11	4.11	4.10	4.10
1.0	3.75	3.71	3.69	3.68	3.68	3.67	3.67
2.0	3.53	3.49	3.48	3.47	3.46	3.46	3.45
10.0	3.36	3.32	3.30	3.30	3.29	3.29	3.28
∞	3.32	3.28	3.26	3.26	3.25	3.25	3.24

1. From Lindsay and Franzini , (1979)

<u>Treatment Control Measures Designed Based on the SQDF</u>

1. Establish the size of the on-site drainage system (pipe diameter or dimensions) based on the drainage design storm
2. Determine the SQDF (see Section 5)
3. Determine the depth of flow in the on-site drainage system when carrying the SQDF using Manning's equation (eqn B-2)

$$SQDF = \frac{1.49}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$$ *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:

$$Q_d = CA(2gh)^{0.5} \qquad \textit{eqn B-3}$$

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 4-4, 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 Grass Swale Filter

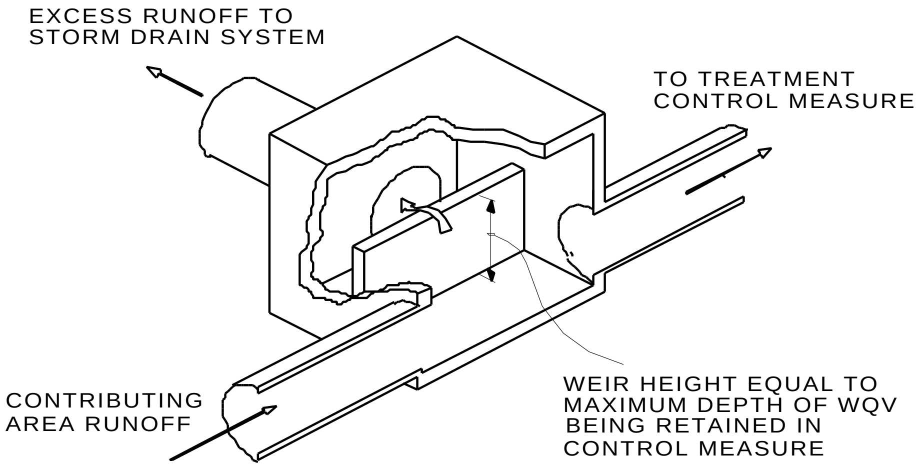
The depth of flow in a grass swale filter at SQDF is determined using a roughness coefficient of 0.2. If additional flows beyond the SQDF are to be directed to the grass swale filter, the roughness coefficient for these flows will be lower (approximately 0.03), because the flows exceeding the SQDF do not flow through the grass 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 grass swale filter designs, there will be two different "n" values. An equivalent "n_e" value can be determined using equation B-5:

$$n_e^{\frac{3}{2}} = \frac{P_1 n_1^{\frac{3}{2}} + P_2 n_2^{\frac{3}{2}}}{P} \qquad \textit{eqn B-5}$$

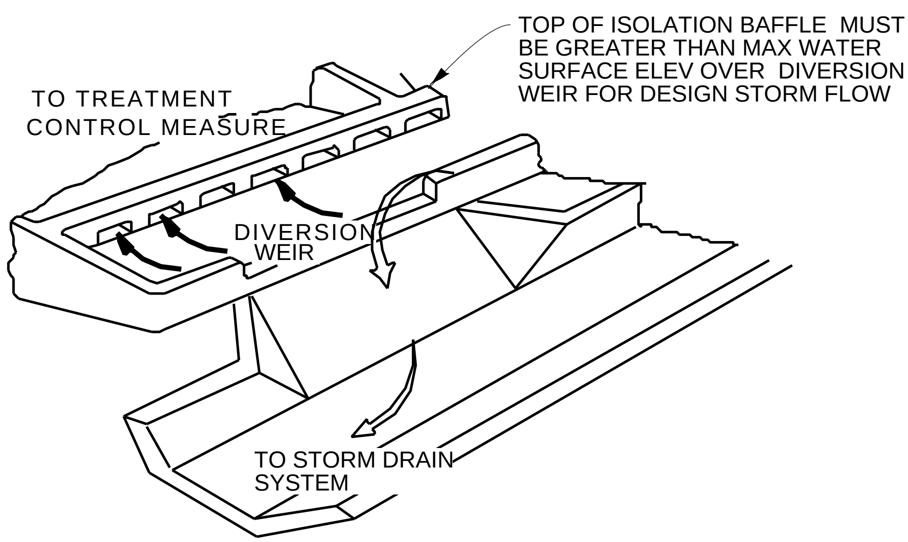
An iterative approach is used to develop an equivalent "n_e", that can be calculated with most computer hydraulic program applications:

1. Estimate an equivalent roughness coefficient (estimated "n_e"),
2. Using the estimated roughness coefficient, 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. Using the calculated depth determine the wetted perimeter for the drainage system,
4. Using the wetted perimeter associated with each "n" for the drainage system, and using Equation B-5, calculate the equivalent roughness coefficient (calculated "n_e"), and compare to the estimated "n_e",
5. The process continues until the calculated "n_e" equals the estimated "n_e". This value is the equivalent roughness coefficient and used to design the grass swale filter 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

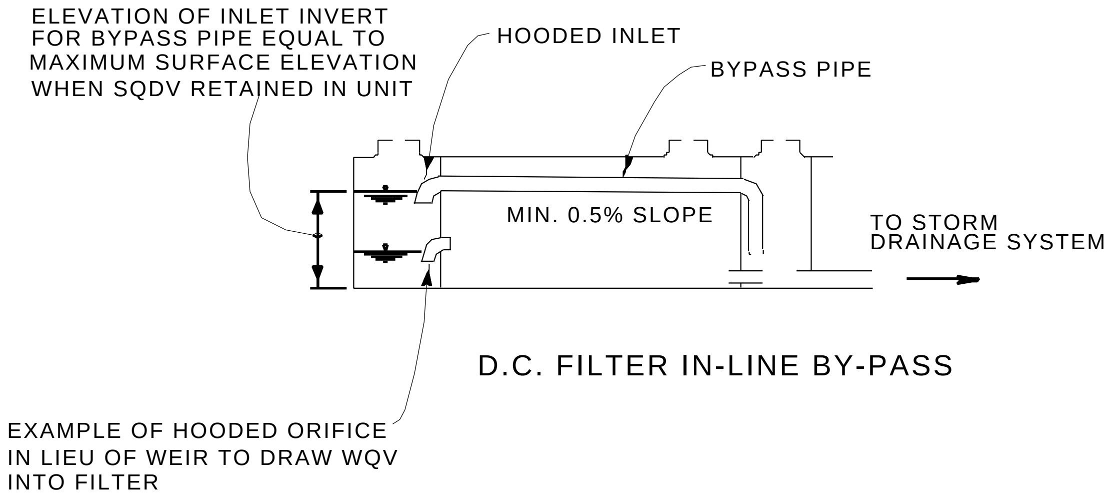


FIGURE B-2. ILLUSTRATION OF PIPE BYPASS IN A FILTRATION DEVICE

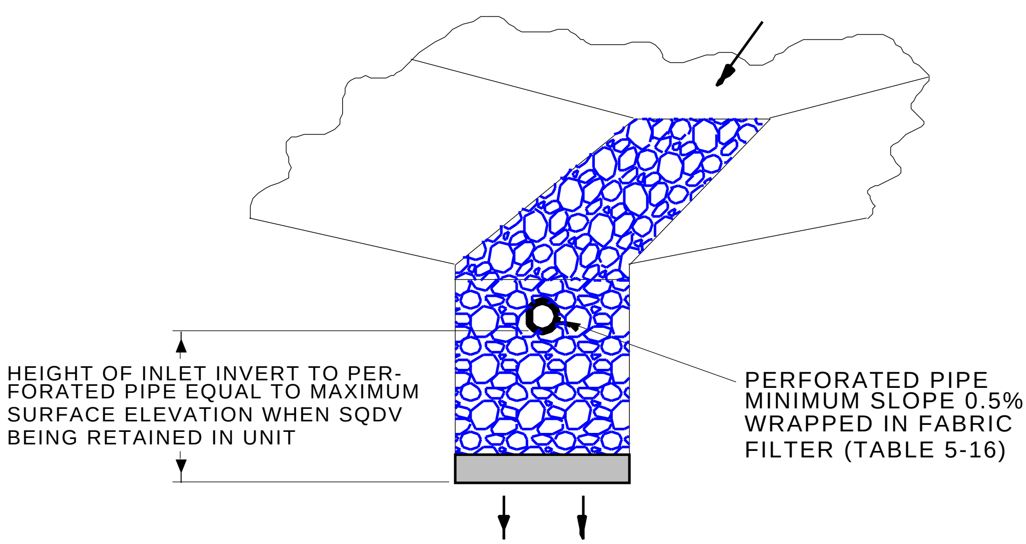


FIGURE B-3. ILLUSTRATION OF PIPE BYPASS IN INFILTRATION TRENCH

Stormwater Treatment Device Access and Maintenance Agreement

(Long Form)

Recorded at the request of:
City of ___________________

____
After recording, return to:
City of ____________
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___________________, a municipal corporation, located in the County of Ventura, State of California hereinafter referred to as "CITY";

WHEREAS, the Owner owns real property ("Property") in the City of _________, County of Ventura, 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 of City's designee complete access, of any duration, to the Device and its immediate vicinity at any time, upon reasonable notice, or in the event of emergency, as determined by City's Director of Public Works no advance notice, for the purpose of inspection, sampling, testing of the Device, and in case of emergency, to undertake all necessary repairs or other preventative measures at owner's expense as provided in paragraph 3 below. 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 state herein. Should the Owner fail to perform the obligations under the Agreement, the City may, in the case of a cash bond, act for the Owner using the proceeds from it, or in the case of a surety bond, require the sureties

to perform the obligations of the Agreement. As an additional remedy, the Director may withdraw any previous stormwater related approval with respect to the property on which a Device has been installed until such time as Owner repays to City it's reasonable costs incurred in accordance with paragraph 3 above.

