4.3.6 Surface Sand Filters

General Application Water Quality BMP

Description: Surface sand filters are multi-chamber structures located above ground that are designed to treat stormwater runoff through filtration, using a sediment forebay, a sand bed as its primary filter media and, typically, an underdrain collection system.

KEY DESIGN CONSIDERATIONS

DESIGN GUIDELINES:

- Typically requires 2 to 6 feet of head.
- Maximum contributing drainage area of 10 acres for surface sand filter; 2 acres for perimeter sand filter.
- Sand filter media with underdrain system.
- Typically needs to be combined with other controls to provide water quality control.

ADVANTAGES / BENEFITS:

- Applicable to small drainage areas.
- Good for highly impervious areas.
- Good retrofit capability.

DISADVANTAGES / LIMITATIONS:

- High maintenance burden.
- Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas.
- Relatively costly.
- Possible odor problems.
- Cannot be installed until site construction is complete.

MAINTENANCE REQUIREMENTS:

- Inspect for clogging – rake first inch of sand.
- Remove sediment from forebay/chamber.
- Replace sand filter media as needed.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

✷ in certain situations

Accepts hotspot runoff: *Yes (requires impermeable liner)*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**80%**

4.3.6.1 General Description

Surface sand filters (also referred to as *sand filters* or *filtration basins*) are ground-level, open air structures that capture and temporarily store stormwater runoff and pass it through a filter bed of sand. An example of a surface sand filter is presented in Figure 4-31. Underground sand filters, discussed in Section 4.4.2, treat stormwater in the same manner, but are located below the ground surface. Because of the increased maintenance requirements, underground sand filters are considered Limited Application BMPs.

Figure 4-31. Example of a Surface Sand Filter

Most sand filter systems, surface and underground, consist of two-chamber structures. The first chamber is a sediment forebay or sedimentation chamber, which removes floatables and heavy sediments. The second is the filtration chamber, which removes finer sediments and other pollutants by filtering the runoff through a sand bed. The filtered runoff is typically collected and returned to the conveyance system, though it can also partially or fully permeate into the surrounding soil in areas with porous soils.

This system can treat drainage areas up to 10 acres in size and is typically located off-line. Surface sand filters can be designed as an excavation with earthen embankments or as a concrete or block structure. Because they have few site constraints beside head requirements, sand filters can be used on development sites where the use of other structural BMPs may be precluded. However, sand filter systems can be relatively expensive to construct and install, and require a relatively high level of maintenance and inspection. Because of this, surface sand filters are not recommended for use in residential areas.

4.3.6.2 Stormwater Management Suitability

Surface sand filter systems are designed primarily as off-line systems for treatment of the water quality volume and will typically need to be used in conjunction with another structural BMP that can provide downstream channel protection and protection of the locally regulated peak discharge. However, under certain circumstances, filters can provide limited runoff quantity control, particularly for smaller storm events.

Water Quality (WQv)
In sand filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration and adsorption. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants. Surface sand filters with a grass cover have additional opportunities for bacterial decomposition as well as vegetation uptake of pollutants, particularly nutrients.

Channel Protection (CPv)
For smaller sites, a sand filter may be designed to capture the entire channel protection volume (CPv) in either an off- or on-line configuration. Given that a sand filter system is typically designed to completely drain over 40 hours, the channel protection design requirement for extended detention of the 1-year, 24-hour storm runoff volume can be met. For larger sites or where only the WQv is diverted to the sand filter facility, another structural control must be used to provide extended detention of the CPv.

4.3.6.3 Pollutant Removal Capabilities

Surface sand filters are presumed to be able to remove 80% of the total suspended solids (TSS) load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed sand filters can reduce TSS removal performance.

The total suspended solids design pollutant removal rate of 80% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for sand filters, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.3.6.4 Application and Site Feasibility Criteria

Surface sand filter systems are well-suited for highly impervious areas where land available for structural BMPs is limited. Sand filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards. Sand filters may also be feasible and appropriate in some multi-family residential developments where maintenance is performed by a landscaping (or other suitably capable) company.

To avoid rapid clogging and failure of the filter media, the use of sand filters should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of a sand filter facility for meeting stormwater management objectives on a site or development.

