FP-1. Introduction

Filtration practices are practices that capture and temporarily store a portion of the Design Volume in a pretreatment sedimentation chamber or a surface ponding area and then pass it through a filter bed of sand or other media. Filtered runoff is then collected and returned to the conveyance system.

Filtration practices can be used to:

- Reduce pollutant loads to meet water quality targets (total maximum daily loads or TMDLs; See **Table FP-2**).
- Provide pretreatment for other practices that require extensive pretreatment to be effective, such as Infiltration.
- Retrofit existing developed areas, especially highly impervious areas, by reducing pollutant loads.

Filtration practices can be applied as underground vault systems or as a surface sand filter.

A surface Filtration practice is differentiated from a Bioretention or Water Quality Swale practice by the use of 100% sand as a filter media and the lack of a vegetated layer. Sand is generally considered a high rate filter since the runoff will pass through the media extremely fast (filtration rate of 16 ft/day and up) and therefore Filtration practices provide no runoff reduction credit.

Design variants include:

- Surface Sand Filter
- Three-Chamber Underground Sand Filter
- Perimeter Sand Filter

Figure FP-1 further illustrates typical applications of Filtration practices, and **Figure FP-2** is a typical schematic. **Figures FP-3 through FP-5** are schematics of typical Filtration practices. **Tables FP-1 and FP-2** describe two levels of Filtration design and associated pollutant removal performance rates. **Table FP-3** is a design checklist to help guide the design process for Filtration practices.

FP-1.1. Planning This Practice

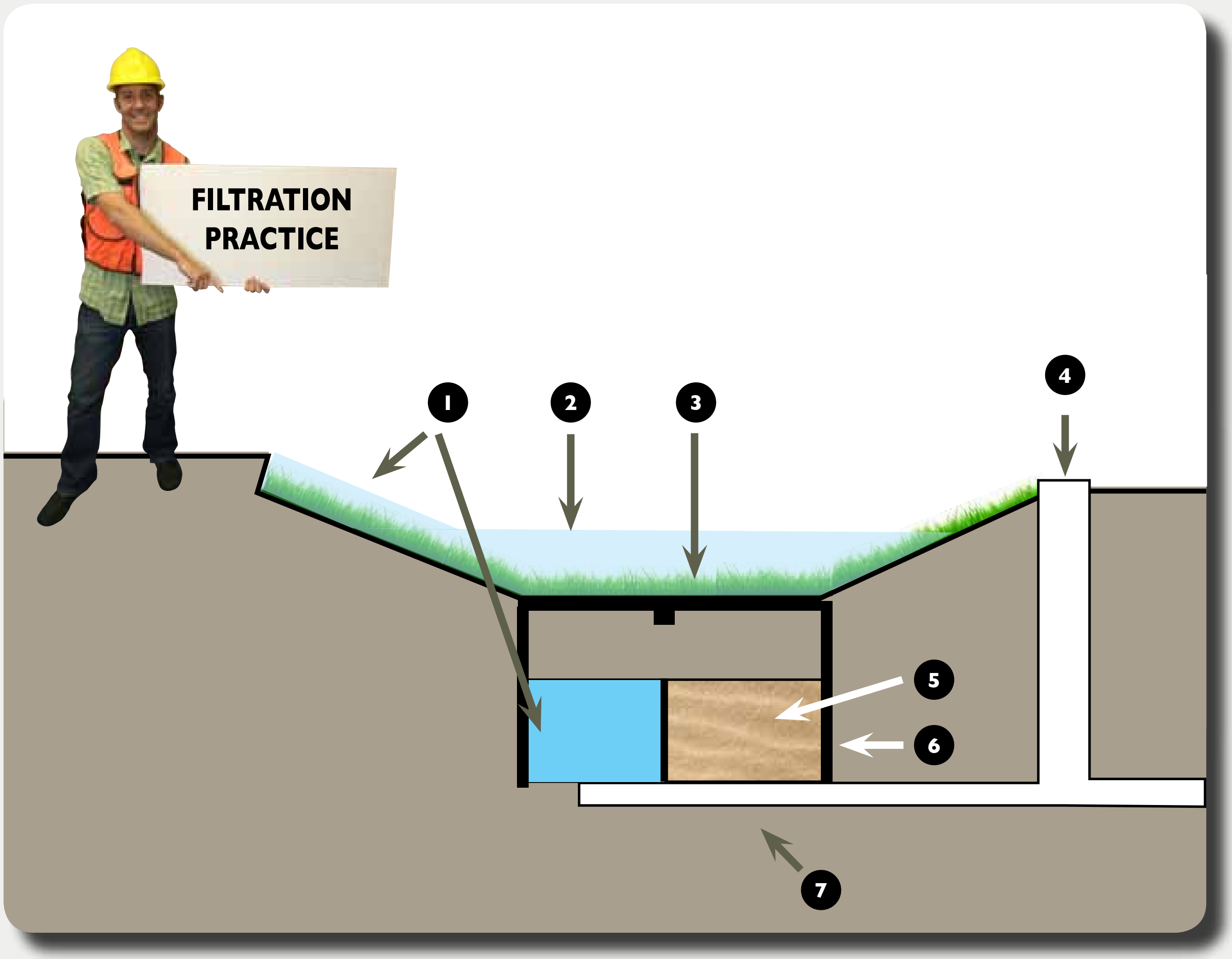
Figure FP-1. Typical Applications of Filtration Practices

Surface Sand Filter

Underground Sand Filter
Photo Courtesy of Albemarle County, VA

Perimeter Sand Filter

Figure FP-2. Typical Schematic for Filtration Practice



1. Pretreatment (typical grass filter strip and/or sedimentation chamber) – **Section FP-4.3**
2. Filter ponding depth – **Section FP-4.5**
3. Surface cover (surface sand filter only) – **Section FP-4.9**
4. Conveyance and overflow for larger flows – **Section FP-4.4**
5. Filter Media – **Sections FP-4.1 & FP-4.8**
6. Geotextile fabric – **Section FP-4.11**
7. Underdrain – **Section FP-4.10**

FP-1.2. Filtration Design Options & Performance

Table FP-1 describes the Level 1 and Level 2 design options and performance credits for Filtration practices. Note that Filtration practices do not meet the MS4 General Permit criteria to "keep and manage on-site the first one-inch of rainfall" and thus do not have an associated runoff reduction performance credit and do not contribute to reducing the overall Target Treatment Volume. Filtration practices can, however, be used in conjunction with Infiltration practices (or other runoff reduction practices) as a "high-end" pretreatment system to ensure the longevity of the Infiltration facility. **Table FP-2** summarizes pollutant removal performance values for Level 1 and Level 2 designs. Note that Filtration practices are very effective at removing pollutant loads for the purpose of calculating site-based pollutant load reductions in the context of TMDLs and/or watershed plans.