5. This agreement shall be recorded in the Office of the Recorder of Ventura 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

OWNER:

____
Name:_____________________________
Title:_____________________________

CITY OF________________________:

____
Name:_____________________________
Title:_____________________________

OWNER:

____
Name:_____________________________
Title:_____________________________

ATTEST:

____
City Clerk Date

NOTARIES ON FOLLOWING PAGE

EXHIBIT A
(Legal Description)

EXHIBIT B
(Map/llustration)

(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 ________________________, County of Ventura, State of Calfornia.

Legal Description: ____

____

as recorded in Book __________________________, Page________, Records of Ventura County,

which property is located and known as **(Address):** ___________________________________

____.

And in consideration of the City of _________________ 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, encumbrancers, 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

Maintenance Plan Guidance

This form 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 which 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. These procedures are listed based on facility operations and can be found in the Ventura County Industrial/Commercial Clean Business Program document.

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. Once annually, perform testing of any mechanical or electrical devices prior to wet weather.
3. Report any significant changes in stormwater control measures to the site management. As appropriate, assure mechanical devices are working properly and/or landscaped BMP plantings are irrigated and nurtured to promote thick growth.
4. Note any significant maintenance requirements due to spills or unexpected discharges.
5. As appropriate, perform maintenance and replacement as scheduled and as needed in a timely manner to assure stormwater control measures are performing as designed and approved.
6. Assure *unauthorized* low-flow discharges from the property do not by-pass stormwater control measures.
7. Perform an annual assessment of each pollution generation operation and it's associated stormwater control measures to determine if any part of the pollution reduction train can be improved.

G. Revisions of Pollution Mitigation Measures:

1. If future correction or modification of pass stormwater control measures or procedures is required, the owner shall obtain approval from the governing stormwater agency prior to commencing any work. Corrective measures or modifications shall not cause discharges to by-pass or otherwise impede existing stormwater control measures.

H. Monitoring & Reporting Program

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

Hydrologic Soil Groups

This appendix includes information on the Hydrologic Soil Groups in Ventura County to use in designing various stormwater control measures:

Relevance of Hydrologic Soil Groups Information

The hydrologic soil groups of a development area are pertinent to design of controls that involve infiltration and for identifying sites appropriate for detention basins. The predominant soil group will control the effectiveness of infiltration facilities or the suitability of an area for impounding water. Hydrologic soil group information should be used for preliminary siting studies only. Actual design should be based on in-situ soil investigations and testing by a qualified engineer or geologist.

Table C-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.

The hydrologic soil information presented here should be used as a general overview. For more specific information, consult the *Ventura County Soil Survey* (USDA, NRCS) or contact the Ventura County Resource Conservation District at (805) 386-4685.

Plants Suitable for Vegetative Control Measures

Vegetation serves primarily to maintain soil porosity and prevent erosion. The effectiveness and aesthetic appeal of control measures are enhanced by selection of appropriate vegetative cover. Turf grass is preferred, and some other ground covers also may be appropriate. Some local agencies have restrictions on use of irrigated turf grass; consult with local agency regarding selection of appropriate vegetation.

An important maintenance consideration in the selection of appropriate vegetation is whether irrigation is planned for the site.

Table F-1 provides a sample list of appropriate vegetative covers. Figure F-1is a map showing approximate zones of suitability for the listed species. These zones represent areas of climatological suitability according to the *Sunset Western Garden Book* and are referenced for each species in Table F-1. Additional suggested vegetative species are listed in Table F-2. The map and tables are intended as guides in selecting vegetative covers. For specific species suitability and care information, refer to the sources listed for these tables. Contact the Natural Resources Conservation Service or the Ventura County Resource Conservation District for additional information.

Figure F-1. Vegetation Suitability Zones

Table F-1. Sample List of Appropriate Vegetative Covers

Plant Name Common (Latin)	***Appropriate Species***	***Map Zones****	***Maintenance and Usage Notes*****
Bermuda Grass (Cynodon)	Santa Ana hybrid	A	Moderate maintenance. Dormant (brown) in winter. Heat tolerant. Erosion control, swales.
Fescue (Festuca)	Red fescue (F. rubra)	A, B	Low to moderate maintenance. Tolerates some shade and poor soil. Lawns, swales, erosion control.
	"Kentucky 31" Tall Fescue (F. elatior)	A, B	Low maintenance. Tolerate shade and compacted soils. Rapid germination. Lawns, swales, erosion control. Useful as overseed for Bermuda grass during dormant (winter) season.
Ryegrass (Lolium)	Perennial (L. perenne)	A, B	Moderate maintenance. Heat intolerant. Fast sprouting. Useful as overseed for Bermuda grass during dormant (winter) season. Swales.
	Annual (L. multiflorum)	A, B	Annual (may live several seasons in mild climate). Moderate maintenance. Heat intolerant. Fast growing. Useful as overseed for winter-dormant species. Swales.

*See Figure F-1
**Generally, these species will require supplemental irrigation.
Sources: ASCE, MWCG, Sunset

Table F-2. Additional Suggested Vegetative Covers

Plant Name Common (Latin)	***Appropriate Species***	***Usage Notes***
Orchard grass (Dactylis)	"Akaroa" or "Berber" (D. glomerata)	Irrigated and Non-irrigated Sites
Wheatgrass (Agropyron)	"Luna" or "Topar" pubescent (A. intermedium trichophorum)	Irrigated and Non-irrigated Sites
Zorro Fescue (Vulpia)	(V. myuros)	Irrigated and Non-irrigated Sites
Creeping wild Rye (Leymus)	(L. triticoides)	Nonirrigated Sites
Brome (Bromus)	Blando (B. mollis)	Nonirrigated Sites
	California or "Cucamonga" (B. carinatus)	Nonirrigated Sites

Source: NRCS-FOTG

Appendix G

Design Forms

Design Procedure Form for G-5.1: Turf Buffer

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Design Flow	$Q_{P, SQDF}$ = ____________ cfs
2. Design Width W_{TB} = (SQDF) / 0.05 cfs/ft	W_{TB} = ____________ ft.
3. Design Length (8 ft minimum)	L_{TB} = ____________ ft.
4. Design Slope (4 percent maximum)	L_{TB} = ____________ %
5. Flow Distribution (Check type used or describe "Other")	_____ Slotted curbing _____ Modular Block Porous Pavement _____ Level Spreader _____ Other ____________________ ____________________
6. Vegetation (describe)	_____ ____________________
7. Outflow Collection (Check type used or describe "Other")	_____ Grass-lined Channel / Swale _____ Street Gutter _____ Storm Drain _____ Underdrain Used _____ Other ____________________ ____________________

Notes ____

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Design Procedure Form for G-5.2: Grass–lined Channel

Designer:______________________________

Company:______________________________

Date:______________________________

Project:______________________________

Location:______________________________

1. Design Flow	$Q_{P, SQDF}$ = ____________ cfs
2. Channel Geometry A. Channel Bottom Width (b) B. Side slope (Z)	 b = ____________ ft. Z = ____________
3. Depth of flow at SQDF (d) (2 ft max, Manning n= 0.05)	d = ____________ ft.
4. Design Slope A. s = 2 percent maximum B. No. of grade controls required	 s = ____________ % ____________ (number)
6. Vegetation (describe)	______________________________ ______________________________
7. Outflow Collection (Check type used or describe "Other")	_____ Grated Inlet _____ Infiltration Trench _____ Other ______________________ ______________________________

Notes ______________________________

Design Procedure Form for T-1: Grass Strip Filter (GSTF)

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Design Flow	$Q_{P,\ SQDF}$ = ____________ cfs
2. Design Width W_{GSTF} = (SQDF) / 0.005 cfs/ft	W_{GSTF} = ____________ ft.
3. Design Length (15 ft minimum)	L_{GSTF} = ____________ ft.
4. Design Slope (4 percent maximum)	S_{GSTF} = ____________ %
5. Flow Distribution (Check type used or describe "Other")	_____ Slotted curbing _____ Modular Block Porous Pavement _____ Level Spreader _____ Other ____________________ __________________________
6. Vegetation (describe)	_____ __________________________
7. Outflow Collection (Check type used or describe "Other")	_____ Grass Channel / Swale _____ Street Gutter _____ Storm Drain _____ Underdrain Used _____ Other ____________________ __________________________

Notes ____

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Design Procedure Form for T-2: Grass Swale Filter (GSWF)