General Feasibility

- Not suitable for use in a residential subdivision
- Suitable for use in high density/ultra-urban areas
- Not suitable for use as a regional stormwater control. On-site applications are typically most feasible.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 10 acres maximum for surface sand filter; 2 acres maximum for perimeter sand filter
- Space Required – Function of available head at site
- Minimum Head – The surface slope across the filter location should be no greater than 6%. The elevation difference needed at a site from the inflow to the outflow: 5 feet for surface sand filters; 2 to 3 feet for perimeter sand filters.

- Minimum Depth to Water Table – If used on a site with an underlying water supply aquifer, a separation distance of 2 feet is required between the bottom of the sand filter and the elevation of the seasonally high water table to prevent groundwater contamination.
- Soils – Not recommended for clay/silt drainage areas that are not stabilized. Karst areas may require a liner.

Other Constraints / Considerations

- Aquifer Protection – Do not allow infiltration of filtered hotspot runoff into groundwater

4.3.6.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of sand filters. Sand filters that are not designed to these standards will not be approved. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of a sand filter shall take place **after** the construction site has been stabilized.
- In the event that the sand filter is not constructed after site stabilization, care shall be taken during construction to minimize the risk of premature failure of the sand filter due to deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around the sand filter during all phases of construction. No runoff or sediment shall enter the sand filter area prior to completion of construction and the complete stabilization of construction areas.
- Sand filters may be used as a temporary sediment trap for construction activities if all accumulated sediment is removed from the pit prior to sand placement.
- During and after excavation of the sand filter, all excavated materials shall be placed downstream, away from the sand filters, to prevent redeposit of the material during runoff events.

B. LOCATION AND SITING

- Surface sand filters shall have a contributing drainage area of 10 acres or less.
- Surface sand filter systems are generally applied to land uses with a high percentage of impervious surfaces. Sand filters shall not be utilized for sites that have less than 50% impervious cover. Pretreatment must be provided as described in part D below, due to the potential for high clay/silt sediment loads that could result in clogging and failure of the filter bed. Any disturbed or denuded areas located within the area draining to and treated by the sand filter shall be stabilized prior to construction and use of the sand filter. The sand filter shall only be constructed after the construction site is stabilized.
- It is preferred that surface sand filters are to be used in an off-line configuration where the water quality volume (WQv) is diverted to the filter facility through the use of a flow diversion structure and flow splitter. Stormwater flows greater than the WQv shall be diverted to other controls or downstream using a diversion structure or flow splitter. In certain situations, as determined by the local jurisdiction, a surface sand filter may be used in an on-line configuration.
- Sand filter systems shall be designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They shall not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.
- Each sand filter shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of the sand filter. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the local jurisdiction:
  - From a property line – 10 feet;
  - From a public water system well – TDEC specified distance per designated category;

- From a private well – 100 feet; if well is downgradient from a land use that requires a Special Pollution Abatement Permit, then the minimum setback is 250 feet;
- From a septic system tank/leach field – 50 feet.