Table FP-1. Filtration Practices Design Levels: Descriptions & Performance

Design Level	Description	Applications	Performance Achieved Towards Reducing 1" of Rainfall
Level 1	• One cell design • Sand media • Contributing drainage area (CDA) contains pervious area	Sites with vertical constraints such as high bedrock or water table OR confirmed karst, stormwater hotspot, or other applications that require an impermeable liner.	0% volume reduction for the Design Volume of the practice[1]
Level 2	• Two cell design • Sand media with an organic layer • CDA is nearly 100% impervious	Generally most sites that have marginal infiltration rates -- Hydrologic Soil Group (HSG) C, and do not require an impermeable liner.	0% volume reduction for the Design Volume of the practice[1]

[1] *May be increased if the 2nd cell is utilized for Infiltration in accordance with **Specification 4.2.6, Infiltration or Specification 4.2.3, Bioretention**. The runoff reduction credit should be proportional to the fraction of the Design Volume designed to be infiltrated.*

Table FP-2. Total Pollutant Load Reduction Performance Values for Level 1 and 2 Design

Design Level	Total Suspended Solids (TSS)[1]	Nutrients: Total Phosphorus (TP) & Total Nitrogen (TN) [1]
Level 1	TSS = 60%	TP = 60% TN = 30%
Level 2	TSS = 85%	TP = 65% TN = 45%

[1] Total Pollutant Load Reduction = combined functions of runoff reduction and pollutant removal. Pollutant removal refers to the change in event mean concentration as it flows through the practice and is subjected to treatment processes, as reported in Hirschman et al. (2008). Filtration does not receive any runoff reduction credit; so Total Pollutant Load Reduction will improve significantly if Infiltration is incorporated into Level 1 or Level 2 Filtration design.

FP-1.3. Filtration Design Checklist

Table FP-3. Filtration Design Checklist

CHECKLIST

This checklist will help the designer through the necessary design steps for Filtration practices.

- ☐ Ascertain the regulatory context of using a Filtering Practice, how the Filtering Practice will be used in conjunction with runoff reduction practices, and how the 1" performance standard can be met on the site or partially waived to allow a water quality treatment practice in conjunction with or in lieu of runoff reduction practices. This will likely require consultation with the local program and West Virginia Department of Environmental Protection (WVDEP).
- ☐ Check feasibility for site – (typically includes available depth to bedrock for an underground system) **Section FP-3**
- ☐ Determine whether a Level 1 or Level 2 design will work for the site. Use Level 2 design unless site constraints necessitate Level 1 design – **Table FP-1**
- ☐ Complete Design Compliance Spreadsheet to determine if the limited credit of Filtration (pollutant removal only) is adequate; or if additional practices are needed for overall site compliance – Design Compliance **Spreadsheet & Chapter 3 of Manual**
- ☐ Check sizing guidance and make sure there is an adequate room for Filtration practice footprint on the site – **Section FP-4.2**
- ☐ Check design adaptation appropriate to the site – **Section FP-6**
- ☐ Design Filtration system in accordance with design criteria and typical details – **Sections FP-2 & FP-4**
- ☐ Provide all necessary plan view, profile, and cross-section details along with elevations, materials specifications, grading, and construction sequence notes.