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Design Flow	$Q_{P, SQDF}$ = ____________ cfs
2. Swale Geometry a. Swale Bottom Width (b) b. Side slope (Z)	 b = ____________ ft. Z = ____________
3. Depth of flow at SQDF (d) (2 ft max, Manning n= 0.20)	d = ____________ inches
4. Design Slope a. s = 2 percent maximum b. No. of grade controls required	 s = ____________ % ____________ (number)
5. Design flow velocity (Manning n= 0.20)	V = ____________ft/sec
6. Design Length L = (7 min) x (flow velocity, ft/sec) x 60	 L = ____________feet
6. Vegetation (describe)	_____ ________________________
7. Outflow Collection (Check type used or describe "Other")	_____ Grated Inlet _____ Infiltration Trench _____ Underdrain Used _____ Other ____________________ ________________________

Notes ____

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Design Procedure Form for T-3: Extended Detention Basin

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = __________ %
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} = __________ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u= __________ acre-ft
d. Watershed Area Tributary to EDB	Area = __________ acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV = __________ acre-ft
f. Calculate Design Volume Design Volume = SQDV x 1.2	Design Volume = __________ acre-ft
2. Outlet Works	
a. Outlet Type (check one)	Single Orifice ________ Multi-orifice Plate ________ Perforated Pipe ________ Other ________________
b. Depth of water above bottom orifice	Depth = ________ feet
c. Single Orifice Outlet	
1) Total Area	A = __________ square inches
2) Diameter or W x L	D = __________ inches
d. Multiple Orifice Outlet	
1) Area per row of perforations	A = ________ square inches
2) Perforation Diameter (2 inches max.)	D = ________
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 = __________ square inches

Design Procedure Form for T-3: Extended Detention Basin (Page 2 of 2)

Project:____

3. Trash Rack or Gravel Pack (check one)	Trash Rack_____	Gravel Pack_____	
4. Basin Length-Width Ratio (2:1 minimum)	Ratio =	____________	L:W
5. Two-Stage Design			
a. Upper Stage			
1) Depth (2 feet minimum)	Depth =	_________	Feet
2) Width (30 feet minimum)	Width =	_________	Feet
3) Bottom Slope (2% to low flow channel)	Slope =	_________	%
b. Bottom Stage			
1) Depth (1.5 to 3 feet deeper than Upper)	Depth =	_________	Feet
2) Storage Volume (5-15% of SQDV min.)	Volume =	_________	Acre-ft
6. Forebay Design			
a. Forebay Volume (5-10% of SQDV min.)	Volume =	__________	Acre-ft
b. Outlet pipe drainage time (~45 minutes)	Drainage Time	__________	Minutes
7. Low Flow Channel			
a. Depth (9 inches min.)	Depth =	___________	Feet
b. Flow Capacity (2 x outlet for Forebay)	Flow Capacity =	___________	GPM/CFM
8. Vegetation	Native Grasses	__________	
	Irrigated Turf	__________	
	Other	______________________________	
9. Embankment			
a. Interior Slope (4:1 max.)	Interior Slope =	__________	H/V
b. Exterior Slope (3:1 max.)	Exterior Slope =	__________	H/V
10. Access			
a. Slope (10% max.)	Slope =	_____________	%
b. Width (16 feet min.)	Width =	_____________	Feet

Notes

Design Procedure Form for T-4: Wet Detention Basin

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	________	acre-ft
d. Watershed Area Tributary to EDB	Area =	________	acres
Calculate SQDV = (V_u / 12) x Area	SQDV =	________	acre-ft
2. Permanent Pool			
a. Volume of Permanent Pool (0.75 times SQDV)	V_p =	________	Acre-ft
b. Littoral Zone Depth (6 to 12 inches)	Depth =	________	Inches/feet
c, Littoral Zone Area (25%-45% Permanent Pool Surface)	Area =	________	acres
	% of Total Area =	________	%
d. Deeper Zone Depth (4 to 8 feet average, 12 feet maximum)	Depth =	________	feet
3. Estimated Net Base Flow (must be > 0)			
$Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} =	________	Acre-ft
	Q_{evap} =	________	Acre-ft
	$Q_{seepage}$ =	________	Acre-ft
	$Q_{evapotranspiration}$	________	Acre-ft
	Q_{net} =	________	Acre-ft

Notes:

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Design Procedure Form for T-4: Wet Detention Basin (Page 2 of 3)

Project:____

4. Outlet Works	
a. Outlet Type (check one)	Single Orifice ________ Multi-orifice Plate ________ Perforated Pipe ________ Other ________________
b. Depth of water above bottom orifice	Depth = ________ feet
c. Single Orifice Outlet	
1) Diameter	D = ________ feet
2) Area	A = ________ square feet
d. Multiple Orifice Outlet	
1) Area per row of perforations	A = ________ square feet
2) Perforation Diameter (2 inches max.)	D = ________ inches
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 = ________ square feet
5. Trash Rack or Gravel Pack Present?	Yes/No ________
6. Basin Shape	
a. Length-Width Ratio	Ratio = __________ L:W
7. Forebay Design	
a. Forebay Volume (5-10% of SQDV min.)	Volume = __________ Acre-ft
b. Outlet pipe drainage time (< 45 minutes)	Drainage Time __________ Mins.
8. Embankment Slope	
a. Interior Slope (4:1 max.)	Interior Slope = __________ L/W
b, Exterior Slope (3:1 max.)	Exterior Slope = __________ L/W

Design Procedure Form for T-4: Wet Detention Basin (Page 3 of 3)

Project:____

9. Vegetation (Check type used or describe "Other")	_____ Native Grasses _____ Irrigated Turf Grass _____ Emergent Aquatic Plants (specify type / density) _____ Other ____________________ ____________________________
10. Underdrains Provided?	Yes /No __________

Notes:

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Design Procedure Form for T-5: Constructed Wetlands Basin

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = ________ %
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} = ________ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u= ________ in.
d. Watershed Area Tributary to EDB	Area = ________ acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV = ________ acre-ft
2. Wetland Pond Volume, Depth, and Water Surface Area	**<u>Minimums</u>**
a. Calculated Requirements, Minimum Permanent Pool: $Vol_{pool} \geq 0.75$ x SQDV	Vol_{pool} > ________ acre-ft Water Area> ________ acres, estimated
	<u>Actual Design</u>
	Vol_{pool} = ________ acre-ft, actual Water Area = ________ acres, actual
b. Forebay Depth Range = 2.0' – 4.0'	Depth = ________ ft
Volume Range = 5%to 10 % of SQDV	Volume = ________ acre-ft,% =_____
c. Outlet Pool Depth Range = 2.0' – 4.0'	Depth = ________ ft
Volume Range = 6%to 10% of SQDV	Volume = ________ acre-ft,% =____

Continued on next page

Design Procedure Form for T-5: Constructed Wetlands Basin (Page 2 of 3)

Project:____

2. Wetland Pond Volume, Depth, and Water Surface Area (Continued)	
d. Free Water Surface Areas (Area = 30-50% combined) (Depth Range = 2.0' – 4.0')	Depth = __________ ft Area = __________ acres, % = ____ Volume = __________ acre-ft
e. Wetland Zones with Emergent Vegetation (Depth Range = 6" – 12") (Area = 50-70%)	Depth = __________ ft Area = __________ acres, % = ____ Volume = __________ acre-ft
3. Estimated Net Base Flow (must be > 0) $Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} = __________ acre-ft Q_{evap} = __________ acre-ft $Q_{seepage}$ = __________ acre-ft $Q_{evapotranspiration}$ __________ acre-ft Q_{net} = __________ acre-ft
4. Outlet Works a. Outlet Type (check one)	Single Orifice __________ Multi-orifice Plate __________ Perforated Pipe __________ Other ____________________
b. Depth of water above bottom orifice	Depth = __________ feet
c. Single Orifice Outlet 1) Diameter 2) Area	 D = __________ feet A = __________ square feet
d. Multiple Orifice Outlet 1) Area per row of perforations 2) Perforation Diameter (2 inches max.) 3) No. of Perforations (columns) per Row 4) No. of Rows (4 inch spacing) 5) Total Orifice Area (Area per row) x (Number of Rows)	 A = __________ square inches D = __________ Perforations = __________ Rows = __________ Area = _____________ square inches

Design Procedure Form for T-5: Constructed Wetlands Basin (Page 3 of 3)

Project:____

5. Trash Rack or Gravel Pack Present?	Yes/No ____________
6. Basin Shape a. Length-Width Ratio	 Ratio = ____________ L:W
8. Embankment Slope a. Interior Slope (4:1 max.) b, Exterior Slope (3:1 max.)	 Interior Slope = __________ L:W Exterior Slope = __________ L:W
9. Vegetation (Check type used or describe "Other")	_____ Native Grasses _____ Irrigated Turf Grass _____ Emergent Aquatic Plants (specify type / density)* _____ Other ___________________________________ *Describe Species Density and Mix: _______________ ____ ____ ____ ____

Notes:

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Design Procedure Form for T-6: Detention Basin / Sand Filter