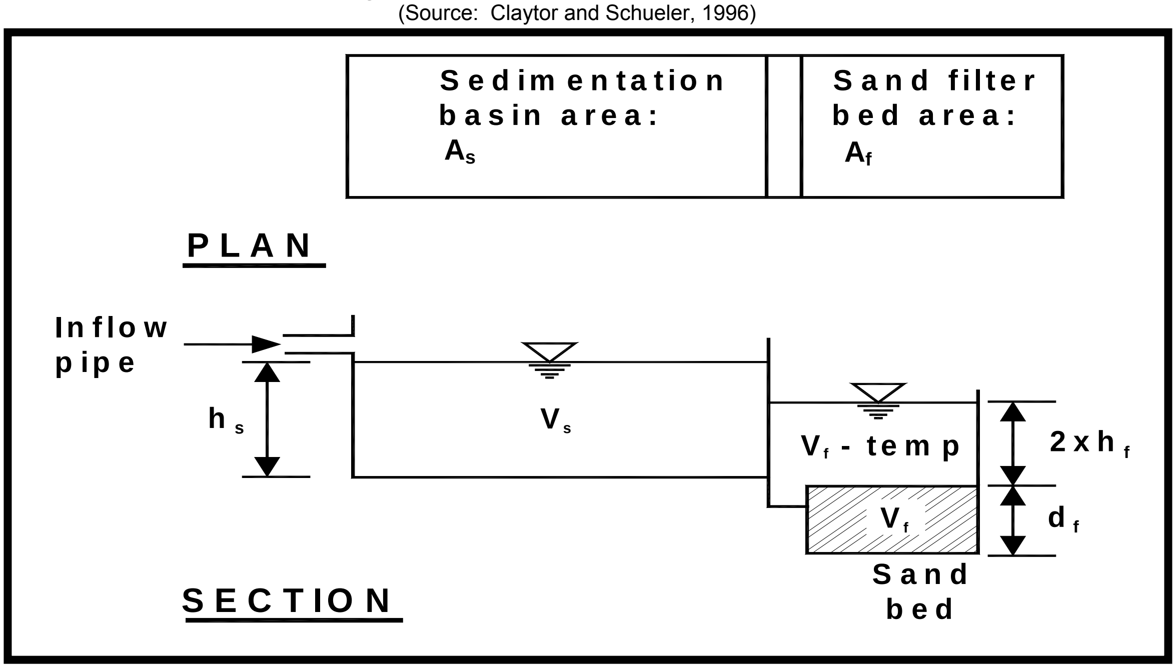
C. GENERAL DESIGN

- A surface sand filter facility shall consist of a two-chamber open-air structure, which is located at ground-level. The first chamber is the sediment forebay (commonly referred to as the sedimentation chamber) while the second chamber houses the sand filter bed. Flow enters the sedimentation chamber where settling of larger sediment particles occurs. Runoff is then discharged from the sedimentation chamber through a perforated standpipe into the filtration chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system.

D. PHYSICAL SPECIFICATIONS / GEOMETRY

- The entire treatment system (including the sedimentation chamber) shall be designed to temporarily hold at least 75% of the WQv prior to filtration. Figure 4-32 illustrates the distribution of the treatment volume (0.75 WQv) among the various components of the surface sand filter, including:
  - V_s – volume within the sedimentation basin
  - V_f – volume within the voids in the filter bed
  - $V_{f\text{-temp}}$ – temporary volume stored above the filter bed
  - A_s – the surface area of the sedimentation basin
  - A_f – surface area of the filter media
  - h_s – height of water in the sedimentation basin
  - h_f – average height of water above the filter media
  - d_f – depth of filter media