4.2.10. Filtration Practice (FP)

FP-2. Typical Details

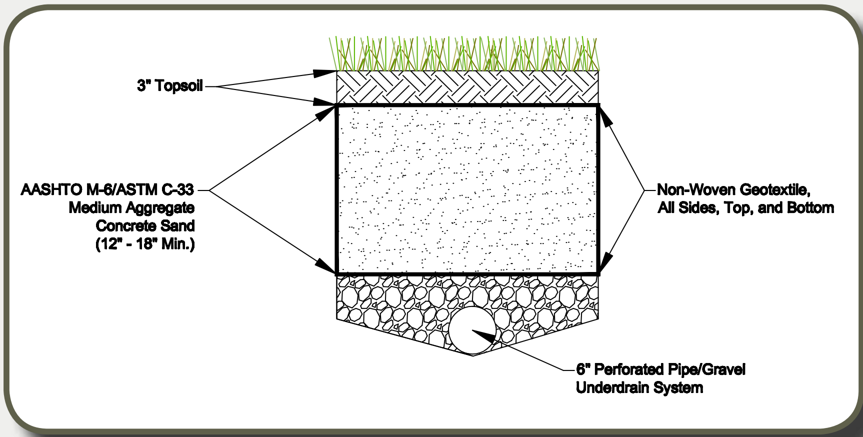


Figure FP-3. Schematic Profile for Typical Surface Sand Filter

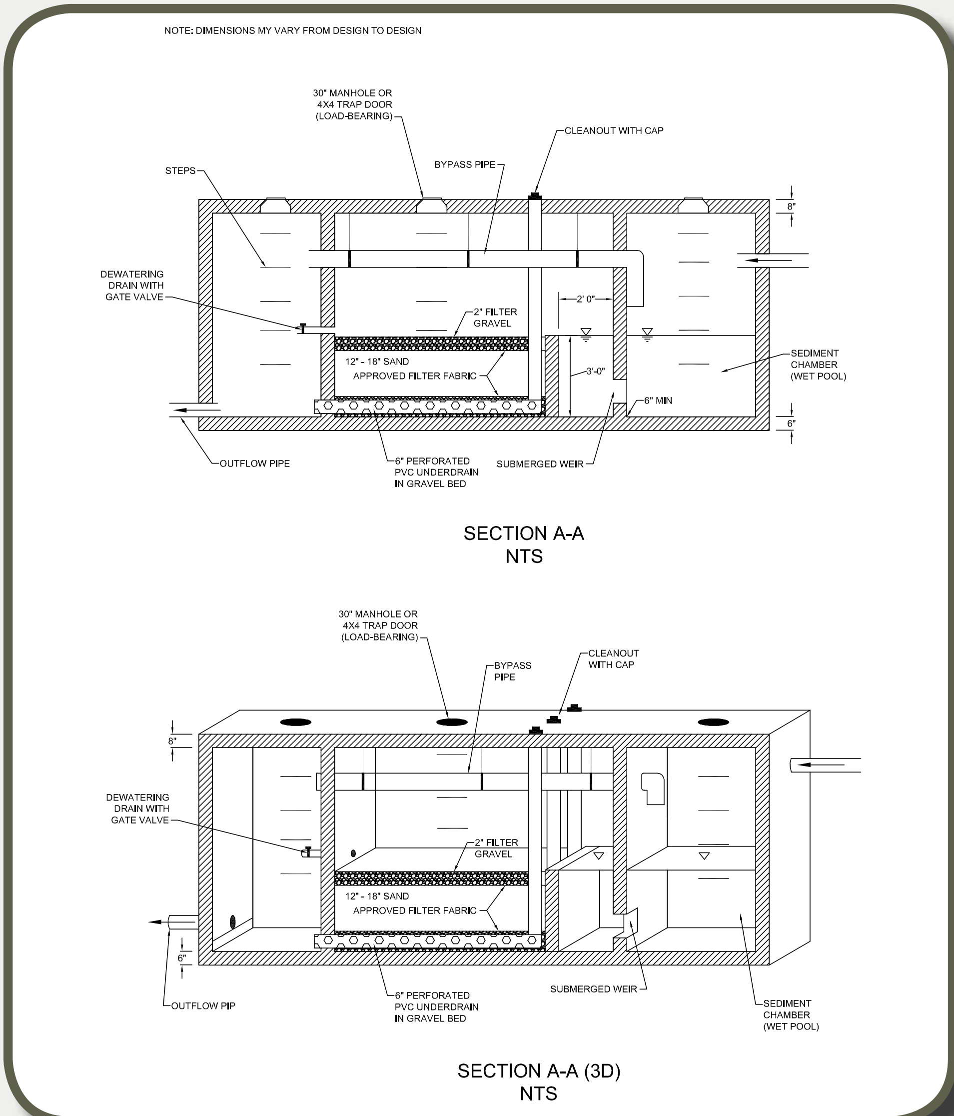


Figure FP-4. Example of Three-Chamber Underground Sand Filter

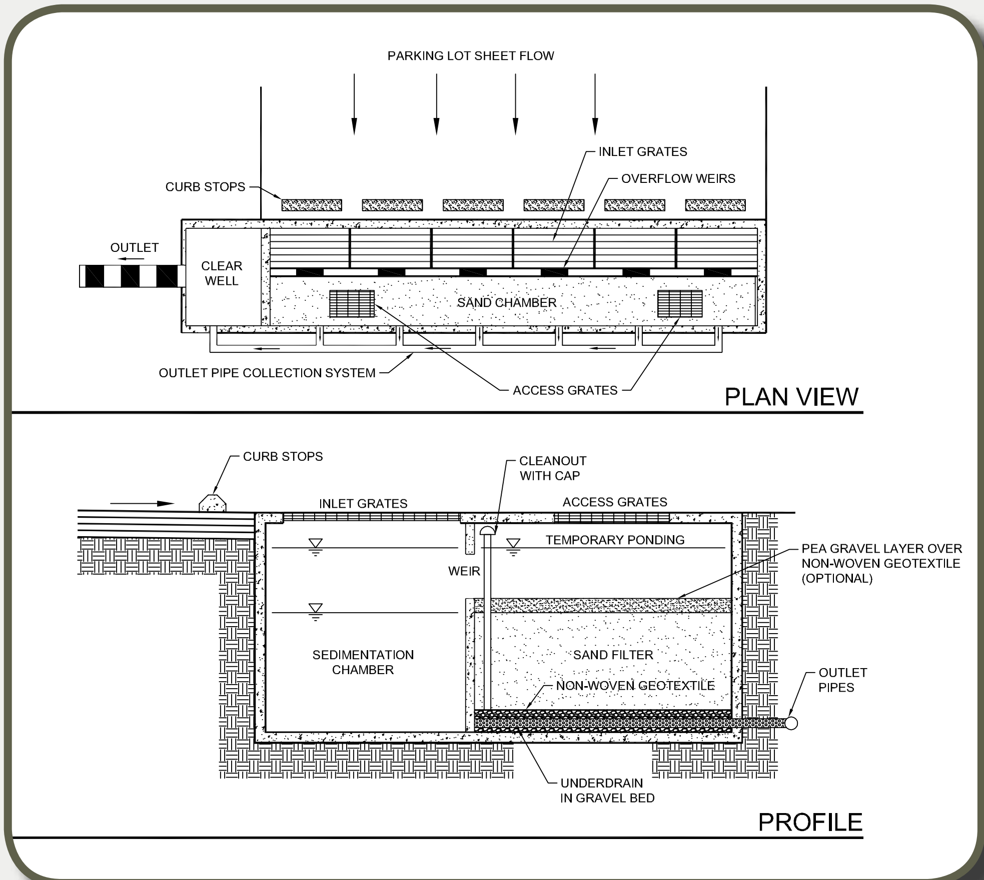


Figure FP-5. Example of Perimeter Sand Filter

4.2.10. Filtration Practice (FP)

FP-3. Feasibility Criteria and Design Considerations

Filtration practices can be applied to most types of urban land. They are not always cost-effective, given their high unit cost and small area served, but there are situations where they may clearly be the best option for stormwater treatment, such as stormwater hotspots, high traffic parking lots with high pollutant loading, and ultra-urban areas, etc. Key constraints with Filtration practices include the following:

Available Space. The amount of space required for a Filtration practice depends on the design variant selected. Surface sand filters typically consume about 1% to 3% of the CDA, while perimeter sand filters typically consume less than 1%. Underground sand filters generally consume no surface area except their manholes. Perimeter sand filters, while located below grade, have a parallel grate and frame and cover (as depicted in **Figure FP-1**.)

Site Topography. Surface filters shall not be located on slopes greater than 6%. Underground sand filters can be located on steep slopes as long as the manhole chimneys are designed to provide access at grade (adequate manhole diameter for the corresponding height of chimney).

Available Hydraulic Head. The principal design constraint for Filtration practices is available hydraulic head, which is defined as the vertical distance between the ponding surface elevation of the pretreatment sedimentation chamber of the filter and the invert elevation of the storm drain system that receives its discharge. The head required for Filtration practices can range from 2 to 10 feet, depending on the design variant, making it difficult to employ filters in extremely flat terrain. The only exception is the perimeter sand filter, which can be applied at sites with as little as 2 feet of head.

Depth to Water Table and Bedrock. Filtering Practices that do not incorporate Infiltration as part of the system are not constrained by bedrock or water table other than the constructability of the practice. Underground systems may require deep excavation that intersects with bedrock or water table, so these factors must be considered in terms of constructability.

Soils. Soil conditions do not constrain the use of filters. At least one soil boring must be taken at a low point within the footprint of the proposed Filtration practice to establish the water table and bedrock elevations to evaluate constructability. A geotechnical investigation is required for all underground best management practices (BMPs), including underground sand filters to verify the load bearing capacity of the existing soils and any special footing requirements.

Contributing Drainage Area. Filtration practices are best applied on small sites where the CDA area is as close to 100% impervious as possible in order to reduce the risk of clogging due to landscape and pervious area sediment erosion. A maximum CDA of 2.5 acres is recommended for surface sand filters, and a maximum CDA of 1 to 2 acres is recommended for underground sand filters. Filtration practices have been used on larger drainage areas in the past, but greater clogging problems have typically resulted.

The perimeter sand filter is only applicable for impervious areas less than 10,000 ft2 (1/4 acre). However, independent perimeter sand filter cells can be employed to treat a combined larger area.

Hotspot Land Uses. As noted above, Filtration practices are particularly well suited to treat runoff from stormwater hotspots and smaller parking lots. Other applications include redevelopment of commercial sites or when existing parking lots are renovated or expanded. Filtration practices can work on most commercial, industrial, institutional or municipal sites and can be located underground if surface area is not available.

