Stormwater Best Management Practice

Sand and Organic Filters

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Filtration

Description

Sand and organic filters provide water quality improvements through settling and filtration. A sand filter typically consists of two chambers: a settling chamber and a filter bed with sand or other filtering media. As stormwater flows into the settling chamber, large particles settle out, and the filtering media then remove finer particles and other pollutants. There are several modifications of the basic sand filter design, including the surface sand filter, underground sand filter, perimeter sand filter and various organic media filters. Some versions even have distinct names, like the Austin Sand Filter, the Washington D.C. Sand Filter and the Delaware Sand Filter. These filters operate on the same basic design of settling, then filtration. Design engineers have modified the traditional surface sand filter to fit sand filters into more challenging sites (e.g., underground and perimeter filters) or to improve pollutant removal (e.g., organic media filter).

A sand filter under construction.

Applicability

Sand filters are suitable for most regions of the country and most types of sites. Some site constraints favor specific versions over others (see “Siting and Design Considerations” below).

Regional Applicability

Sand filters are suitable for cold climates, but surface or perimeter filters will not be effective during the winter months. Using an alternative conveyance measure such as a weir system between the settling chamber and filter bed may avoid freezing associated with the traditional standpipe. Where possible, the filter bed should be below the frost line. Some sand filter variations (e.g., organic filters) should not operate during the winter, as organic media can become completely impervious when frozen. Using a larger underdrain system to encourage rapid draining in winter may help limit freezing of the filter bed.

In cold and arid climates, design engineers should also consider the size of the settling chamber. In cold climates that practice road sanding, this additional sediment load can take up as much as half the storage volume. In arid climates, sand filters are not widely used; in these climates, designers may need to make similar accommodations to account for the naturally higher sediment loads in these regions.

Urban Areas

Urban areas are usually densely developed places in which little pervious surface is present. Sand filters are generally good options in these areas because they consume little space, particularly if they are underground.

Stormwater Hot Spots

Sand filters that incorporate liners or sit on poorly infiltrating soils are often a good option to treat discharge from stormwater hot spots due to the treatment they provide and their limited potential to contaminate groundwater. Organic media are an effective adsorbent of many hotspot pollutants, such as metals and hydrocarbons. In all cases, design engineers should follow local regulations regarding treatment requirements for stormwater hotspots.

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Stormwater Retrofit

Sand filters are a good option to achieve water quality goals in retrofit studies where space is limited, because they take up very little surface space and have few physical site restrictions. However, they are not suitable for treating stormwater flows from large drainage basins, as they often have limited hydraulic capacity.

Common Terms

Stormwater hot spots are areas where land use or activities generate highly contaminated stormwater discharge, with pollutant concentrations exceeding those typically found in stormwater. Examples include gas stations, vehicle repair areas and waste storage areas.

A **stormwater retrofit** is a stormwater management practice (usually structural) put into place after development or construction of a stormwater control to improve water quality, protect downstream channels, reduce flooding or meet other specific objectives that did not exist at the time of original construction.

Pretreatment plays an important role in stormwater treatment. Pretreatment structures, installed immediately upgradient to a stormwater control, reduce flow rates and remove sediment and debris before stormwater enters a stormwater control. This helps to improve the stormwater control's pollutant removal efficiency and reduces maintenance requirements.

Cold Water (Trout) Streams

Some aquatic species in cold water streams, notably trout, are extremely sensitive to changes in temperature. Sand filters may be a good treatment option for cold water streams. However, design engineers should consider site-specific placement, as the sun can warm pooling water within a surface sand filter. To protect aquatic life, designers may consider shortening the detention time for surface sand filters that discharge to cold waterbodies. Underground and perimeter sand filter designs have little potential for warming because they are not exposed to the sun.

Siting and Design Considerations

Drainage Area

Sand filters are best for smaller sites: up to 10 acres for surface sand filters, up to 5 acres for organic filters, and up to 2 acres for underground and perimeter filters (MDE, 2009). Designers have used sand filters for larger drainage areas (up to 100 acres), but these systems tend to clog easier, causing stormwater to overwhelm or bypass the system entirely.

Slope

Sand filters are suitable for sites with mild to moderate slopes, as they generally require 4 to 8 feet of head (elevation drop) to promote flow through the system. Smaller versions, sometimes called "pocket filters," can function with as little as 2 feet of head, though their capacity is lower. Sand filters can be challenging or impractical to construct on flat terrain.

Soils/Topography

Design engineers can install sand filters on almost any soil, including poorly infiltrating soils. In soils with high infiltration rates, engineers can design sand filters to exfiltrate into the surrounding soil to promote groundwater recharge. If groundwater contamination is a concern or if soils have low infiltration rates, design engineers can incorporate an impermeable liner with an underdrain. All options provide water quality treatment.

Groundwater

Designers should provide at least 2 feet of separation between the bottom of the filter and the seasonally high groundwater table. This design feature allows for sufficient hydraulic head within the system and prevents structural damage from prolonged inundation.

Pretreatment

Pretreatment is an important part of the sand filter. It happens in the sedimentation chamber, where the coarsest particles settle out and thus do not reach the filter bed. A common practice is to provide at least 25 percent of the water quality volume in a dry or wet sedimentation chamber as pretreatment to the filter system. (The water quality volume is the amount of stormwater from a single storm event that the control measure will treat. Although regulations vary by location, most approximate this quantity as the volume the control measure receives from a 1-inch storm event.)

Although pretreatment is highly recommended, not all locations require it, especially for smaller sand filters (e.g., at sites smaller than half an acre) (City of Portland, 2016; MDE, 2009; SPU, 2017. Design engineers should always follow local specifications.