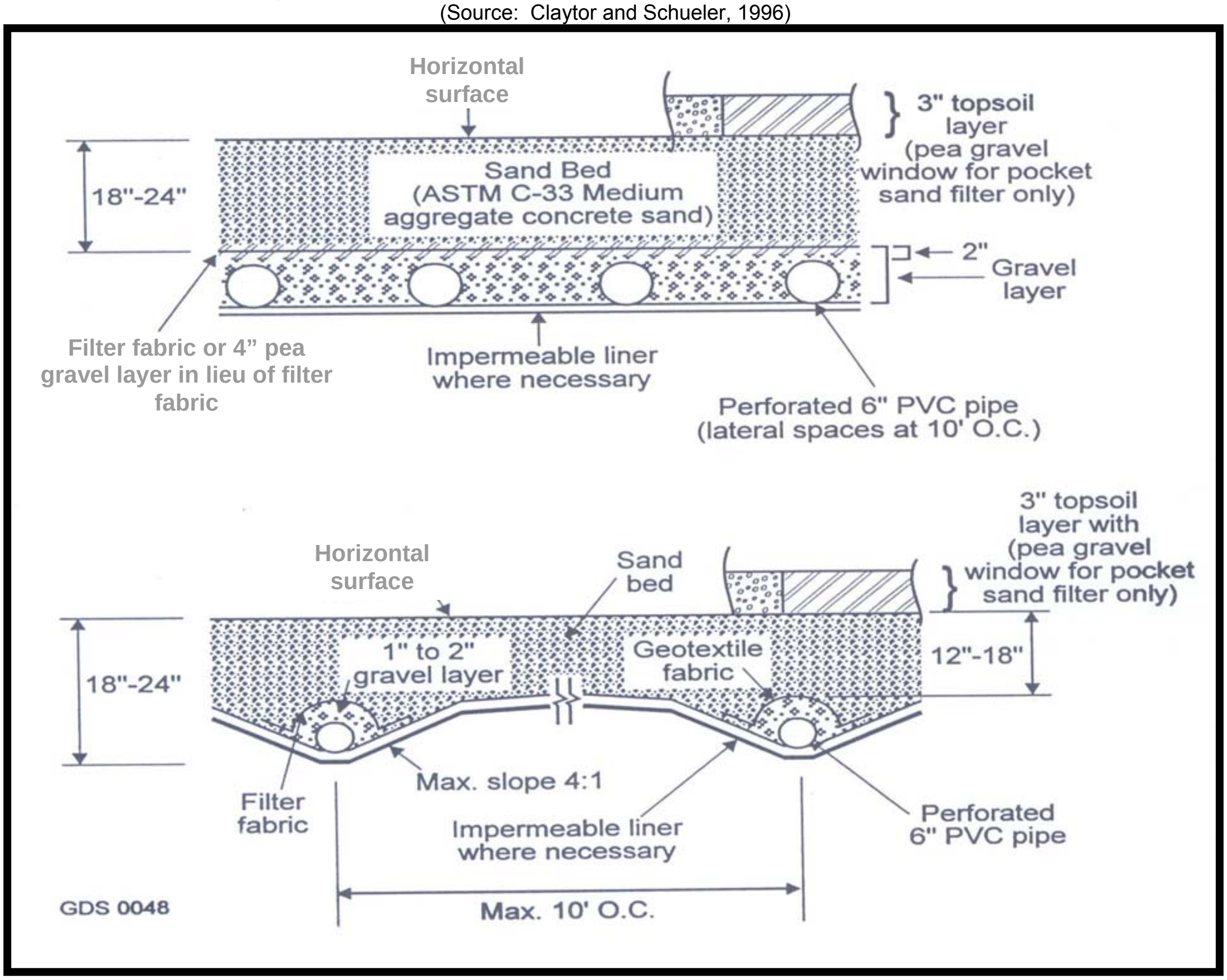
Figure 4-32. Surface Sand Filter Volumes
(Source: Claytor and Schueler, 1996)



- The sedimentation chamber shall be sized to hold at least 25% of the computed WQv and have a length-to-width ratio of at least 2:1. Inlet and outlet structures should be located at opposite ends of the chamber.

- The filter area shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand shall be used. The filter bed shall be designed to completely drain in 40 hours or less.
- The filter media shall consist of an 18-inch layer of clean washed medium aggregate concrete sand (ASTM C-33) on top of the underdrain system. Three inches of topsoil shall be placed over the sand bed. Permeable filter fabric shall be placed both above and below the sand bed to prevent clogging of the sand filter and the underdrain system. Figure 4-33 illustrates a typical media cross section.
- The filter bed shall be equipped with a 6-inch perforated pipe underdrain (PVC AASHTO M 252, HDPE, or other suitable pipe material) in a gravel layer. The underdrain shall have a minimum grade of 1/8-inch per foot (1% slope). Holes shall be 3/8-inch diameter and spaced approximately 6 inches on center. Gravel shall 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 40%. Aggregate contaminated with soil shall not be used.
- The structure of the surface sand filter may be constructed of impermeable media such as concrete, or through the use of excavations and earthen embankments. When constructed with earthen walls/embankments, filter fabric shall be used to line the bottom and side slopes of the structures before installation of the underdrain system and filter media.