For a list of potential stormwater hotspots, please consult **Chapter 5** of the Manual.

Floodplains. Filtration practices should be constructed outside the limits of the mapped 100-year floodplain, unless a waiver is obtained from the local authority.

Proximity to Utilities. All utilities shall have a minimum 5 foot horizontal clearance from the Filtration practices.

Facility Access. All Filtration practices shall be located in areas where they are accessible for inspection and for maintenance. Maintenance to underground systems is typically by vacuum truck, so adequate access must be planned during initial site design.

Community Factors. Maintenance requirements for underground sand filters can be very technical (and often require confined space credentials in order to perform basic inspections) such that underground sand filter systems are not recommended for single family residential developments (and there are numerous other BMP options better suited for residential areas). Either underground or surface sand filters may be considered for high density residential areas, but should be maintained by a contractor through a community association.

Underground Injection Permits. Filtration practices areas are not subject to permits under the Underground Injection Control (UIC) Program (U.S. EPA, 2008) unless there is an additional component that includes Infiltration in close proximity to sensitive groundwater areas (e.g., aquifers overlain with thin, porous soils), designs with a subsurface fluid distribution system (e.g., underdrains that do not discharge to the surface or the storm drain system), and/or designs that are deeper than their widest surface dimension. The designer should confer with WVDEP or the local plan approving authority about the possible applicability of a UIC permit when these conditions are present.

4.2.10. Filtration Practice (FP)

FP-4. Design Criteria

FP-4.1. Types of Filters

There are several design variations of the basic Filtration practice that enable them to be used at challenging sites or to improve pollutant removal rates. Filtration practices are especially useful at hotspots or high traffic/high pollutant loading sites where a robust pre-treatment practice is essential for the long term effectiveness of a downstream runoff reduction practice such as Infiltration or Bioretention.

The choice of which filter design to apply depends on available space and hydraulic head and the level of pollutant removal desired. In ultra-urban situations where surface space is at a premium, underground sand filters are often the only design that can be used. Surface and perimeter sand filters are often a more economical choice when adequate surface area is available. The most common design variants include the following:

- **Surface Sand Filter.** The surface sand filter is designed with both the filter bed and sediment chamber located at ground level. The most common filter media is sand; however, a peat/sand mixture may be used to increase the removal efficiency of the system. In most cases, the filter chambers are created using pre-cast or cast-in-place concrete. Surface sand filters are normally designed to be off-line facilities, so that only the desired water quality or runoff reduction volume is directed to the filter for treatment. However, in some cases they can be installed on the bottom of a Dry Extended Detention Pond.
- **Underground Sand Filter.** The underground sand filter consists of an underground concrete vault divided into chambers to accommodate the pretreatment, filter, and outlet chambers. The underground sand filter is often designed with a flow splitter or overflow device that bypasses runoff from larger stormwater events around the filter. Underground sand filters are expensive to construct, but they consume very little space and are well suited to ultra-urban areas.

The most common configuration of an underground sand filter is the gravity flow three-chambered system that can either be a pre-cast or cast-in-place concrete vault with access manholes to each chamber.

- The first chamber acts as a pretreatment facility that contains a standing pool of water and is configured with a submerged orifice to remove any floating organic material such as oil, grease, and tree leaves. The chamber also serves as a sedimentation chamber to allow coarse sediments to settle to the bottom rather than clog the filter media surface. This chamber should therefore be designed to minimize the energy of incoming stormwater to avoid re-suspension of settled material. **Figure FP-3** illustrates a common configuration of the pretreatment design as having two chambers.
- The second chamber is the filter chamber and contains the 12' to 18' deep filter bed underlain by a drain system consisting of parallel perforated PVC pipes in a gravel bed. A dewatering valve should be installed at the top of the filter layer to release the ponded water in cases of media failure (clogging) or an emergency.

  The configuration of the filter bed material has been modified over the years to theoretically improve the filter media longevity and minimize maintenance costs:
  - One option is the placement of a shallow layer of pea gravel directly on the sand. The gravel serves to break up the growth of algae that often blinds (seals) the sand surface after repeated wet/dry cycles.
  - Expanding on the pea gravel option to assist in maintenance, some applications include a non-woven geotextile fabric between the sand and the gravel to assist in periodic removal of the gravel.

Consider the Difficulty of Maintenance Tasks

While the pea gravel and geotextile options discussed above were intended to facilitate maintenance by prolonging the longevity and thereby minimizing the frequency of maintenance, they both serve to complicate maintenance of the system. The removal of gravel is difficult through the access manholes (volume and weight). Similarly, the removal of a large sheet of filter fabric that is loaded with saturated sediment and gravel is also very difficult.

  - An alternate approach is to enhance the pretreatment chamber by incorporating baffles and energy dissipaters, and increase the media depth to 18" or 24". This will serve to minimize the sediment load to the filter media. In addition, the deeper media depth will facilitate maintenance by allowing for the periodic scraping and removal of the top 1" of sand media, leaving an adequate media depth for continued operation (the depth of clogging of the sand media is often limited to the first inch)

- The third chamber is the discharge chamber. It receives the discharge from the underdrain system as well as the overflow from the first chamber through a bypass pipe when the storage volume is exceeded.

- **Perimeter Sand Filter.** The perimeter sand filter also includes the basic design elements of a sediment chamber and a filter bed. The perimeter sand filter typically consists of two parallel trenches connected by a series of overflow weir notches at the top of the partitioning wall which allows water to enter the second trench as sheet flow; or where heavy hydrocarbon loading is expected, a series of submerged orifices with energy dissipaters on the outlets. The first trench is a pretreatment chamber removing heavy sediment particles and debris, or floatable oils. The second trench consists of the sand filter layer. A subsurface drainage pipe is at the bottom of the second chamber to convey the filtered water to a receiving system.

In this design, flow enters the system through grates, usually at the edge of a parking lot. The perimeter sand filter is usually designed as an on-line practice (i.e., all flows enter the system), but larger events bypass treatment by entering an overflow chamber. One major advantage of the perimeter sand filter design is that it requires little hydraulic head and is therefore a good option for sites with low topographic relief.

- **Proprietary Filters.** Proprietary filters use various filter media and geometric configurations to achieve filtration and provide manageable maintenance processes and access within a packaged structure. In some cases, these systems can provide excellent targeting of specific pollutants. However, designers must verify that the particular product has been reviewed for performance, sizing, and longevity and has been approved as a viable practice by WVDEP.

FP-4.2. Filtration Practice Sizing for Water Quality & Volume Reduction

A Note on Terminology Describing Volume

There are two types of volumes that the designer should consider when designing a BMP plan:

Target Treatment Volume (Tv) = Volume associated with managing 1" of rainfall based on the size and land cover of the CDA, as determined by the Design Compliance Spreadsheet. Any given BMP may treat the full Tv, or only part of it if used in conjunction with other practices as part of a treatment train.