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	__________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	__________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	__________	acre-ft
d. Watershed Area Tributary to DBSF	Area =	__________	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	__________	acre-ft
2. Filter Surface Area (A_s)			
a. A_s (min) = Design Volume / (3 x 43,560 ft^2)	A_s (min) =	__________	ft^2
b. Design A_s	A_s =	__________	ft^2
3. Design basin depth, based on design filter area			
D = Design Volume/ Design A_s	D =	__________	ft
4. Filter Bed			
a) ASTM C33 Sand Layer (18 in. minimum)		__________	inches
b) ASSHTO M43-No.8 Gravel Layer (9 in. min.)		__________	inches

Notes:

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Design Procedure Form for T-7: Porous Pavement Detention

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = ______ %
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} = ______ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12 hr drawdown and I_{wq}	V_u= ______ acre-ft
d. Watershed Area Tributary to DBSF	Area = ______ acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV = ______ acre-ft
1. Basin Surface Area	
a. Design Volume (SQDV)	SQDV = ______ ft^3
b. A_s = Design Volume / (0.17 ft) (based on surcharge depth of 2 inches)	A_s = ______ ft^2
2. Block Type	Block name: ______
	Manufacturer: ______
a. Minimum open area = 40%	Open Area = ______ %
b. Minimum thickness = 4 inches	Thickness ______ inches
3. Base Course (Check)	
a. ASTM C33 Sand Layer (1 inch)	Sand Layer ______
b. ASSHTO M43-No.8 Gravel Layer (9 inches)	Gravel Layer ______

Notes:

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Design Procedure Form for T-8: Porous Landscape Detention Basin

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12 hr drawdown and I_{wq}	V_u=	________	acre-ft
d. Watershed Area Tributary to DBSF	Area =	________	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	________	acre-ft
2. Basin Surface Area			
a. Design Volume (SQDV)	SQDV =	________	ft^3
b. Average Depth	Average Depth =	________	ft
c. A_s = Design Volume / Average Depth	A_s =	________	ft^2
3. Base Course Layers (check)	Sandy Loam Turf	________	in. (6” min)
	Sand/peat mix	________	in. (18” min)
	Gravel	________	in. (9” min)
4. Subsurface Drainage (check)	________	Infiltration to subgrade with permeable geotextile membrane	
	________	Underdrain with impermeable membrane	
	________	Underdrain with permeable goetextile membrane	

Notes:

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Design Procedure Form for T-9: Infiltration Basin

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	__________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	__________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	__________	acre-ft
d. Watershed Area Tributary to DBSF	Area =	__________	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	__________	acre-ft
2. Maximum Allowable Depth ($D_m = tI/12s$)			
a. Site infiltration rate (I)	I =	__________	in/hr
b. minimum drawdown time (t = 40 hours)	t =	__________	hrs
c. safety factor (s)	s =	__________	
d. $D_m = tI/12s$	D_m =	__________	ft.
3. Basin Surface Area A_m = SQDV / D_m	A_m =	__________	ft^2
4. Vegetation (Check type used or describe "Other")	____ Native Grasses ____ Irrigated Turf Grass ____ Other		

Notes:

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Design Procedure Form for T-10: Infiltration Trench

Designer:___________________________

Company:___________________________

Date:___________________________

Project:___________________________

Location:___________________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u=	________	acre-ft
d. Watershed Area Tributary to DBSF	Area =	________	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV =	________	acre-ft
2. Trench Water Depth			
a. Soil iniltration rate	I =	________	In/hr
b. Safety factor (S)	s =	________	ft
c. Drawdown time (t = 40 hours)	t =	________	hrs
d. Max water depth (≤ 8 ft)			
D_m = (I x t) /12s	D_m =	________	ft.
3. Trench Bottom Surface Area			
A_s = SQDV / D_m	A_s =	________	ft^2

Notes:

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Design Procedure Form for T-11.1: Austin Sand Filter

Designer:___________________________

Company:___________________________

Date:___________________________

Project:___________________________

Location:___________________________

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = ________ %
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} = ________ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u= ________ in.
d. Watershed Area Tributary to DBSF	Area = ________ acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV = ________ acre-ft
2. Maximum Water Depth	
a. Storm drainage system invert elevation at proposed connection to storm drain	Inlet Elevation ________ ft
b. Minimum control measure outlet invert elevation of sand filter at minimum grade:	Outlet Elevation ________ ft
c, Estimate filter depth or use minimum depth of filter media and determine the difference in elevation between inverts of filter inlet and outlet:	Filter Depth ________ ft
d. Site plan surface elevation at control measure location	Surface Elvation ________ ft
e. Determine inlet invert elevation into sedimentation basin	Inlet Elevation (Sed. Basin) ________ ft
f. Determine maximum allowable depth of water (2h) in the sedimentation basin considering elevation differences between inlet and outlet invert elevations of sedimentation basin and filterand surface elevation. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices.)	Maximum Allowable Depth ________ ft

Design Procedure Form for T-11.1: Austin Sand Filter (Page 2 of 2)

Project:____

3. Filter Surface Area		
a. Sand Bed Depth	d_f = __________	ft
b. Coefficient of permeability for sand filter	k = __________	ft. / hr.
c. One half of maximum allowable depth over filter. (h)	h = __________	ft
d. Time required for runoff to pass through filter.	t_f = __________	hrs.
e. Filter Surface Area (minimum) $A_{fm} = \frac{(SQDV)(d_f)}{k(h+d_f)(t_f)}$	A_{fm} = __________	ft^2
4. Filter Basin Volume		
Filter Basin Volume = 0.2 x SQDV	FBV = __________	ft^3

Notes:

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Design Procedure Form for T-11.2:: DC Sand Filter

Designer: ______________________________

Company: ______________________________

Date: ______________________________

Project: ______________________________

Location: ______________________________

1. Determine Basin Storage Volume		
a. Percent Imperviousness of Tributary Area	I_a = ________	%
b. Effective Imperviousness (Determine using Figure 3-4	I_{wq} = ________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40 hr drawdown and I_{wq}	V_u= ________	in.
d. Watershed Area Tributary to DBSF	Area = ________	acres
e. Calculate SQDV SQDV = (V_u / 12) x Area	SQDV = ________	acre-ft
2. Minimum Filter Area $$A_{fm} = \frac{(SQDV)(d_f)}{k(h+d_f)(t_f)}$$		
a. SQDV	SQDV = ________	ft^3
b. Sand bed depth (d_f)	d_f = ________	ft
c. Filter Coefficient (k)	k = ________	ft. / hr.
d. Draw-down time (t_f= 40 hour)	t = ________	hr
e. one half maximum allowable water depth over filter (h)	h = ________	ft
f. Minimum filter area	A_{fm} = ________	ft^2
3. Select Filter Width, Compute Filter Length		
a. Select a Filter Width (W_f)	W_f = ________	ft.
b. Compute filter length $L_f = A_{fm}/W_f$	L_f = ________	ft.
c. Determine adjusted filter area (Round L_f to closest whole number) A_f = W_f x L_f	A_f = ________	ft^2
(From this point, formula assume rectangular cross section of filter shell.)		

Design Procedure Form for T-11.2: DC Filter (Page 2 of 2)

Project:______________________________

4. Compute the Storage Volume of Top of the Filter (V_{tf}) $V_{tf} = A_f \times 2h$	V_{tf} = ____________ ft^3
5. Compute the Storage in the Filter Voids (Vv) (Assume 40% voids in the filter media) $V_v = A_f \times (d_f + d_g) \times 0.40$	V_v = ____________ ft^3
6. Flow Through Filter During Filling (V_Q) (Assume 1-hour to fill) $V_Q = k \times A_f \times (d_f + d_g) \times t_f / d_f$ Use: k = 2 ft/day = 0.0833 ft/hr. t_f = 1 hr. to fill voids	V_O = ____________ ft^3
7. Compute Net Volume to be Stored in Permanent Pool Awaiting Filtration (Vst) $V_{st} = SQDV - V_{tf} – V_v - V_Q$	V_{st} = ____________ ft^3
8. Compute Minimum Length of Permanent Pool (Lpm) $L_{pm} = V_{st} /(2h)(W_f)$	L_{pm} = ____________ ft
9. Compute Minimum Length of Sediment Chamber (L_s) (to contain 20% of SQDV) If $V_{st} < (0.2SQDV)$, use: $L_s = 0.2SQDV /(2h)(W_f)$ If $V_{st} > (0.2SQDV)$, use: $L_s = V_{st} /(2h)(W_f)$	L_s = ____________ ft
10. Set Final Length of Permanent Pool (Lp) If $L_{pm} \geq (L_s + 2$ ft), use: $L_p = L_m$ If $L_{pm} < (L_s + 2$ ft), use: $L_p = (L_s + 2$ ft)	L_p = ____________ ft
11. Set Final Length of Clear Well (Lcw) L_{cw} = 3 ft minimum	L_{cw} = ____________ ft

Notes:

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Design Procedure Form for T-11.3: Delaware Sand Filter