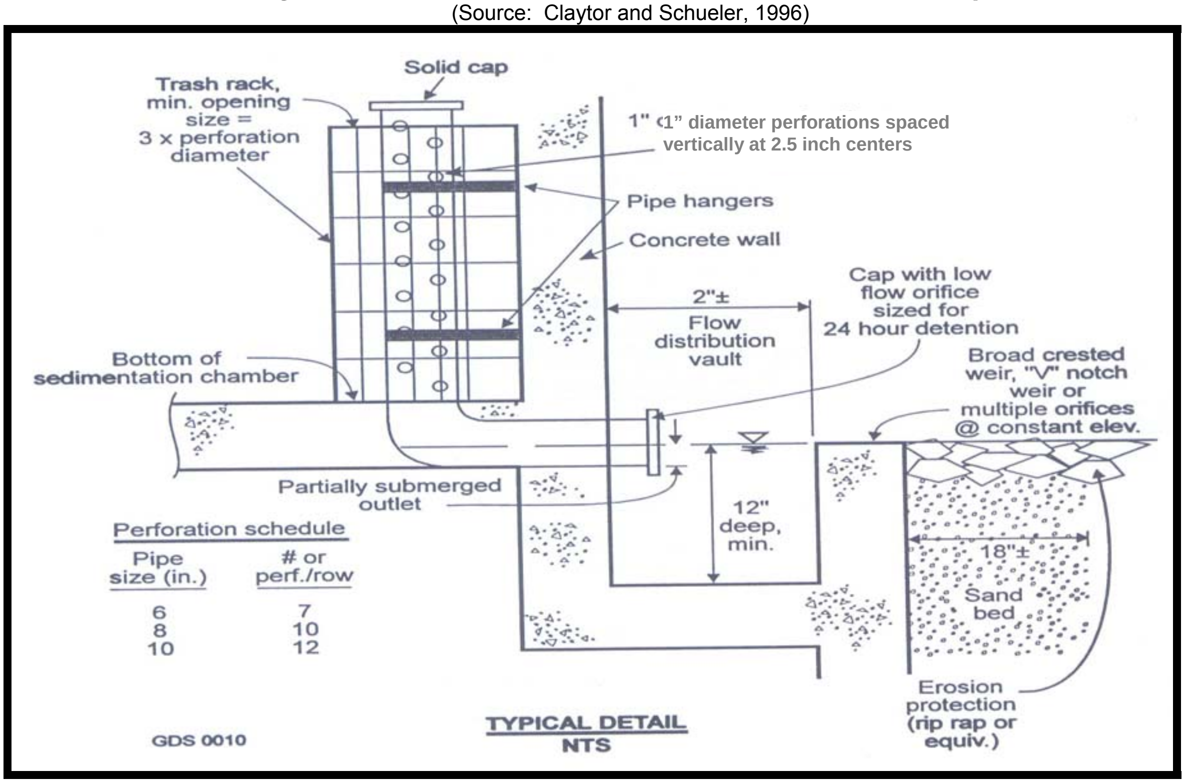
Figure 4-33. Typical Sand Filter Media Cross Sections
(Source: Claytor and Schueler, 1996)



E. PRETREATMENT / INLETS

- Pretreatment of runoff in a sand filter system shall be by a sedimentation chamber, designed in accordance with the criteria stated above.
- Energy dissipators shall be used at the inlets to surface sand filters. Figure 4-34 shows a typical inlet pipe from the sedimentation basin to the filter media basin for the surface sand filter.
- The sand filter shall be designed so that runoff exits the chamber at a non-erosive velocity.

Figure 4-34. Surface Sand Filter Perforated Stand-Pipe
(Source: Claytor and Schueler, 1996)



F. OUTLET STRUCTURES

- An outlet pipe shall 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). However, the design shall ensure that the discharges from the underdrain system occur in a non-erosive manner.

G. EMERGENCY SPILLWAY

- An emergency or bypass spillway must be included in the surface sand filter design to safely pass flows that exceed the WQv (and CPv if the filter is utilized for channel protection purposes). The spillway prevents filter water levels from overtopping the embankment and causing structural damage. The emergency spillway shall be located so that embankments, downstream buildings and structures will not be impacted by spillway discharges.

H. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right of way or drainage easement shall be provided for a sand filter from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. Facility designs must enable maintenance personnel to easily remove and replace the filter media.

I. SAFETY FEATURES

- Where necessary, surface sand filter facilities can be fenced to prevent access.

J. LANDSCAPING

- Surface sand filters can be designed with a grass cover to aid in pollutant removal and prevent clogging. The grass should be capable of withstanding frequent periods of inundation and drought.

K. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Use of surface sand filter may be limited by low head
- High Relief – Filter bed surface must be level
- Karst – Use liner or impermeable membrane to seal bottom earthen surface of the sand filter or use watertight structure

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type “A” and “B” soils; Pretreat hotspots; provide 2 to 4 foot separation distance from water table

4.3.6.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv, CPv, and the locally regulated peak discharges, in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of a surface sand filter.

Consider the Application and Site Feasibility Criteria, and the Additional Site Specific Design Criteria and Issues noted above. Check with the local jurisdiction and other agencies as appropriate to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see Chapter 3 for more information on this calculation).