Design Volume (Dv) = The volume designed into a particular practice based on storage in the practice, as prescribed in the BMP specification. Note that, while Filtration practices can be designed to store temporarily a particular Dv, they do not meet the MS4 General Permit criteria to "keep and manage on-site the first one-inch of rainfall" and thus do not have an associated runoff reduction credit and do not contribute to reducing the overall Tv. However, Filtration practices do achieve pollutant removal rates as outlined in Table FP-2. Designers should check with the local plan approval authority on use and approval of Filtration practices as part of an overall BMP plan.

See **Chapter 3** for more information on the runoff reduction design methodology.

For the purposes of this sizing section, the sizing relates to the Dv of the Filtration practice being designed.

Filtration devices are sized to accommodate the Dv. The filter components that are sized according to the Dv are the pre-treatment or sedimentation chamber volume, the surface area of the filter, and the volume of ponding storage above the filter. For a given design volume, **Equation FP-1**, Darcy's Law, is used to determine the required filter surface area:

Equation FP-1. Darcy's Law
Minimum Filter Surface Area for Filtration Practices

$$SA_{filter} = \frac{(Dv)(d_f)}{[(k)(h_{avg} + d_f)(t_f)]}$$

Where:

SA_{filter}	=	area of the filter surface (ft2)
Dv	=	Design Volume (ft3)
df	=	filter media depth (thickness, ft) = minimum 1 ft above underdrains
k	=	Coefficient of permeability (partially clogged sand) = 3.5 ft/day
hf	=	Average height of water above filter surface bed (ft) = maximum 5 ft
tf	=	Design drawdown time (days) = 40 hours = 1.67 days

The coefficient of permeability (ft./day) is intended to reflect the worst case situation (i.e., the condition of the sand media at the point in its operational life where it is in need of replacement or maintenance). Filtering practices are therefore sized to properly function within the desired constraints up to the end of the media's operational life.

The entire filter treatment system (including the pretreatment/sedimentation and any additional storage upstream of the filter system) shall temporarily hold at least 75% of the design storm volume prior to filtration (**Equation FP-2**). This reduced volume takes into account the varying filtration rate of the water through the media, as a function of a gradually declining hydraulic head.

Equation FP-2. Required Volume of Storage for Filtration Practices

$$V_{ponding} = 0.75(Dv)$$

Where:

$V_{ponding}$	=	storage volume required prior to filtration (ft^3)
Dv	=	Design Volume

Pre-Treatment is Essential

Adequate pre-treatment is needed to prevent premature filter clogging and ensure filter longevity. Incorporating baffles, submerged orifices, and other techniques into the pre-treatment/sedimentation chamber will improve performance longevity and therefore reduce maintenance costs.

An effective method of increasing the functional longevity of the filter is to limit the drainage area to impervious cover only. This helps to minimize the sources of sediment and organic material that combine to clog the surface of filtering practices.

Dry or wet pretreatment shall be provided prior to the filter media of surface sand filters. **Figure FP-6** shows various pre-treatment options for filters, and **Figure FP-7** is a detail for pre-treatment as the pavement edge.

Wet pretreatment shall be provided for underground and perimeter sand filters.

Pre-treatment devices are subject to the following criteria:

- Surface sand filters may use alternative pre-treatment measures, such as a grass filter strip, forebay, gravel diaphragm, check dam, level spreader, or combination.
    - o The grass filter strip must be a minimum length of 15 feet and have a slope of 3% or less.
    - o The check dam may be wooden or concrete and must be installed so that it extends only 2 inches above the filter strip and has lateral slots to allow runoff to be evenly distributed across the filter surface.
    - o Alternative pre-treatment measures should contain a non-erosive flow path that distributes the flow evenly over the filter surface.
    - o If a forebay is used it should be designed to accommodate at least 25% of the total design storm volume (both the wet pool and temporary ponding inclusive).
- Sedimentation chambers for underground sand filters must be wet and sized to accommodate at least 25% of the total design storm volume (both the wet pool and temporary ponding inclusive).
- Sediment chambers for underground sand filters should be designed as level spreaders such that inflows to the filter bed have near zero velocity and spread runoff evenly across the bed.
- If proprietary devices are used for pre-treatment for underground sand filters, designers must confirm through WVDEP that the practice has been approved with the capability to effectively trap and retain particles down to 20 microns in size for the design flow rate (up to the bypass flow rate design).

FP-4.3. Pretreatment

Figure FP-6. Examples of Pre-Treatment Applicable to Filtration Practices

Grass filter strips are generally perpendicular to incoming sheet flow and extend from the edge of pavement (with a slight drop of 2 to 3 inches at the pavement edge) to the edge of the Filtration basin. The grass filter strip must be a minimum width of 15 feet and have a slope of 3% or less.

This **Dry Pre-Treatment Cell** or forebay is located at concentrated inflow points such as pipes or curb cuts leading to the Filtration practice, and consists of an energy dissipater sized for the expected rates of discharge. It has a Design Volume equivalent to at least 25% of the total storage volume (inclusive) with a recommended 2:1 length-to-width ratio. The cell may be formed by a wooden or stone check dam or an earthen or rock berm.

A **Grass Swale** can serve as pre-treatment to a Filtration practice.

An approved **Proprietary Device** with demonstrated capability of reducing sediment and hydrocarbons may be used to provide pre-treatment. Refer to **Chapter 3.2.4** for information on the approval process for such devices.