Designer: ____________________

Company: ____________________

Date: ____________________

Project: ____________________

Location: ____________________

1. Minimum Surface Areas of the Chambers	
If 2h < 2.67 feet (2'-8")	
$A_{sm} = A_{fm} = SQDV / (4.1h + 0.9)$	
If 2h > 2.67 feet (2'-8")	
$A_{sm} = A_{fm} = \frac{(SQDV)(d_f)}{k\, t_f (h + d_f)}$	
a. SQDV	SQDV = ______ ft^3
b. Sand bed depth (d_f)	d_f = ______ ft
c. Filter Coefficient (k)	k = ______ ft. / hr.
d. Draw-down time (t_f)	t = ______ hr
e. One half maximum allowable water depth over filter (h)	h = ______ ft
f. A_{sm} (Sediment Chamber Area) and A_{fm} (Filter Surface Area)	A_{sm} and A_{fm} = ______ ft^2
2. Sediment Chamber and Filter Width / Length	
a. Select width ($W_s = W_f$ = 18 to 30 inches)	$W_s = W_f$ = ______ ft.
b. Filter length ($L_s = L_f = A_{fm} / W_f$)	$L_s = L_f$ = ______ ft.
c. Adjusted length (rounded)	$L_s = L_f$ = ______ ft.
d. Adjusted area ($A_s = A_f = W_f \times L_f$)	$A_s = A_f$ = ______ ft^2
3. System Storage Volume	
a. Storage in filter voids ($V_v = A_f \times (d_f + d_f) \times 0.4$)	V_v = ______ ft.
b. Flow through filter ($V_Q = k A_f (d_f + h)$ 1hr/ d_f)	V_Q = ______ ft.
c. Required net storage ($V_{st} = SQDV – V_v – V_Q$)	V_{st} = ______ ft.
d. Available storage ($V_{sf} = 2h(A_f + A_s)$)	V_{sf} = ______ ft^2
If $V_{sf} \geq V_{st}$, sizing is complete	
If $V_{sf} < V_{st}$, repeat steps 2 and 3	

VENTURA COUNTYWIDE STORMWATER QUALITY URBAN IMPACT MITIGATION PLAN

FOR THE VENTURA COUNTY FLOOD CONTROL DISTRICT, THE COUNTY OF VENTURA, AND THE CITIES OF VENTURA COUNTY

VENTURA COUNTYWIDE URBAN RUNOFF AND STORM WATER NPDES PERMIT

STORM WATER QUALITY URBAN IMPACT MITIGATION PLAN

BACKGROUND

The Ventura Countywide Stormwater Quality Management Program (Ventura Program) was established pursuant to Section 402(p) of the Federal Clean Water Act, which requires that all point source discharges of pollutants into waters of the United States, including discharges from municipal storm drain systems, be regulated by a National Pollutant Discharge Elimination System (NPDES) permit. On August 22, 1994 the California Regional Water Quality Control Board, Los Angeles Region (Regional Board), issued NPDES permit CAS063339 (Permit) to the Ventura County Flood Control District (VCFCD), the County of Ventura, and the cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, San Buenaventura, Santa Paula, Simi Valley, and Thousand Oaks for discharges from municipal storm drain systems in Ventura County. On February 11, 1999 these twelve agencies, the Co-permittees, submitted a Stormwater Quality Management Plan (1999 Plan) in accordance with Title 23, California Code of Regulation and as required by Permit. The 1999 Plan served as application for reissuance of waste discharge requirements and presented activities designed to advance the municipal storm water program that the Co-permittees implemented during the first five-year permit term. The 1999 Plan included a program for development planning. The Regional Board accepted the 1999 Plan, however, delayed reissuance of the Permit. On March 8, 2000, the Regional Board approved a final Standard Urban Storm Water Mitigation Plan (SUSMP) for Los Angles County and the Cities in Los Angeles County. Subsequently, at the request of the Regional Board, the Co-permittees prepared the Ventura Countywide Stormwater Quality Urban Impact Mitigation Plan (SQUIMP) to be consistent with SUSMP requirements and will be modifying the 1999 Plan to include the modified requirements.

The requirement to implement a program for development planning is based on, federal and state statutes including: Section 402 (p) of the Clean Water Act, Section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990 (“CZARA”), and the California Water Code. The Clean Water Act amendments of 1987 established a framework for regulating storm water discharges from municipal, industrial, and construction activities under the NPDES program. The primary objectives of the municipal storm water program requirements are to:

1. Effectively prohibit non-storm water discharges, and

2. Reduce the discharge of pollutants from storm water conveyance systems to the Maximum Extent Practicable (MEP statutory standard).

The SQUIMP was developed as part of the municipal storm water program to address storm water pollution from new development and redevelopment by the private sector. This SQUIMP contains a list of the minimum required Best Management Practices (BMPs) that shall be used for a designated project. Additional BMPs may be required by ordinance or code adopted by the Co-permittees and applied generally or on a case by case basis. The Co-permittees are required to implement the requirements set herein in their own jurisdictions. Developers shall incorporate appropriate SQUIMP requirements into the project plans for the projects covered by the SQUIMP requirements. Each Co-permittee will approve the project plan as part of the development plan approval process.

All projects that fall into one of eight categories are identified in the Ventura Countywide Municipal Permit as requiring SQUIMPs. These categories are:

- Single-Family Hillside Residences
- 100,000 Square Foot Commercial Developments
- Automotive Repair Shops
- Retail Gasoline Outlets
- Restaurants
- Home Subdivisions with 10 or more housing units
- Location within or directly adjacent to or discharging directly to an environmentally sensitive area
- Parking lots with 5,000 square feet or more impervious parking or access surfaces or with 25 or more parking spaces and potentially exposed to storm water runoff

The SQUIMP requirements shall take effect not later than January 27, 2001 for projects identified herein that have not received development/planning permit approval or been deemed complete for processing prior to July 27, 2000..

DEFINITIONS

"100,000 Square Foot Commercial Development" means any commercial development that creates at least 100,000 square feet of impermeable area, including parking areas.

"Automotive Repair Shop" means a facility that is categorized in any one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, or 7536-7539.

"Best Management Practice (BMP)" means any program, technology, process, siting criteria, operational methods or measures, or engineered systems, which when implemented prevent, control, remove, or reduce pollution.

"Commercial Development" means any development on private land that is not heavy industrial or residential. The category includes, but is not limited to: hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, multi-apartment buildings, car wash facilities, mini-malls and other business complexes, shopping malls, hotels, office buildings, public warehouses and other light industrial complexes.

“Designated Public Access Points” means any pedestrian, bicycle, equestrian, or vehicular point of access to jurisdictional channels in the area of Ventura County subject to permit requirements.

“Directly Adjacent” means situated within 200 feet of the contiguous zone required for the continued maintenance, function, and structural stability of the environmentally sensitive area.

“Directly Connected Impervious Area (DCIA)” means the area covered by a building, impermeable pavement, and/ or other impervious surfaces, which drains directly into the storm drain without first flowing across permeable land area (e.g. lawns).

.“Directly Discharging” means outflow from a drainage conveyance system that is composed entirely or predominantly of flows from the subject, property, development, subdivision, or industrial facility, and not commingled with the flows from adjacent lands.

“Environmentally Sensitive Area” means an area “in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which would be easily disturbed or degraded by human activities and developments” (California Public Resources Code § 30107.5)

Areas subject to storm water mitigation requirements are: areas designated as an Area of Special Biological Significance (ASBS) by the State Water Resources Control Board, an area designated as a significant natural resource by the California Resources Agency, or an area identified by the Discharger as environmentally sensitive for water quality purposes, based on the Regional Board Basin Plan and Clean Water Act Section 303(d) Impaired Water-bodies List for the County of Ventura.

“Hillside” means 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.

“Infiltration” means the downward entry of water into the surface of the soil.

“New Development” means land disturbing activities; structural development, including construction or installation of a building or structure, creation of impervious surfaces; and land subdivision.

“Parking Lot” means 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.

“Redevelopment” means, but is not limited to, the 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; land disturbing activities related with structural or impervious surfaces. Redevelopment that results in the creation or addition of 5,000 square feet or more of impervious surfaces is subject to the requirements for storm water mitigation. If the creation or addition of impervious surfaces is fifty percent or more of the existing impervious surface area, then storm water runoff from the entire area (existing and additions) must be considered for purposes of storm water mitigation. If the creation or additions is less than fifty percent of the existing impervious area, then storm water runoff from only the addition area needs mitigation.

“Restaurant” means 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).

“Retail Gasoline Outlet” means any facility engaged in selling gasoline and lubricating oils.

“Source Control BMP” means any schedules of activities, structural devices, prohibitions of practices, maintenance procedures, managerial practices or operational practices that aim to prevent storm water pollution by reducing the potential for contamination at the source of pollution.

“Storm Event” means a rainfall event that produces more than 0.1 inch of precipitation and that, which is separated from the previous storm event by at least 72 hours of dry weather.

“Structural BMP” means any structural facility designed and constructed to mitigate the adverse impacts of storm water and urban runoff pollution (e.g. canopy, structural enclosure). The category may include both Treatment Control BMPs and Source Control BMPs.

“Treatment” means 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 UV radiation.

“Treatment Control BMP” means 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.

CONFLICTS WITH LOCAL PRACTICES

Where provisions of the SQUIMP requirements conflict with established local codes, (e.g., specific language of signage used on storm drain stenciling), the Co-permittees may continue the local practice and modify the SQUIMP to be consistent with the code, except that to the extent that the standards in the SQUIMP are more stringent than those under local codes, such more stringent standards shall apply.

