Perimeter Sand Filters

Description: Multi-chamber structure designed to treat stormwater runoff through filtration, using a sediment forebay, a sand bed as its primary filter media and an underdrain collection system (usually). Perimeter sand filters are located along the edge of impervious areas.

Variations: Surface Sand Filter (see PTP-04) and Underground Sand Filter (see PTP-10).

Components:
- Forebay—settles coarse particles and trash
- Sand bed chamber—provides water quality treatment through sand filtration.
- Overflow chamber to outlet for larger storm flows

Advantages/Benefits:
- Applicable to small drainage areas
- Good for highly impervious areas
- Good for water quality retrofits to existing developments

Disadvantages/Limitations:
- Standing water raises mosquito concerns
- High maintenance burden
- Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas
- Relatively costly
- Possible odor problems
- Typically needs to be combined with other controls to provide water quantity control

Design considerations:
- Typically requires 2 to 6 feet of head
- Maximum contributing drainage area of 2 acres

Selection Criteria:

- [x] **Water Quality 80 % TSS Removal**
- [x] **Accepts Hotspot Runoff**
- [ ] **Residential Subdivision**
- [x] **High Density / Ultra Urban Use**

Maintenance:
- Inspect for clogging—rake first inch of sand
- Remove sediment from forebay-chamber
- Replace sand filter media as needed
- Clean spillway system(s)

H — **Maintenance Burden**

L = Low M = Moderate H = High

General Description

The perimeter sand filter is an enclosed filter system typically constructed just below grade in a vault along the edge of an impervious area such as a parking lot. The filter captures and temporarily stores stormwater runoff, filtering it through a bed of sand. Runoff flows into the structure through a series of inlet grates located along the top of the filter. The system consists of a forebay (sedimentation chamber) and a sand bed (filtration) chamber. The first chamber is a forebay or sedimentation chamber, which removes floatables and heavy sediments. The second is the sand bed or filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. The filtered runoff is collected and returned to the conveyance system. In addition, since perimeter sand filters receive all runoff, as on-line controls, they include an overflow for flows larger than the water quality volume. A schematic of a perimeter sand filter is shown in Figure 16.1.

Because they have few site constraints beside head requirements, perimeter sand filters can be used on development sites where the use of other structural controls may be precluded. However, perimeter sand filter systems can be relatively expensive to construct and install and they have high maintenance requirements. Because perimeter sand filters have a permanent pool of standing water, they present vector concerns. Their use is limited to situations in which they can be inspected and maintained frequently enough to control mosquito breeding. In addition, although perimeter sand filter systems are designed as on-line systems, they do not control water quantity.

In perimeter sand filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration and adsorption. The filtration process effectively traps suspended solids and particulates. As solids are trapped in the sand bed, some reduction of associated pollutants such as biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants may be achieved.

Site and Design Considerations

Two design variants of perimeter sand filters are the surface sand filter (PTP-04) and the underground sand filter (PTP-10).

Location and Siting

1. The maximum drainage area for a perimeter sand filter is 2 acres.
2. Perimeter sand filter systems are generally applied to land uses with a high percentage of impervious surfaces. Sites with less than 50% imperviousness or with high clay/silt sediment loads must not use sand filters without adequate pretreatment because the sediment causes clogging and failure of the filter bed. Any disturbed areas within the sand filter facility drainage area should be identified and stabilized. Filtration controls should only be constructed after the construction site is stabilized.

Site and Design Considerations (Continued)

3. Perimeter sand filters are typically sited along the edge, or perimeter, of an impervious area such as a parking lot.
4. Perimeter and filter systems are designed for intermittent flow and must be allowed to drain and aerate between rainfall events. They should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

General Design

5. A perimeter sand filter facility is a vault structure located just below grade level. Runoff enters the device through inlet grates along the top of the structure into the sediment forebay (or sedimentation chamber). Unlike the surface sand filter, the perimeter sand filter sediment forebay contains a permanent forebay volume. Runoff is discharged from the forebay through a weir into the sand bed chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system. An overflow must be provided for flows larger than the design storm.