(1) Using WQv, compute CN

(2) Compute time of concentration using TR-55 method

(3) Determine appropriate unit peak discharge from time of concentration

(4) Compute Q_{wq} in inches from unit peak discharge, drainage area, and WQv.

Step 4. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQv to the sand filter facility. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 5. Size filtration basin chamber

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

$$A_f = (WQv)\,(d_f) / [(k)\,(h_f + d_f)\,(t_f)]$$

where:

A_f = surface area of filter bed (ft^2)

d_f	=	filter bed depth (1.5 ft) (at least 18 inches, no more than 24 inches)
k	=	coefficient of permeability of filter media (ft/day) (use 3.5 ft/day for sand)
h_f	=	average height of water above filter bed (ft) (1/2 h_{max}, which varies based on site but h_{max} is typically $\leq$ 6 feet)
t_f	=	design filter bed drain time (days) (1.67 days or 40 hours is maximum time)

Set preliminary dimensions of filtration basin chamber.

Step 6. Size sedimentation chamber

The sedimentation chamber shall be sized to at least 25% of the computed WQv and have a length-to-width ratio of 2:1. The Camp-Hazen equation is used to compute the required surface area:

$$A_s = -(Q_o/w) * \text{Ln}(1-E)$$

where:

A_s = sedimentation basin surface area (ft^2)
Q_o = rate of outflow = the WQv (ft^3) / 86400 seconds
w = particle settling velocity (ft/sec)
E = trap efficiency

Assuming:

- 90% sediment trap efficiency (0.9)
- particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness ≥ 75%
- particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness < 75%
- average of 24 hour holding period

Then:

A_s = (0.0081) (WQv) ft^2 for I $\geq$ 75%
A_s = (0.066) (WQv) ft^2 for I < 75%

Set preliminary dimensions of sedimentation chamber.

Step 7. Compute V_{min}

$$V_{min} = 0.75 * WQv$$

Step 8. Compute storage volumes within entire facility and sedimentation chamber orifice size

$$V_{min} = 0.75\ WQv = V_s + V_f + V_{f\text{-}temp}$$

(1) Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
Where: n = porosity = 0.4 for most applications

(2) Compute $V_{f\text{-}temp}$ = temporary storage volume above the filter bed = $2 * h_f * A_f$

(3) Compute V_s = volume within sediment chamber = $V_{min} - V_f - V_{f\text{-}temp}$

(4) Compute h_s = height in sedimentation chamber = V_s/A_s

(5) Ensure h_s and h_f fit available head and other dimensions still fit – change as necessary in design iterations until all site dimensions fit.

(6) Size orifice from sediment chamber to filter chamber to release V_s within 24-hours at average release rate with 0.5 h_s as average head.

(7) Design outlet structure with perforations allowing for a safety factor of 10 times the orifice capacity.

(8) Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

Step 9. Design inlets, pretreatment facilities, underdrain system, and outlet structures

See design criteria above for more details.

Step 10. Compute overflow weir sizes

(1) Size overflow weir at elevation hs in sedimentation chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm.

(2) Plan inlet protection for overflow from sedimentation chamber and size overflow weir at elevation hf in filtration chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm.

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4.3.6.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.6.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of a sand filter as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for sand filters, along with a suggested frequency for each activity. Individual sand filters may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the sand filter in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• A record should be kept of the dewatering time (i.e., the time required to drain the filter bed completely after a storm event) for a sand filter to determine if maintenance is necessary. The filter bed should drain completely in about 40 hours after the end of the rainfall. • Check to ensure that the filter surface does not clog after storm events.	After Rain Events
• Check the contributing drainage area, facility, inlets and outlets for debris. • Check to ensure that the filter surface is not clogging.	Monthly
• Check to see that the filter bed is clean of sediment, and the sediment chamber is not more than 50% full or 6 inches, whichever is less, of sediment. Remove sediment as necessary. • Make sure that there is no evidence of deterioration, spalling, bulging, or cracking of concrete. • Inspect grates (perimeter sand filter). • Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. • Check to see if stormwater flow is bypassing the facility. • Ensure that no noticeable odors are detected outside the facility.	Annually
Maintenance Activities	**Suggested Schedule**
• Mow and stabilize (prevent erosion, vegetate denuded areas) the area draining to the sand filter. Collect and remove grass clippings. Remove trash and debris. • Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system. • If permanent water level is present (perimeter sand filter), ensure that the chamber does not leak, and normal pool level is retained.	Monthly
• Check to see that the filter bed is clean of sediment, and the sediment chamber is not more than 50% full or 6 inches, whichever is less, of sediment. Remove sediment as necessary. • Repair or replace any damaged structural parts. • Stabilize any eroded areas.	Annually
• If filter bed is clogged or partially clogged, manual manipulation of the surface layer of sand may be required. Remove the top few inches of sand, roto-till or otherwise cultivate the surface, and replace media with sand meeting the design specifications. • Replace any filter fabric that has become clogged.	As needed