SQUIMP PROVISIONS APPLICABLE TO ALL CATEGORIES

REQUIREMENTS

1. PEAK STORM WATER RUNOFF DISCHARGE RATES

The Discharger shall control the post-development peak storm water runoff discharge rates to maintain or reduce pre-development downstream erosion, and to protect stream habitat.

2. CONSERVE NATURAL AREAS

If applicable, the following items are required and shall be implemented in the site layout during the subdivision design and approval process, consistent with applicable General Plan and Local Area Plan policies:

- Concentrate or cluster Development on portions of a site while leaving the remaining land in a natural undisturbed condition.
- Limit clearing and grading of native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection.
- 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.
- Promote natural vegetation by using parking lot islands and other landscaped areas.
- Preserve riparian areas and wetlands.

3. MINIMIZE STORM WATER POLLUTANTS OF CONCERN

Storm water runoff from a site has the potential to contribute oil and grease, suspended solids, metals, gasoline, pesticides, and pathogens to the storm water conveyance system. The development shall be designed so as to minimize, to the maximum extent practicable, the introduction of pollutants of concern that may result in significant impacts, generated from site runoff of directly connected impervious areas (DCIA), to the storm water conveyance system. Pollutants of concern consist of any pollutants that exhibit one or more of the following characteristics: current loadings or historic deposits of the pollutant are impacting the beneficial uses of a receiving water, elevated levels of the pollutant are found in sediments of a receiving water and/or have the potential to bioaccumulate in organisms therein, or the detectable inputs of the pollutant are at concentrations or loads considered potentially toxic to humans and/or flora and fauna. The storm water pollutants of concern currently identified by the Program are total and fecal coliform, mercury, PAHs, DDT and byproducts, diazinon, sediment/TSS, chlorpyrifos, copper, lead, thallium, bis(2-ethylhexyl)phthalate, and phosphorous. The program may amend the list of pollutants of concern as additional information becomes available.

In meeting this specific requirement, "minimization of the pollutants of concern" will require the incorporation of a BMP or combination of BMPs best suited to maximize the reduction of pollutant loadings in that runoff to the Maximum Extent Practicable. Those BMPs best suited for that purpose are those listed in the ***Ventura Countywide Stormwater Quality Management Program's Land Development Guidelines***; ***California Storm Water Best Management Practices Handbooks***; ***Caltrans Storm Water Quality Handbook: Planning and Design Staff Guide***; ***Start at the Source (1999) by Bay Area Stormwater Management Agencies Association***, ***Manual for Storm Water Management in Washington State***; ***The Maryland Storm Water Design Manual***; ***Florida Development Manual: A Guide to Sound Land and Water Management***; Denver ***Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices*** and ***Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters***, USEPA Report No. EPA-840-B-92-002, as "likely to have significant impact" beneficial to water quality for targeted pollutants that are of concern at the site in question. However, it is possible that a combination of BMPs not so designated may, in a particular circumstance, be better suited to maximize the reduction of the pollutants.

Examples of BMPs that can be used for minimizing the introduction of pollutants of concern generated from site runoff are identified in Table 2. All BMPs for development planning recommended in one of the above references may be used, subject to the criteria set in this SQUIMP.

4. PROTECT SLOPES AND CHANNELS

Project plans shall include BMPs consistent with local codes and ordinances and the SQUIMP to decrease the potential of slopes and/or channels from eroding and impacting storm water runoff:

- Convey runoff safely from the tops of slopes and stabilize disturbed slopes
- Utilize natural drainage systems to the Maximum Extent Practicable
- Control or reduce or eliminate flow to natural drainage systems to the Maximum Extent Practicable
- Stabilize permanent channel crossings
- Vegetate slopes with first consideration given to native or drought tolerant species
- Install energy dissipaters, such as riprap, at the outlets of new storm drains, culverts, conduits, or channels that enter unlined channels in accordance with applicable specificationsto minimize erosion, with the approval of all agencies

with jurisdiction, e.g., the U.S. Army Corps of Engineers and the California Department of Fish and Game

5. PROVIDE STORM DRAIN SYSTEM STENCILING AND SIGNAGE

Storm drain stencils are highly visible source controls that are typically placed directly adjacent to storm drain inlets. The stencil contains a brief statement that prohibits the dumping of improper materials into the storm water conveyance system. Graphical icons, either illustrating anti-dumping symbols or images of receiving water fauna, are effective supplements to the anti-dumping message.

- All storm drain inlets and catch basins within the project area shall be stenciled with prohibitive language (such as: "DON'T DUMP! DRAINS TO OCEAN") and/or graphical icons to discourage illegal dumping.
- Signs and prohibitive language and/or graphical icons, which prohibit illegal dumping, shall be posted at designated public access points along channels and creeks within the project area.
- Legibility of stencils and signs shall be maintained.

6. PROPERLY DESIGN OUTDOOR MATERIAL STORAGE AREAS

Outdoor material storage areas refer to storage areas or storage facilities solely for the storage of materials. Improper storage of materials outdoors may provide an opportunity for toxic compounds, oil and grease, heavy metals, nutrients, suspended solids, and other pollutants to enter the storm water conveyance system. Where proposed project plans include outdoor areas for permanent storage of materials that may contribute pollutants to the storm water conveyance system, the following Structural or Treatment BMPs are required:

- Materials with the potential to contaminate storm water shall be: (1) placed in an enclosure such as, but not limited to, a cabinet, shed, or similar structure that prevents contact with runoff or spillage to the storm water conveyance system; or (2) protected by secondary containment structures such as berms, dikes, or curbs.
- The storage area shall be paved and sufficiently impervious to contain leaks and spills.

- The storage area shall have a roof or awning to minimize collection of storm water within the secondary containment area.

7. PROPERLY DESIGN TRASH STORAGE AREAS

A trash storage area refers to an area where a trash receptacle or receptacles are located for use as a repository for solid wastes. Loose trash and debris can be easily transported by the forces of water or wind into nearby storm drain inlets, channels, and/or creeks. All trash container areas shall meet the following Structural or Treatment Control BMP requirements (individual single family residences are exempt from these requirements):

- Trash container areas shall have drainage from adjoining roofs and pavement diverted around the area(s).
- Trash container areas shall be screened or walled to prevent off-site transport of trash.

8. PROVIDE PROOF OF ONGOING BMP MAINTENANCE

Improper maintenance is one of the most common reasons why water quality controls will not function as designed or systems to fail entirely. It is important to consider who will be responsible for maintenance of a permanent BMP and what equipment is required to perform the maintenance properly. As part of project review, if a project applicant has included or is required to include, Structural or Treatment Control BMPs in project plans, the Co-permittee shall require that the applicant provide verification of maintenance provisions through such means as may be appropriate, including, but not limited to legal agreements, covenants, CEQA mitigation requirements and/or Conditional Use Permits.

For all properties, the verification will include the developer’s signed statement, as part of the project application, accepting responsibility for all structural and treatment control BMP maintenance until the time the property is transferred and, where applicable, a signed agreement from the public or private entity assuming responsibility for Structural or Treatment Control BMP maintenance. The transfer of property to a private or public owner shall have conditions requiring the recipient to assume responsibility for maintenance of any Structural or Treatment Control BMP included in the sales or lease agreement for that property. The condition of transfer shall include a provision that the property owners conduct maintenance inspection of all Structural or Treatment Control BMPs at least once a year and retain proof of inspection. For residential properties where the Structural or Treatment Control BMPs are located within a common area which will be maintained by a homeowner’s association, language regarding the responsibility for maintenance shall be included in the projects conditions, covenants and restrictions (CC&Rs). Printed educational materials will be required to accompany the first deed transfer to highlight the existence of the requirement and to provide information on what storm water management facilities are present, signs that maintenance is needed, how the necessary maintenance can be performed, and assistance that the Co-permittee can provide. The transfer of this information shall also be required with any subsequent sale of the property.

If Structural or Treatment Control BMPs are located within a public area proposed for transfer, they will be the responsibility of the developer until they are accepted for transfer by the appropriate public agency. Structural or Treatment Control BMPs proposed for transfer shall meet design standards adopted by the public entity for the BMP installed and should be approved by the appropriate public agency prior to installation.

9. DESIGN STANDARDS FOR STRUCTURAL OR TREATMENT CONTROL BMPs

Structural or Treatment Control BMPs selected for use at any project covered by this SQUIMP shall meet the design standards of this Section unless specifically exempted.

Volume-based and flow-based design standards may be used separately or in combination to equivalent treatment of storm water discharges. Volume-based criteria should be used in the sizing of detention/retention or infiltration structures; flow-based criteria should be used on swales, catch basin devices, or wetlands. Other, BMP-specific criteria may be applicable. Project applicants should refer to the ***Ventura Countywide Storm Water Quality Management Program Land Development Guidelines*** for further information.