Physical Specifications/Geometry

6. The entire treatment system (excluding the permanent pool in the forebay) must temporarily hold the WQ_v prior to filtration. Table 16.1 presents the design parameters and values for the perimeter sand filter. Figure 16.2 illustrates these design parameters.
7. The forebay must be sized to at least 50% of the computed WQ_v.
8. The filter area is sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand should be used. The filter bed is typically designed to completely drain in ≤ 36 hours.
9. The filter media should consist of a 12- to 18-inch layer of clean washed medium sand (meeting ASTM C-33 concrete sand) on top of the underdrain system. See PTP-04, Figure 4.3 for a typical filter section.
10. The perimeter sand filter is equipped with a 6-inch perforated pipe (ASTM Schedule 40) underdrain in a gravel layer. The underdrain must have a minimum grade of 1/8 inch per foot (1% slope). Holes should be 3/8-inch diameter and spaced approximately 10 inches on center. A permeable filter fabric should be placed between the gravel layer and the filter media. Gravel should be clean washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 30%. Aggregate contaminated with soil shall not be used. Gravel layer and perforated underdrain piping must have infiltration rates at least twice as fast as the design infiltration rate of the sand bed.

Pretreatment/Inlets

11. Pretreatment of runoff in a sand filter system is provided by the forebay.
12. Inlets to surface sand filters are to be provided with energy dissipaters.

Site and Design Considerations (Continued)

Outlet Structures

13. Outlet pipe is to be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways).
14. All flows enter the perimeter sand filter. However, flows larger than the water quality volume are not treated. They pass to an overflow chamber and outlet.

Maintenance Access

15. Adequate access through maintenance easements must be provided for all sand filter systems for inspection and maintenance. Access grates to the filter bed need to be included in a perimeter sand filter design. Facility designs must enable maintenance personnel to easily replace the upper layers of the filter media.

Table 16.1 Perimeter Sand Filter Design Parameters

Parameter Description	*Parameter*	*Parameter Value*
Total Temporary Volume in Forebay and Sand Bed Chamber[1]	WQ_v	WQ_v; See Design Step #1
Approximate Temporary Sand Bed Volume[2]	V_{ST}	(0.5) WQ_v
Minimum Sand Bed Thickness	T_S	18 inches
Sand Bed Design Porosity	n	0.3
Sand Bed Design Permeability	k	3.5 feet/day
Sand Bed Design Drain Time	t_d	1.5 days, 36 hours max
Minimum Sand Bed Chamber Area	A_S	See Design Step #6
Approximate Temporary Forebay and Sand Bed Chamber Volume[3]	V_{FT}	(0.5) WQ_v
Minimum Forebay Surface Area	A_F	(0.05) WQ_v
Maximum Temporary Sand Bed Depth[4]	D_{ST}	See Design Step #3
Maximum Temporary Forebay Depth	D_{FT}	See Design Step #3
Minimum Permanent Forebay Depth	D_{FP}	2 feet

1. Includes temporary storage volume in sand, but excludes storage volume in forebay permanent pool.
2. Includes temporary storage volume in sand.
3. Excludes storage volume in forebay permanent pool.
4. Measured from top of sand bed.

(Adapted from the New Jersey Stormwater Best Management Practices Manual)

Design Procedures

Design of a sand filter is usually a trial and error process because of the number of variables involved.

Step 1. Compute the Water Quality Volume.

Calculate the Water Quality Volume (WQ_v), which must be temporarily stored within the perimeter sand filter's entire treatment system, excluding the forebay permanent pool.

$$WQ_v = P \times Rv \times A/12$$

Where:
WQ_v = water quality treatment volume, ac-ft
P = rainfall for the 85% storm event (1.1 in)
Rv = runoff coefficient (see below)
A = site area, acres

$$Rv = 0.015 + 0.0092*I$$

Where:
I = site impervious cover, % (for example 50% equals 50)

Step 2. Determine approximate required volumes of the forebay and sand bed chambers.

Each should be equal to approximately 0.5 WQ_v, as shown in Table 16.1.

Step 3. Determine approximate temporary depths in sand bed (D_{ST}) and forebay (D_{FT}) for the WQ_v.

The estimate will depend on and be based on analysis of site conditions including the difference between the invert elevation of the downstream conveyance system and the maximum ground elevation at filter facility. Make sure to include the minimum sand bed thickness (T_S) and the permanent forebay depth (D_{FP}) into the consideration for these temporary depths. Note that the maximum temporary depth in the sand bed zone (D_{ST}) is measured from the top of the sand bed, while the maximum temporary forebay depth (D_{FT}) is measured from the permanent forebay water surface.