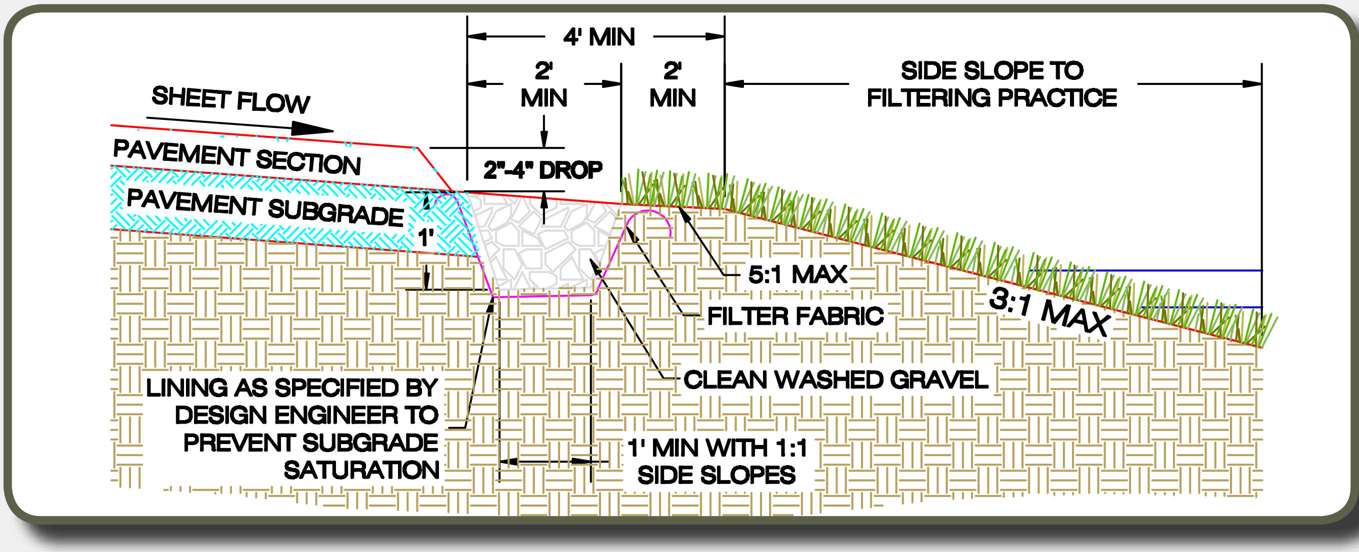


Figure FP-7. Typical Detail for Pre-Treatment at Pavement Edge – A 2 to 4 inch drop from the pavement to the top of stone helps to prevent clogging.

FP-4.4. Conveyance and Overflow

Most Filtration practices are designed as off-line systems so that all flows enter the filter storage chamber until the chamber reaches capacity, at which point larger flows are then diverted or bypassed around the filter to an outlet chamber and are not treated. Runoff from larger storm events should be bypassed using an overflow structure or a flow splitter. Claytor and Schueler (1996) and ARC (2001) provide design guidance for flow splitters for Filtration practices.

Some underground sand filters will be designed and constructed as on-line BMPs. In these cases, designers must indicate how the device will safely pass larger storm events (e.g., the 10-year event) to a stabilized water course without re-suspending or flushing previously trapped material.

All Filtration practices should be designed to drain or dewater within 40 hours after a storm event to reduce the potential for nuisance conditions.

FP-4.5. Design Geometry

Filtration practices are gravity flow systems that may require anywhere from 2 to 10 feet of elevation from inflow to outflow, depending on the design variant and the sizing of the individual filter components or chambers; therefore, sufficient vertical clearance between the inverts of the inflow and outflow pipes is required.

The sizing of the individual system components includes the ponding depth and the filter media depth. Since Darcy's Law calculates the surface area of the filter using media permeability (K-factor, independent of ponding depth), the ponding depth (to derive filtration rate), and the media depth, it is important to establish the minimum and maximum for these variables to maintain the appropriate relationship between the Design Volume and the filter surface area.

- **Ponding Depth.** The recommended maximum ponding depth on Filtration practices is 5 feet. This is to establish a maximum overall depth so that maintenance can be achieved in a practical manner. A maximum depth will also prevent the inappropriate downsizing of the filter media surface area, as a minimum surface area is needed to achieve the intended level of filtration.
- **Media Depth.** The minimum recommended media depth or thickness is 12 inches. However, setting the depth at 18 to 24 inches will facilitate periodic scraping and removal of the top 1 inch of media (or as needed) when the surface of the filter is occluded. Establishing the deeper media will allow for multiple maintenance events without

having to replace the sand media. Alternatively, a very shallow media depth will result in a larger required filter media surface area. So even though a shallower media depth may be effective in filtering runoff, the minimum design depth must be 12 inches, and preferably 18 inches to support a longer maintenance cycle.

Limit the Design Geometry of the Ponding and Media Depth

The design dimensions of Filtration system components must be limited to minimum or maximum values in order to ensure the proper ratio of Design Volume to media surface area when using Darcy's Law to size the practice.

FP-4.6. Detention Time

All Filtration practices should be designed to drain the Design Volume from the filter chamber within 40 hours after each rainfall event.

FP-4.7. Structural Requirements

If a filter will be located underground or experience traffic loads, a licensed structural engineer should certify the structural integrity of the design.

FP-4.8. Filter Media

- **Type of Filter Media.** The normal filter media consists of clean, washed AASHTO M-6/ASTM C-33 medium aggregate concrete sand with individual grains between 0.02 and 0.04 inches in diameter.
- **Depth of Filter Media.** The depth of the filter media plays a role in how quickly stormwater moves through the filter bed and how well it removes pollutants. The recommended filter bed depth is 18 inches. An absolute minimum filter bed depth of 12" above underdrains is required, although designers should note that specifying the minimum depth of 12" will incur a more intensive maintenance schedule and possibly result in greater annual maintenance cost.

FP-4.9. Surface Cover

The surface cover for surface sand filters should consist of a 3-inch layer of topsoil on top of a non-woven filter fabric laid above the sand layer (**Figure FP-8**).

If an underground sand filter is observed to be clogging due to bio-fouling or surface blinding, a surface pea gravel layer on top of a coarse non-woven fabric can be laid over the sand layer after a maintenance event. The pea-gravel helps to prevent bio-fouling or blinding of the sand surface. The fabric serves to facilitate removing the gravel during maintenance operations. Bio-fouling is especially prevalent on sites where large air-conditioning condensers discharge cool water to the drainage system and into the underground sand filter on a continuous basis.

Figure FP-8. Gravel forebay and top soil and turf cover over the sand media (Source: Chesapeake Stormwater Network)

FP-4.10. Underdrains

Filtration practices include an underdrain system that meets the criteria provided in Table FP-4 below. The underdrain should be covered by a minimum 6-inch gravel layer consisting of clean, washed #57 stone.

FP-4.11. Geotextile Fabric

A non-woven geotextile should be placed beneath the filter media and above the underdrain gravel layer. The geotextile should meet the criteria provided in Table FP-4 below.

FP-4.12. Impermeable Liner

Surface sand filters can be designed with an impermeable liner below the underdrain system in karst areas or areas constructed in fill materials. Refer to Table FP-4 below for specifications.

FP-4.13. Signage

Informational and/or educational signage may be appropriate for surface sand filters. The location of manhole access points should be documented for underground sand filters.

FP-4.14. Planting Criteria

Surface sand filters can have a grass cover to aid in the pollutant adsorption. The grass should be capable of withstanding frequent periods of inundation and drought.

4.2.10. Filtration Practice (FP)

FP-5. Materials Specifications

The basic material specifications for Filtration practices that utilize sand as a filter media are outlined in **Table FP-4**.