Volume-based Post-construction Structural or Treatment Control BMPs shall be designed to mitigate (infiltrate or treat) storm water runoff from either:

1. the volume of annual runoff based on unit basin storage water quality volume, to achieve 80 percent or more volume treatment by the method recommended in ***California Stormwater Best Management Practices Handbook – Industrial/ Commercial,*** (1993), the ***Ventura Countywide Stormwater Quality Management Program Land Development Guidelines***, or

2. the 85th percentile 24-hour runoff event determined as the maximized capture storm water volume for the area, from the formula recommended in ***Urban Runoff Quality Management, WEF Manual of Practice No. 23/ ASCE Manual of Practice No. 87, (1998***), or

3. the volume of runoff produced from a 0.75 inch storm event, prior to its discharge to a storm water conveyance system, or

4. the volume of runoff produced from a historical-record based reference 24-hour rainfall criterion for "treatment" that achieves approximately the same reduction in pollutant loads achieved by the 85th percentile 24-hour runoff event,

OR

Flow Based Post-Construction Structural or Treatment Control BMPs shall be sized to handle the flow generated from either:

1. 10% of the 50-year design flow rate, or

2. a flow that will result in treatment of the same portion of runoff as treated using volumetric standards above, or

3. a rain event equal to at least 0.2 inches per hour intensity, or

4. a rain event equal to at least two times the 85th percentile hourly rainfall intensity for Ventura County

Limited Exclusion

Where the land area for development or redevelopment is less than 5,000 square feet, restaurants are excluded from the numerical Structural or Treatment Control BMP design standard requirement only.

10. PROVISIONS APPLICABLE TO INDIVIDUAL PRIORITY PROJECT CATEGORIES

REQUIREMENTS

A. 100,000 SQUARE FOOT COMMERCIAL DEVELOPMENTS

1. PROPERLY DESIGN LOADING/UNLOADING DOCK AREAS

Loading/unloading dock areas have the potential for material spills to be quickly transported to the storm water conveyance system. To minimize this potential, the following design criteria are required:

- Cover loading dock areas or design drainage to minimize run-on and runoff of storm water.
- Direct connections to storm drains from depressed loading docks (truck wells) are prohibited.

2. PROPERLY DESIGN REPAIR/MAINTENANCE BAYS

Oil and grease, solvents, car battery acid, coolant and gasoline from the repair/maintenance bays can negatively impact storm water if allowed to come into contact with storm water runoff. Therefore, design plans for repair bays shall include the following:

- Repair/maintenance bays shall be indoors or designed in such a way that does not allow storm water run-on or contact with storm water runoff.
- Design a repair/maintenance bay drainage system to capture all washwater, leaks and spills. Connect drains to a sump for collection and disposal. Direct connection of the repair/maintenance bays to the storm drain system is prohibited. If required by local jurisdiction, obtain an Industrial Waste Discharge Permit.

3. PROPERLY DESIGN VEHICLE/EQUIPMENT WASH AREAS

The activity of vehicle/equipment washing/steam cleaning has the potential to contribute metals, oil and grease, solvents, phosphates, and suspended solids to the storm water conveyance system. Include, in the project plans, an area for washing/steam cleaning of vehicles and equipment. The area in the site design shall be:

- Self-contained and/or covered, equipped with a clarifier, or other pretreatment facility, and properly connected to a sanitary sewer.

B. RESTAURANTS

1. PROPERLY DESIGN EQUIPMENT/ACCESSORY WASH AREAS

The activity of outdoor equipment/accessory washing/steam cleaning has the potential to contribute metals, oil and grease, solvents, phosphates, and suspended solids to the storm water conveyance system. Include in the project plans an area for the washing/steam cleaning of equipment and accessories. This area shall be:

- Self-contained, connected to a grease interceptor, and properly connected to a sanitary sewer.
- If the wash area is to be located outdoors, it shall be covered, paved, have secondary containment, be connected to a grease interceptor and be connected to the sanitary sewer.

C. RETAIL GASOLINE OUTLETS

1. PROPERLY DESIGN FUELING AREA

Fueling areas have the potential to contribute oil and grease, solvents, car battery acid, coolant and gasoline to the storm water conveyance system. The project plans shall include the following BMPs:

- The fuel dispensing area shall be covered with an overhanging roof structure or canopy. The canopy's minimum dimensions shall be equal to or greater than the area within the grade break. The canopy shall not drain onto the fuel dispensing area, and the canopy downspouts shall be routed to prevent drainage across the fueling area.
- The fuel dispensing area shall be paved with Portland cement concrete (or equivalent smooth impervious surface), and the use of asphalt concrete shall be prohibited.

- The fuel dispensing area shall have a 2% to 4% slope to prevent ponding, and shall be separated from the rest of the site by a grade break that prevents run-on of storm water to the extent practicable.
- At a minimum, the concrete fuel dispensing area shall extend 6.5 feet (2.0 meters) from the corner of each fuel dispenser, or the length at which the hose and nozzle assembly may be operated plus 1 foot (0.3 meter), whichever is less.

D. AUTOMOTIVE REPAIR SHOPS

1. PROPERLY DESIGN FUELING AREA

Fueling areas have the potential to contribute oil and grease, solvents, car battery acid, coolant and gasoline to the storm water conveyance system. Therefore, design plans, which include fueling areas, shall contain the following:

- The fuel dispensing area shall be covered with an overhanging roof structure or canopy. The cover's minimum dimensions shall be equal to or greater than the area within the grade break. The cover shall not drain onto the fuel dispensing area and the downspouts shall be routed to prevent drainage across the fueling area.
- The fuel dispensing areas shall be paved with Portland cement concrete (or equivalent smooth impervious surface), and the use of asphalt concrete shall be prohibited.

- The fuel dispensing area shall have a 2% to 4% slope to prevent ponding, and shall be separated from the rest of the site by a grade break that prevents run-on of storm water.
- At a minimum, the concrete fuel dispensing area shall extend 6.5 feet (2.0 meters) from the corner of each fuel dispenser, or the length at which the hose and nozzle assembly may be operated plus 1 foot (0.3 meter), whichever is less.

2. PROPERLY DESIGN REPAIR/MAINTENANCE BAYS

Oil and grease, solvents, car battery acid, coolant and gasoline from the repair/maintenance bays can negatively impact storm water if allowed to come into contact with storm water runoff. Therefore, design plans for repair bays shall include the following:

- Repair/maintenance bays shall be indoors or designed in such a way that does not allow storm water run-on or contact with storm water runoff.

- Design a repair/maintenance bay drainage system to capture all wash-water, leaks and spills. Connect drains to a sump for collection and disposal. Direct connection of the repair/maintenance bays to the storm drain system is prohibited. If required by local jurisdiction, an Industrial Waste Discharge Permit should be obtained.

3. PROPERLY DESIGN VEHICLE/EQUIPMENT WASH AREAS

The activity of vehicle/equipment washing/steam cleaning has the potential to contribute metals, oil and grease, solvents, phosphates, and suspended solids to the storm water conveyance system. Include, in the project plans, an area for washing/steam cleaning of vehicles and equipment. This area shall be:

- Self-contained and/or covered, equipped with a clarifier, or other pretreatment facility, and properly connected to a sanitary sewer or to a permitted disposal facility.

4. PROPERLY DESIGN LOADING/UNLOADING DOCK AREAS

Loading/unloading dock areas have the potential for material spills to be quickly transported to the storm water conveyance system. To minimize this potential, the following design criteria are required:

- Cover loading dock areas or design drainage to minimize run-on and runoff of storm water

- Direct connections to storm drains from depressed loading docks (truck wells) are prohibited

E. <u>PARKING LOTS</u>

1. PROPERLY DESIGN PARKING AREA

Parking lots contain pollutants such as heavy metals, oil and grease, and polycyclic aromatic hydrocarbons that are deposited on parking lot surfaces by motor vehicles. These pollutants are directly transported to surface waters. To minimize the offsite transport of pollutants, the following design criteria are required:

- Reduce impervious land coverage of parking areas
- Infiltrate runoff before it reaches the storm drain system
- Treat runoff before it reaches the storm drain system

2. PROPERLY DESIGN TO LIMIT OIL CONTAMINATION AND PERFORM MAINTENANCE

Parking lots may accumulate oil, grease, and water insoluble hydrocarbons from vehicle drippings and engine system leaks.

- Treat to remove oil and petroleum hydrocarbons at parking lots that are heavily used (e.g. fast food outlets, lots with 25 or more parking spaces, sports event parking lots, shopping malls, grocery stores, discount warehouse stores)
- Ensure adequate operation and maintenance of treatment systems, particularly sludge and oil removal, and system fouling/plugging prevention control

11. WAIVER

A Co-permittee may, through adoption of an ordinance or code incorporating the treatment requirements of the SQUIMP, provide for a waiver from the requirement if impracticability for a specific property can be established. A waiver for impracticability shall be granted only when all other Structural or Treatment Control BMPs have been considered and rejected as infeasible. Recognized situations of impracticability include, (i) extreme limitations of space for treatment on a redevelopment project, (ii) unfavorable or unstable soil conditions at a site to attempt infiltration, and (iii) risk of ground water contamination because a known unconfined aquifer lies beneath the land surface or an existing or potential underground source of drinking water is less than 10 feet from the soil surface. Any other justificationfor impracticability shall be separately petitioned by the Co-permittee and submitted to the Regional Board for consideration. The Regional Board may consider approval of the waiver justification or may delegate the authority to approve a class of waiver justifications to the Regional Board Executive Officer. The supplementary waiver justification becomes recognized and effective only after approval by the Regional Board or the Regional Board Executive Officer. A waiver granted by a Co-permittee to any development or redevelopment project may be revoked by the Regional Board Executive Officer for cause and with proper notice upon petition.