Step 4. Compute minimum forebay surface area (A_F).

The minimum surface area is
$$A_F = 0.05\ (WQ_v)$$

Where:

Design Procedures (Continued)

A_F = forebay area
0.05 = a multiplier in units per area of volume (L^2/L^3)

Step 5. Compute total temporary storage volume in the forebay (V_{FT}).

From the maximum temporary depth in the forebay (D_{FT}) from Step 3 and the minimum forebay area (A_F) from Step 4, compute the total temporary storage volume in the forebay (V_{FT}). *Compare* this volume with the approximate required forebay volume computed in Step 2. *Adjust* the maximum temporary forebay depth (D_{FT}) and/or forebay area (A_F) as necessary to achieve a total temporary forebay storage volume (V_{FT}) as close as practical to the required forebay volume from Step 2. While adjusting the forebay surface area (A_F) by varying its length and width, remember that the forebay will be located immediately adjacent to the sand bed zone.

Step 6. Compute sand bed chamber area (A_S).

The filter area is sized using the following equation (based on Darcy's Law):

$$\mathbf{A_S = (WQ_v)\ (T_S / [(k)\ (D_{ST}/2 + T_S)\ (T_D)]}$$

Where:
A_S = Sand Bed Surface Area (in square feet)
T_S = Thickness of Sand in Sand Bed (typically 18 inches, no more than 24 inches)
k = Coefficient of permeability of filter media (ft/day) (use 3.5 ft/day for sand)
D_{ST} = Maximum Temporary Sand Bed Depth (ft)
t_d = Sand Bed Design Drain Time (1.5 days or 36 hours is recommended maximum)

See the Physical Specifications/Geometry section of the *Site and Design Considerations* for filter media specifications.

Step 7. Compute total temporary storage volume in sand bed.

$$\mathbf{V_{ST} = (A_S)(D_{ST}) + (A_S)(T_S)(n)}$$

Where:
V_{ST} = Temporary Sand Bed Storage Volume (in cubic feet)
A_S = Sand Bed Surface Area (in square feet)
D_{ST} = Maximum Temporary Sand Bed Depth (ft)
T_S = Thickness of Sand in Sand Bed, recommended 18 inches (in feet)

Design Procedures (Continued)

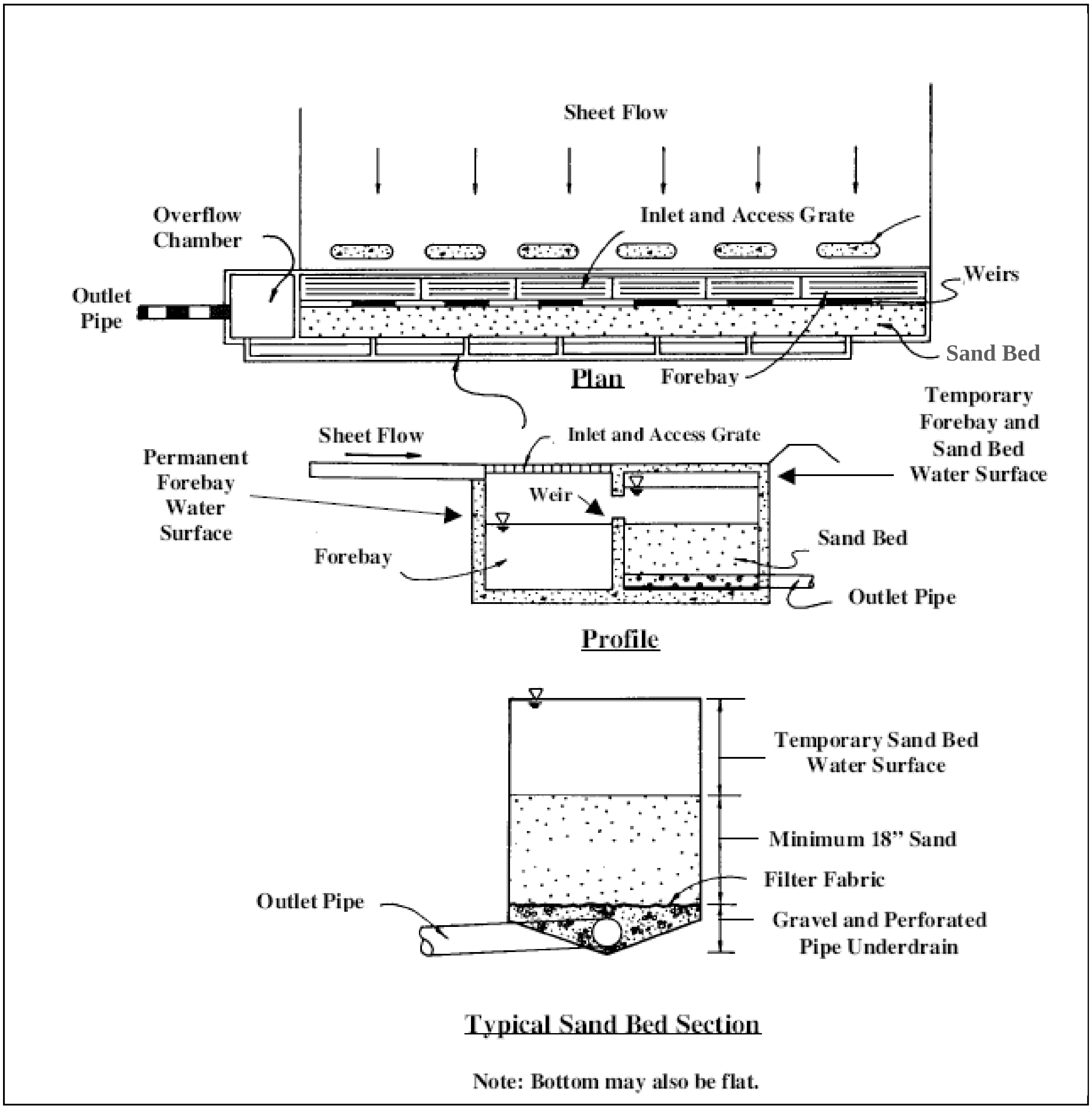
n = Sand Bed Design Porosity, recommended 0.3