Table FP-4. Filtration Practice Material Specifications

Material	Specification
Surface Cover	***Surface sand filters:*** 3-inch layer of topsoil on top of a non-woven geotextile above the sand layer. ***Underground sand filters:*** Optional - Pea gravel layer on top of a coarse non-woven geotextile laid over the sand layer.
Sand	Clean AASHTO M-6/ASTM C-33 medium aggregate concrete sand with a particle size range of 0.02 to 0.04 inch in diameter.
Underdrain	The underdrain should consist of High Density Polyethylene smooth or corrugated flexible-wall pipe. Pipes must comply with ASHTO M252 and ASTM F405. Underdrains meeting ASTM F758 should be perforated with slots that have a maximum width of 3/8 inch and provide a minimum inlet area of 1.76 square inches per linear foot of pipe. Underdrains meeting ASTM F949 should be perforated with slots with a maximum width of 1/8 inch that provide a minimum inlet area of 1.5 square inches per linear foot of pipe. Underdrain pipe supplied with precision-machined slots provides greater intake capacity and superior clog-resistant drainage of fluids, as compared to standard round-hole perforated pipe. Slotted underdrain reduces entrance velocity into the pipe, thereby reducing the possibility that solids will be carried into the system. Slot rows can generally be positioned symmetrically or asymmetrically around the pipe circumference, depending upon the application.
Non-woven Geotextile	Use needled, non-woven, polypropylene geotextile meeting the following specifications: Grab Tensile Strength (ASTM D4632) ≥ 120 lbs Mullen Burst Strength (ASTM D3786) ≥ 225 lbs/sq. in. Flow Rate (ASTM D4491) ≥125 gpm/sq. ft. Apparent Opening Size (ASTM D4751) = US #70 or #80 sieve NOTE: Heat-set or heat-calendared fabrics are not recommended.
Underdrain Stone	Use #57 stone or the ASTM equivalent (1 inch maximum).
Impermeable Liner	Use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd. non-woven geotextile.

FP-6. Design Adaptations

FP-6.1. Karst Terrain

Karst regions are found in much of the Ridge and Valley and Panhandle. Karst complicates both land development and stormwater design. Filtration practices are a good option in karst areas, since they are not connected to groundwater and therefore minimize the risk of sinkhole formation and groundwater contamination. Construction inspection should certify that the filters are indeed water tight and that excavation will not extend into a karst layer.

FP-6.2. Steep Slopes

The gradient of slopes contributing runoff to surface sand filters can be increased to 15% in areas of steep terrain, as long as a two cell, terraced design is used to dissipate erosive energy prior to filtering. The drop in elevation between cells should be limited to 1 foot and the slope should be armored with river stone or a suitable equivalent.

Underground sand filter performance is generally not limited by the steepness of the CDA other than to recognize the potential for pervious areas to contribute greater loads of sediment.

FP-6.3. Cold Climate and Winter Performance

Surface or perimeter sand filters may not always be effective during the winter months. The main problem is ice that forms over and within the filter bed. Ice formation may briefly cause nuisance flooding if the filter bed is still frozen when spring melt occurs. To avoid these problems, filters should be inspected before the onset of winter (prior to the first freeze) to dewater wet cells and scarify the filter surface. Other measures to improve winter performance include the following:

- Place a weir between the pre-treatment chamber and filter bed to reduce ice formation; the weir is a more effective substitute than a traditional standpipe orifice.
- Extend the filter bed below the frost line to prevent freezing within the filter bed.
- Oversize the underdrain to encourage more rapid drainage and to minimize freezing of the filter bed.
- Expand the sediment chamber to account for road sand. Pre-treatment chambers should be sized to accommodate up to 40% of the Design Volume.

FP-6.4. Stormwater Retrofitting

Filtration practices are a versatile retrofit option that offer moderate pollutant removal performance. They are especially attractive for on-site retrofits where space is limited, because they consume very little surface land and have few site restrictions.

For more information on retrofitting, see the Center for Watershed Protection's manual, Urban Stormwater Retrofit Practices (Schueler et al., 2007).

FP-7. Construction & Installation

FP-7.1. Erosion and Sediment Controls

No runoff shall be allowed to enter the Filtration practice prior to completion of all construction activities, including revegetation and final site stabilization. Construction runoff shall be treated in separate sedimentation basins and routed to bypass the Filtration system. Should construction runoff enter the system prior to final site stabilization, all contaminated materials must be removed and replaced with new clean filter materials before a regulatory inspector approves its completion. The approved erosion and sediment control plans shall include specific measures to provide for the protection of the Filtration practice before the final stabilization of the site.

Drainage Areas Should Be Stabilized Before Installation of Underdrains & Sand Media

The #1 source of failure for sand filters is installation too early during the construction process and/or lack of erosion control measures during installation. Construction sediment will readily clog the sand media. Drainage areas to sand filter areas should be stabilized with vegetation prior to installation of these materials.

FP-7.2. Filter Installation

The following is the typical construction sequence to properly install a structural sand filter. This sequence can be modified to reflect different filter designs, site conditions, and the size, complexity and configuration of the proposed Filtration application.

Step 1. Filtration practices should only be constructed after the CDA to the facility is completely stabilized, so sediment from the CDA does not flow into and clog the filter. If the proposed Filtration area is used as a sediment trap or basin during the construction phase, the construction notes should clearly specify that, after site construction is complete, the sediment control facility will be dewatered, dredged and re-graded to design dimensions for the post-construction filter.

Step 2. Stormwater should be diverted around Filtration practices as they are being constructed. This is usually not difficult to accomplish for off-line Filtration practices. It is extremely important to keep runoff and eroded sediments away from the filter throughout the construction process. Silt fence or other sediment controls should be installed around the perimeter of the filter, and erosion control fabric may be needed during construction on exposed side-slopes with gradients exceeding 4H:1V. Exposed soils in the vicinity of the Filtration practice should be rapidly stabilized by hydro-seed, sod, mulch, or other method.

Step 3: Assemble construction materials on-site, make sure they meet design specifications, and prepare any staging areas.

Step 4: Clear and strip the project area to the desired subgrade.

Step 5: Excavate/grade until the appropriate elevation and desired contours are achieved for the bottom and side slopes of the Filtration practice.

Step 6: Install the filter structure and check all design elevations (concrete vaults for surface, underground and perimeter sand filters). Upon completion of the filter structure shell, inlets and outlets should be temporarily plugged and the structure filled with water to the brim to demonstrate water tightness. Maximum allowable leakage is 5% of the water volume in a

24-hour period. If the structure fails the test, repairs must be performed to make the structure watertight before any sand is placed into it.

Step 7: Install the gravel, underdrains, and choker layer of the filter.

Step 8: Spread sand across the filter bed in 1 foot lifts up to the design elevation. Backhoes or other equipment can deliver the sand from outside the filter structure. Sand should be manually raked. Clean water is then added until the sedimentation chamber and filter bed are completely full. The facility is then allowed to drain, hydraulically compacting the sand layers. After 48 hours of drying, refill the structure to the final top elevation of the filter bed.

Step 9 (Surface Sand Filters Only): Install the permeable filter fabric over the sand, add a 3-inch topsoil layer and pea gravel inlets, and immediately seed with the permanent grass species. The grass should be watered, and the facility should not be switched on-line until a vigorous grass cover has become established.