If a waiver is granted for impracticability, the Co-permittee shall require the project proponent to transfer the savings in cost, as determined by the Co-permittee, to a storm water mitigation fund operated by a public agency or a non-profit entity to be used to promote regional or alternative solutions for storm water pollution in the watershed.

12. LIMITATION ON USE OF INFILTRATION BMPs

Three factors significantly influence the potential for storm water to contaminate ground water. They are (i) pollutant mobility, (ii) pollutant abundance in storm water, (iii) and soluble fraction of pollutant. The risk of contamination of groundwater may be reduced by pretreatment of storm water. A discussion of limitations and guidance for infiltration practices is contained in, ***Potential Groundwater Contamination from Intentional and Non-Intentional Storm water Infiltration, Report No. EPA/600/R-94/051, USEPA (1994).***

The distance of the groundwater table from the infiltration BMP may also be a factor determining the risk of contamination. A historic high water table distance separation of ten feet depth in California presumptively poses negligible risk for storm water not associated with industrial activity or high vehicular traffic except in cases where groundwater basins are unconfined. Unconfined groundwater basins and vulnerable unconfined aquifers are areas that have been identified by the County of Ventura Public Works Agency, Water Resources Division and the Regional Board as areas where the application of infiltration BMPs should be limited to those that provide pre-treatment to ensure groundwater is protected from pollutants of concern.

Infiltration BMPs are not recommended for areas of industrial activity or areas subject to high vehicular traffic (25,000 or greater average daily traffic (ADT) on main roadway or 15,000 or more ADT on any intersecting roadway) unless appropriate pretreatment is provided to ensure groundwater is protected and the infiltration BMP is not rendered ineffective by overload.

13. ALTERNATIVE CERTIFICATION FOR STORM WATER TREATMENT MITIGATION

In lieu of conducting detailed BMP review to verify Structural or Treatment Control BMPs adequacy, a Co-permittee may elect to accept a signed certification from a Civil Engineer or a Licensed Architect registered in the State of California, that the plan meets the criteria established herein. The Co-permittee is encouraged to verify that certifying person(s) have been trained on BMP design for water quality, not more than two years prior to the signature date. Training conducted by an organization with storm water BMP design expertise (e.g., a University,American Society of Civil Engineers,American Society of Landscape Architects, American Public Works Association, or the California Water Environment Association) may be considered qualifying.

14. RESOURCES AND REFERENCE

TABLE 1

SUGGESTED RESOURCES	HOW TO GET A COPY

Ventura Countywide Stormwater Quality Management Program Land Development Guidelines Presents guidance for designing storm water BMPs	Ventura County Flood Control District 800 South Victoria Avenue Ventura, CA 93009 805-650-4064
Start at the Source (1999) by Bay Area Stormwater Management Agencies Association Detailed discussion of permeable pavements and alternative driveway designs presented.	Bay Area Stormwater Management Agencies Association 2101 Webster Street Suite 500 Oakland, CA 510-286-1255
Design of Stormwater Filtering Systems (1996) by Richard A. Claytor and Thomas R. Schuler Presents detailed engineering guidance on ten different storm water-filtering systems.	Center for Watershed Protection 8391 Main Street Ellicott City, MD 21043 410-461-8323
Better Site Design: A Handbook for Changing Development Rules in Your Community (1998) Presents guidance for different model development alternatives.	Center for Watershed Protection 8391 Main Street Ellicott City, MD 21043 410-461-8323
Design Manual for Use of Bioretention in Stormwater Management (1993) Presents guidance for designing bioretention facilities.	Prince George's County Watershed Protection Branch 9400 Peppercorn Place, Suite 600 Landover, MD 20785
Operation, Maintenance and Management of Stormwater Management (1997) Provides a thorough look at storm water practices including, planning and design considerations, programmatic and regulatory aspects, maintenance considerations, and costs.	Watershed Management Institute, Inc. 410 White Oak Drive Crawfordville, FL 32327 850-926-5310
California Storm Water Best Management Practices Handbooks (1993) for Construction Activity, Municipal, and Industrial/Commercial Presents a description of a large variety of Structural BMPs, Treatment Control, BMPs and Source Control BMPs	Los Angeles County Department of Public Works Cashiers Office 900 S. Fremont Avenue Alhambra, CA 91803 626-458-6959

Second Nature: Adapting LA's Landscape for Sustainable Living (1999) by Tree People Detailed discussion of BMP designs presented to conserve water, improve water quality, and achieve flood protection.	Tree People 12601 Mullholland Drive Beverly Hills, CA 90210 818-753-4600
Florida Development Manual: A Guide to Sound Land and Water Management (1988) Presents detailed guidance for designing BMPs	Florida Department of the Environment 2600 Blairstone Road, Mail Station 3570 Tallahassee, FL 32399 850-921-9472
Stormwater Management in Washington State (2000) Vols. 1-5 Presents detailed guidance on BMP design for new development and construction.	Department of Printing State of Washington Department of Ecology P.O. Box 798 Olympia, WA 98507-0798 360-407-7529
Maryland Stormwater Design Manual (2000) Presents guidance for designing storm water BMPs	Maryland Department of the Environment 2500 Broening Highway Baltimore, MD 21224 410-631-3000
Texas Nonpoint Source Book – Online Module (1998)www.txnpsbook.org Presents BMP design and guidance information on-line	Texas Statewide Storm Water Quality Task Force North Central Texas Council of Governments 616 Six Flags Drive Arlington, TX 76005 817-695-9150
Urban Storm Drainage, Criteria Manual – Volume 3, Best Management Practices (1999) Presents guidance for designing BMPs	Urban Drainage and Flood Control District 2480 West 26th Avenue, Suite 156-B Denver, CO 80211 303-455-6277
National Storm water Best Management Practices (BMP) Database, Version 1.0 Provides data on performance and evaluation of storm water BMPs	American Society of Civil Engineers 1801 Alexander Bell Drive Reston, VA 20191 703-296-6000
Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters (1993) Report No. EPA–840-B-92-002. Provides an overview of, planning and design considerations, programmatic and regulatory aspects, maintenance considerations, and costs.	National Technical Information Service U.S. Department of Commerce Springfield, VA 22161 800-553-6847
Caltrans Storm Water Quality Handbook: Planning and Design Staff Guide (Best Management Practices Handbooks (1998) Presents guidance for design of storm water BMPs	California Department of Transportation P.O. Box 942874 Sacramento, CA 94274-0001 916-653-2975

TABLE 2

EXAMPLE BEST MANAGEMENT PRACTICES (BMPs)

The following are examples of BMPs that can be used for minimizing the introduction of pollutants of concern that may result in significant impacts, generated from site runoff to the storm water conveyance system. (See Table 1: Suggested Resources for additional sources of information):

- Provide reduced width sidewalks and incorporate landscaped buffer areas between sidewalks and streets. However, sidewalk widths shall still comply with regulations for the Americans with Disabilities Act and other life safety requirements.
- Design residential streets for the minimum required pavement widths needed to comply with all zoning and applicable ordinances to support travel lanes; on-street parking; emergency, maintenance, and service vehicle access; sidewalks; and vegetated open channels.
- Comply with all zoning and applicable ordinances to minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles. Alternative turnarounds should be considered.
- Use permeable materials for private sidewalks, driveways, parking lots, or interior roadway surfaces (examples: hybrid lots, parking groves, permeable overflow parking, etc.).
- Use open space development that incorporates smaller lot sizes.
- Reduce building density.
- Comply with all zoning and applicable ordinances to reduce overall lot imperviousness by promoting alternative driveway surfaces and shared driveways that connect two or more homes together.
- Comply with all zoning and applicable ordinances to reduce the overall imperviousness associatedwith parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, and using pervious materials in spillover parking areas.
- Direct rooftop runoff to pervious areas such as yards, open channels, or vegetated areas, and avoid routing rooftop runoff to the roadway or the storm water conveyance system.
- Biofilters including vegetated swales and strips
- Extended/dry detention basins
- Infiltration basin
- Infiltration trenches or vaults
- Wet detention basins/wet ponds
- Constructed wetlands

TABLE 2 (Continued)

- Media filtration
- Bioretention facility
- Foundation planting
- Normal flow storage/separation systems
- Clarifiers
- Filtration systems
- Primary waste water treatment systems
- Cistern

Environmentally Sensitive Areas

All projects located in or directly adjacent to or directly discharging to an Environmentally Sensitive Area (ESA) are subject to stormwater mitigation requirements, where the development will:

- Discharge stormwater and urban runoff that is likely to impact a sensitive biological species or habitat; and
- Create 2,500 square feet or more of impervious surface area.

Re-development of single family homes are exempt.

ESAs will include 303d listed water bodies in all reaches that are unimproved and soft-bottomed and all California Coastal Commission's *Environmentally Sensitive Habitat Areas* as delineated on maps in Local Coastal Plans. The California Department of Fish and Game's (CDFG) *Significant Natural Areas* map will be considered for inclusion as the department field verifies the designated locations (CDFG has requested that these areas not be included until they are field verified).

This appendix will be updated in the future to include a map(s) showing the location of any newly identified ESAs within Ventura County.

Appendix J
References

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Bay Area Stormwater Management Agencies Association (BASMAA), 1999. Start at the Source, Design Guidance for Stormwater Quality Protection.

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