Step 8. Compare and adjust areas and volumes to achieve storage of WQ_v within the entire facility.

Compare the total temporary sand bed storage volume (V_{ST}) with the approximate required sand bed zone volume computed in Step 2. As shown on Table 16.1, this temporary sand bed storage volume should be approximately one half of the stormwater quality design storm runoff volume (WQ_v). In addition, add the total temporary sand bed volume (V_{ST}) to the total temporary forebay storage volume (V_{FT}) to determine the total temporary storage volume in the sand filter. As shown in Table 16.1, this total temporary storage volume must equal the stormwater quality design storm runoff volume (WQ_v). Adjust the maximum temporary sand bed depth (D_{ST}) and/or sand bed area (A_S) as necessary to achieve a total temporary sand bed storage volume (V_{ST}) as close as practical to the required sand bed volume from Step 2 and a total filter volume equal to WQ_v.

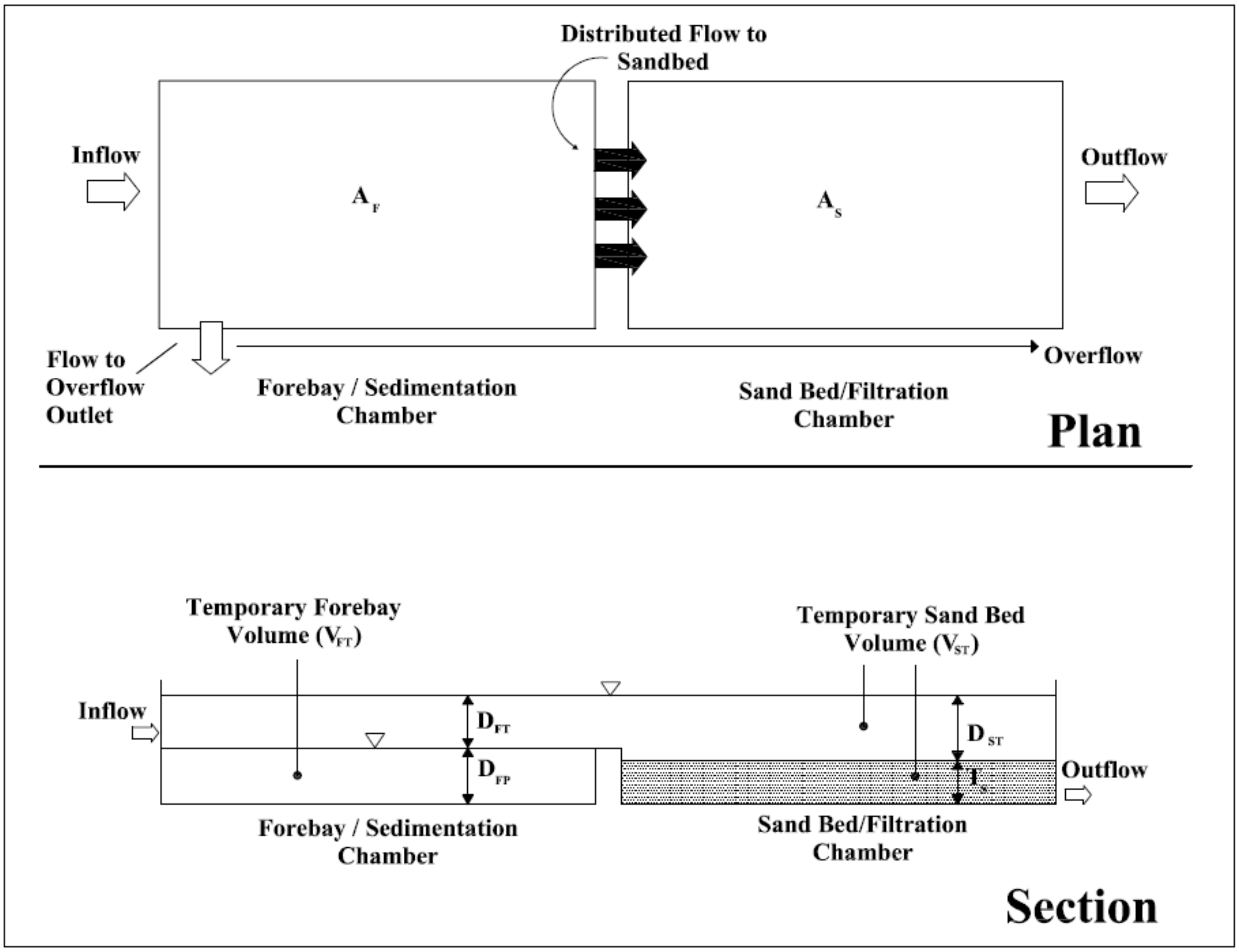
Step 9. Design inlets, underdrain system, overflow weirs, and outlet structures.

See *Site and Design Considerations* for more information on underdrain specifications and outlet structures. PTP-01 provides more information on sizing orifices, weirs, and outlets.



(Source: New Jersey Stormwater Best Management Practices Manual, 2003)

Figure 16.1 Perimeter Sand Filter



(Source: New Jersey Stormwater Best Management Practices Manual, 2003)

Figure 16.2 Schematic of Perimeter Sand Filter Showing Design Parameters