Step 10: Stabilize exposed soils on the perimeter of the structure with temporary seed mixtures appropriate for a buffer. All areas above the normal pool should be permanently stabilized by hydroseed, sod, or seeding and mulch.

Step 11: Conduct the final construction inspection, then log the GPS coordinates for each filter facility and submit them for entry into the local maintenance tracking database. Multiple construction inspections are critical to ensure that Filtration practices are properly constructed. Inspections are recommended during the following stages of construction:

- Pre-construction meeting.
- Initial site preparation (including installation of project erosion and sediment controls).
- Excavation/grading to design dimensions and elevations.
- Installation of the filter structure, including the water tightness test.
- Installation of the underdrain and filter bed.
- Check that turf cover is vigorous enough to switch the facility on-line.
- Final inspection (after a rainfall event to ensure that it drains properly and all pipe connections are watertight). Develop a punch list for facility acceptance. Log the Filtration practice's GPS coordinates and submit them for entry into the local BMP maintenance tracking database.

An example construction phase inspection checklist is available in Appendix A of the Manual.

4.2.10. Filtration Practice (FP)

FP-8. Maintenance Criteria

Maintenance is a crucial element that ensures the long-term performance of Filtration practices. Underground sand filters especially are suspect to maintenance issues in that a clogged underground sand filter will not be noticed without intentionally lifting the manhole and observing the status of the filter media. Surface sand filters are much more observable by those trained and untrained alike. Because these are such different practices with different maintenance requirements, this section is divided between surface and underground sand filters

FP-8.1 Surface Sand Filters

Periodic maintenance should be integrated into routine landscape maintenance tasks:

- If landscaping contractors will be expected to perform maintenance (as is likely on commercial, business, or high density residential land uses), their contracts should contain provisions for trained personnel who understand the nuances of stormwater management practices.
- If maintenance is conducted by a homeowner, they should be:

(1) educated about their routine maintenance needs;
(2) understand the long-term maintenance elements; and
(3) be subject to modified maintenance agreements (as described below).

Consider Maintenance during the Design Process

The many design choices made during the design of Filtration practices can be critical to the long term maintenance and effectiveness of the practice. The context of the site along with the maintenance capabilities of the owner(s) should be considered during the design process.

Table FP-5. Design Decisions That Influence Long-Term Maintenance of Filtration Practices

Design Feature	Lower Maintenance	Higher Maintenance
Surface Cover (**Section FP-4.9**) (Surface Sand Filters)	• Sand or gravel surface cover; • Meadow or wildflower cover with native grasses	Grass cover that must be mowed regularly
Surface Cover (**Section FP-4.8**) (Underground Sand Filters)	Sand with no gravel or fabric: (more frequent, but easier maintenance)	Filter fabric and gravel over sand: Less frequent but more complex maintenance
Pre-Treatment (**Section FP-4.2**) (Surface Sand Filters)	Sheet flow entry to filter: pre-treatment cell or grass filter strips with a 2 to 4" drop from the pavement surface	Concentrated flow entry to filter: curb cuts or pipes that accumulate grit and debris at the entry point that must be remove periodically in order to prevent clogging of inlet
Pre-Treatment (**Section FP-4.2**) (Underground Sand Filters)	• Restrict drainage area to impervious cover; • Increase the volume/depth of pre-treatment/ sedimentation chamber normal pool; • Use baffles in pre-treatment/ sedimentation chamber.	Pervious turf and landscaped areas in CDA

FP-8.2 Underground Sand Filters

Underground sand filters must be maintained by qualified individuals with confined space entry credentials. Typical maintenance involves a vacuum truck to remove water from the pre-treatment sedimentation chamber, and other mechanical equipment to lift large volume of gravel, filter fabric, and sand up through the access manhole.

Routine maintenance can include periodically lifting the manhole lid and

FP-8.3 Maintenance Agreements

As with all BMPs, maintenance agreements must be executed between the owner(s) and the local authority to ensure that the practices are maintained and function properly. The agreements will specify the property owner's primary maintenance responsibilities and authorize local agency staff to access the property for inspection or corrective action in the event that proper maintenance is not performed.

Filtration practices must be covered by a drainage easement to allow inspection and maintenance by local authority staff.

FP-8.4 Recommended Maintenance

Maintenance of Filtration practices involves several routine maintenance tasks which are outlined in **Table FP-6**. If the filter treats runoff from a stormwater hotspot, crews may need to test the filter bed media before disposing of the media and trapped pollutants. Petroleum hydrocarbon contaminated sand or filter cloth must be disposed of according to the State of West Virginia's (or local authority's) solid waste disposal regulations. Testing is not needed if the filter does not receive runoff from a designated stormwater hotspot, in which case the media can be safely disposed of in a landfill.

Table FP-6. Recommended Maintenance Tasks For Filtration Practices.

Maintenance Tasks	Frequency
• Remove blockages and obstructions from inflows. Remove trash accumulation in surface sand filters and at storm drain inlets upstream of underground sand filters. • Stabilize contributing drainage area and side-slopes to prevent erosion. Filters with a turf cover should have 95% vegetative cover. • Remove manhole lid of underground sand filter to observe if standing water is present 40 hours after rain event of 0.5 inches or more.	As needed
• Mow grass filter strips and perimeter turf around surface sand filters. Maximum grass heights should be less than 12 inches.	At least four times per growing season
• Check to see if sediment accumulation in the sedimentation chamber has exceeded 6 inches. If so, schedule a cleanout.	2 times per year (may be more or less frequent depending on land use)

Maintenance Tasks	Frequency
• Conduct inspection and cleanup • Dig a small test pit in the filter bed to determine whether the first 1 to 3 inches of sand are visibly discolored and need replacement. • Check to see if inlets and flow splitters are clear of debris and are operating properly. • Check inside of concrete structures and outlets for any evidence of spalling, joint failure, leakage, corrosion, etc. • Ensure that the filter bed is level and remove trash and debris from the filter bed. Sand or gravel covers should be raked to a depth of 3 inches.	Annually
• Replace top sand layer. • Till or aerate surface to improve infiltration/grass cover	Every 5 years
• Corrective maintenance is required any time the sedimentation basin and sediment trap do not draw down completely after 40 hours (i.e., no standing water is allowed).	Upon failure

Regular inspections are critical to schedule sediment removal operations, replace filter media, and relieve any surface clogging. Frequent inspections are especially needed for underground and perimeter sand filters, since they are out of sight and can be easily forgotten. Depending on the level of traffic or the particular land use, a filter system may either become clogged within a few months of normal rainfall, or could possibly last several years with only routine maintenance. Maintenance inspections should be conducted within 24 hours following a storm that exceeds 1/2 inch of rainfall, to evaluate the condition and performance of the Filtration practice. For underground sand filters, this includes simply removing the manhole and verifying that the filter chamber has drawn down within 40 hours. Example maintenance inspection checklists for Filtration practices can be found in **Appendix A of the Manual.**

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