The local jurisdiction encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of sand filters. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the sand filter. Questions regarding stormwater facility inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
SURFACE SAND FILTER INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions: ____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Sand Filter Inspection List		
Complete drainage of the filter in about 40 hours after a rain event?		
Clogging of filter surface?		
Clogging of inlet/outlet structures?		
Clogging of filter fabric?		
Filter clear of debris and functional?		
Leaks or seeps in filter?		
Obstructions of spillway(s)?		
Animal burrows in filter?		
Sediment accumulation in filter bed (less than 50% is acceptable)?		
Cracking, spalling, bulging or deterioration of concrete?		
Erosion in area draining to sand filter?		
Erosion around inlets, filter bed, or outlets?		
Pipes and other structures in good condition?		
Undesirable vegetation growth?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

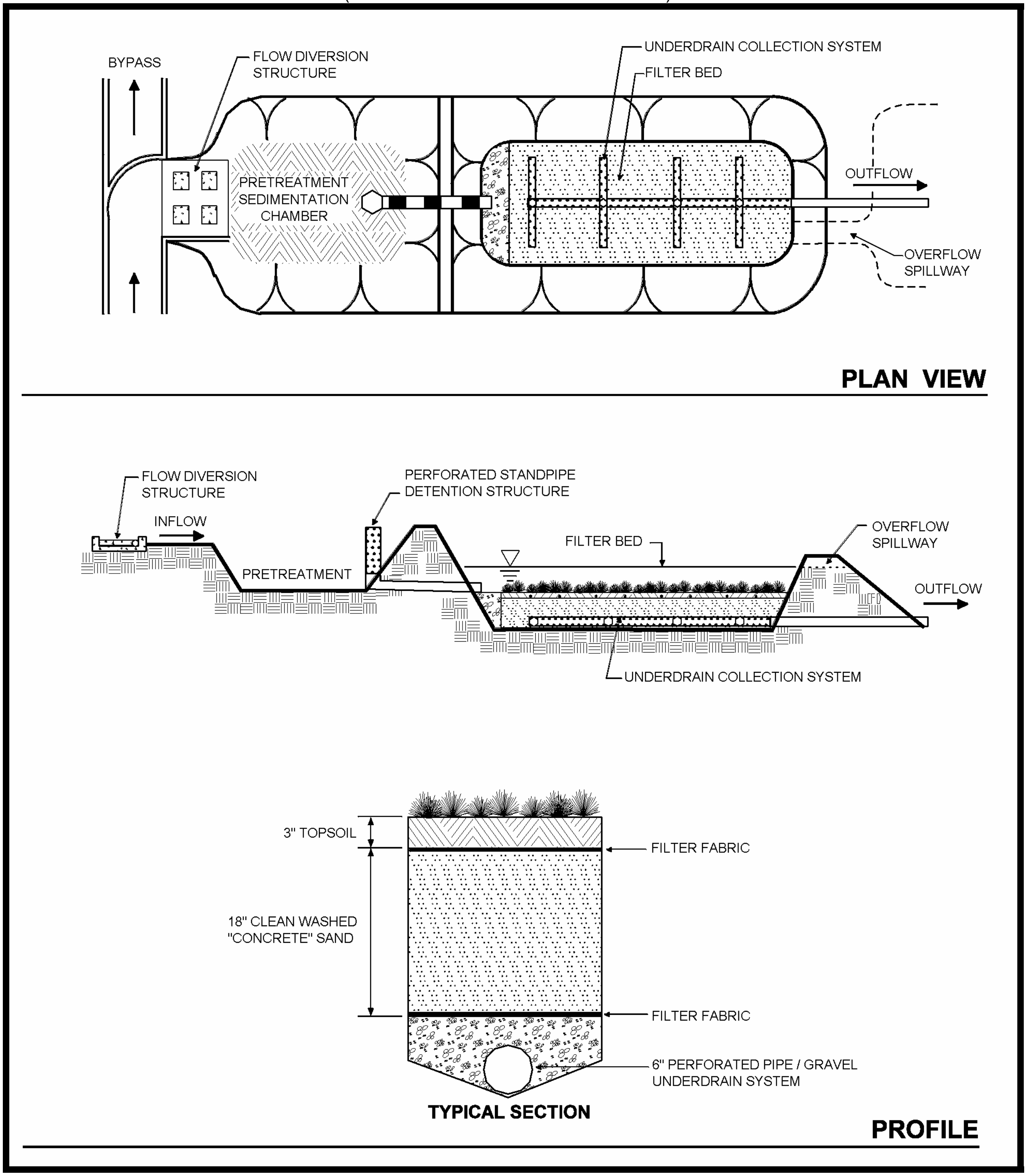
If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature: _________________________________ Inspector Name (printed) _____________________________