References

ARC, 2001. Georgia Stormwater Management Manual Volume 2 Technical Handbook.

Connecticut Department of Environmental Protection, 2004. Stormwater Quality Manual.

Center for Watershed Protection, Accessed July 2005. Stormwater Manager's Resource Center. Manual Builder. *www.stormwatercenter.net*.

New Jersey Department of Environmental Protection, 2004. Stormwater Best Management Practices Manual.

StormwaterAuthority.com, Accessed January, 2006. "Sand and Organic Filters." www.stormwaterauthority.com .

Suggested Reading

California Storm Water Quality Task Force, 1993. California Storm Water Best Management Practice Handbooks.

City of Austin, TX, 1988. Water Quality Management. Environmental Criteria Manual. Environmental and Conservation Services.

City of Sacramento, CA, 2000. Guidance Manual for On-Site Stormwater Quality Control Measures. Department of Utilities

Claytor, R.A., and T.R. Schueler. 1996. Design of Stormwater Filtering Systems. The Center for Watershed Protection, Silver Spring, MD.

Maryland Department of the Environment, 2000. Maryland Stormwater Design Manual, Volumes I and II. Prepared by Center for Watershed Protection (CWP).

Metropolitan Washington Council of Governments (MWCOG), March, 1992, "A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone".

Northern Virginia Regional Commission (NVRC), 1992. The Northern Virginia BMP Handbook. Annandale, VA.

US EPA, 1999. Storm Water Technology Fact Sheet: Sand Filters. EPA 832-F-99-007. Office of Water.