4.3.6.8 Example Schematic

Figure 4-35. Schematic of a Surface Sand Filter
(Source: Center for Watershed Protection)



4.3.6.9 Design Form

The local jurisdiction recommends the use of the following design procedure forms when designing sand filters. Proper use and completion of the form may allow a faster review of the Water Quality Management Plan by the local jurisdiction.

Design Procedure Forms: Sand Filters

PRELIMINARY HYDROLOGIC CALCULATIONS	
1a. Compute WQv volume requirements	
Compute Runoff Coefficient, Rv	Rv = ______
Compute WQv	WQv = ______ acre-ft
1b. Compute CPv	CPv = ______ acre-ft
SAND FILTER DESIGN	
2. Is the use of a sand filter appropriate?	Low point in development area = ______
	Low point at stream invert = ______
	Total available head = ______
	Average depth, h_f = ______
	See subsections 4.3.6.4 and 4.3.6.5 - A
3. Confirm design criteria and applicability.	***See subsection 4.3.6.5 - J***
4. Compute WQv peak discharge (Q_{wq})	
Compute Curve Number	CN = ______
Compute Time of Concentration, t_c	t_c = ______ hour
Compute Q_{wq}	Q_{wq} = ______ cfs
5. Size flow diversion structure	
Low flow orifice - orifice equation	A = ______ ft^2
	diameter = ______ in
	length = ______ ft
Overflow weir - Weir equation	
6. Size filtration bed chamber	
Compute area from Darcy's Law	A_f = ______ ft^2
Using length to width (2:1) ratio	L = ______ ft
	W = ______ ft
7. Size sedimentation chamber	
Compute area from Camp-Hazen equation	A_s = ______ ft^2
Given W from step 5, compute Length	L = ______
8. Compute V_{min}	V_{min} = ______ ft^3

Design Procedure Form: Sand Filters (continued)

9. Compute volume within practice	
Surface Sand Filter	
Volume within filter bed	V_f = ________ ft^3
Temporary storage above filter bed	$V_{f\text{-temp}}$ = ________ ft3
Sedimentation chamber (remaining volume)	V_s = ________ ft3
Height in sedimentation chamber	h_s = ________ ft
Perforated stand pipe - orfice equation	A = ________ ft^2
	diameter = ________ in
Perimeter Sand Filter	
Compute volume in filter bed	V_f = ________ ft^3
Compute wet pool storage	V_w = ________ ft^3
Compute temporary storage	$V_{f\text{-temp}}$ = ________ ft^3
	h_{temp} = ________ ft
10. Compute overflow weir sizes	
Compute overflow - Orifice equation	Q = ________ cfs
Weir from sedimentation chamber - Weir equation	Length = ________ ft
Weir from filtration chamber - Weir equation	Length = ________ ft
11. Verify peak flow control, water quality drawdown time and channel protection detention time	

4.3.6.10 References

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4.3.6.11 Suggested Reading

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