Treatment

Treatment design features help enhance the ability of a stormwater control to mitigate or remove pollutants of concern. Design engineers may choose media based the desired hydraulic conductivity, desired pollutant removal performance, or targeting of specific pollutants. Custom media blends are now available in many locations that provide very specific performance characteristics. For example, certain organic amendments can promote denitrification and provide sorption sites to bind pollutants like phosphorus, metals and hydrocarbons (Hirschman et al., 2017). Design engineers should consult local stormwater authorities to identify approved media sources for specific applications.

The volume of the treatment component generally depends on the water quality volume, with the requirement that it be able to temporarily store a certain percentage. For example, in Maryland, the pretreatment and treatment components together should be able to store at least 75 percent of the water quality volume (MDE, 2009), while in Seattle the requirement is 91 percent (SPU, 2017). The design engineer should size the filter bed area using Darcy's law or an approved equivalent method, which relates the velocity of fluid through a medium to the hydraulic head and the medium's hydraulic conductivity. Designers may use multiple layers of different media in a sand filter, depending on the targeted flow rate and targeted pollutants. They should also incorporate a factor of safety to account for a possible decrease in permeability over time (e.g., NJDEP, 2014).

Conveyance

A properly designed sand filter should convey stormwater in a manner that minimizes erosion and provides for the design flow rate through the system. Ideally, vegetated filter strips or grass swales can achieve some stormwater treatment during conveyance to and from the filter. In many cases, sand filters are offline systems, meaning they use flow splitters to divert part of the stormwater flow from the main conveyance feature. One exception is the perimeter filter: all flows enter the system in this design, but larger flows overflow to an outlet chamber and are not treated. Every sand filter (with the rare exception of pure exfiltration filters) has an underdrain below the filter bed. An underdrain is a perforated pipe system in a gravel bed, installed on the bottom of the filter, that collects and conveys filtered stormwater.

Maintenance

Table 1 presents typical maintenance requirements. Design engineers can incorporate certain features to make regular maintenance easier. They should provide easy access to filtering systems, especially pretreatment components to allow for regular sediment removal. For underground sand filters, they should also follow the Occupational Safety and Health Administration's confined space rules.

Table 1. Typical maintenance activities for sand filters.

Activity	Timeframe
Remove trash and debris, including clippings from regular landscaping activities	After storm events or as needed, at least semi-annually
Inspect for structural damage and leaks	Annually
Inspect for evidence of erosion	After storm events or as needed, at least annually
Inspect to ensure stormwater is not bypassing the unit	After storm events or as needed, at least annually
Repair or replace damaged parts	As necessary
Clear sediment from sediment chamber	If sediment accumulates to half the chamber volume
Replace filter media	As necessary, as indicated by prolonged periods of pooling water over the filter bed during dry weather

Sources: MassDEP, 2008; MDE, 2009

Landscaping

Landscaping can add to both the aesthetic value and the treatment ability of stormwater controls. Sand filters generally need minimal landscaping, although surface sand filters and organic media filters may have a grass cover. In all filters, designers need to ensure that the contributing drainage has dense vegetation to reduce sediment loads and that debris from regular landscaping activities (e.g., grass or shrub clippings) do not flow into the filter.

Limitations

Sand filters are not appropriate for large drainage areas, do not provide flood control and generally do not protect stream channels from erosion. Sand filters that do promote groundwater recharge are not suitable in areas with high groundwater tables. In addition, sand filters need frequent maintenance, and underground and perimeter versions are out of sight so can be easy to forget.

Effectiveness

Filters typically provide pollutant removal rather than retention or detention. In some cases, where local soil and groundwater conditions allow, they can also achieve groundwater infiltration. Sand filters effectively remove most pollutants with the exception of nitrates which can both pass through the filter untreated or even be produced within the filter through the mineralization of organic nitrogen (various media amendments can remedy this; see Hirschman et al., 2017). Table 2 summarizes removal efficiencies for sand filters.

Table 2. Percent reductions in pollutant concentrations for sand filters.

Parameter	Units	Median Influent EMC	Median Effluent EMC	Percent Reduction
Total suspended solids	mg/L	56	9.0	84%
Fecal coliform	MPN/100 mL	900	400	56%
Total arsenic	µg/L	0.91	0.74	19%
Total cadmium	µg/L	0.30	0.08	73%
Total chromium	µg/L	2.0	1.0	50%
Total copper	µg/L	10	5.5	45%
Total iron	µg/L	642	210	67%
Total lead	µg/L	10	1.7	83%
Total nickel	µg/L	3.3	2	39%
Total zinc	µg/L	63	14	78%
Total phosphorus	mg/L	0.15	0.09	40%
Total nitrogen	mg/L	1.2	1.1	14%
Nitrate+nitrite (as nitrogen)	mg/L	0.35	0.57	-63%

Source: Clary et al., 2017
EMC = event mean concentration

Cost Considerations[1]

Table 3 summarizes average costs from multiple projects for installing and maintaining surface and underground sand filters. Costs are in terms of acres of impervious surface treated. The initial costs include pre-construction (site discovery, surveying, design, planning) and construction (labor, materials, installation) costs. The cost of maintenance activities includes regular maintenance, intermittent repair and associated inspection/monitoring costs.

[1] Prices updated to 2019 dollars. Inflation rates obtained from the Bureau of Labor Statistics CPI Inflation Calculator website: https://data.bls.gov/cgi-bin/cpicalc.pl.

Table 3. Average sand filter costs per acre of impervious surface treated.

Stormwater Control	Total Initial Cost	Annual Maintenance Costs
Surface sand filter	$56,000	$1,700
Underground sand filter	$64,000	$1,900

Source: King & Hagan, 2011

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

City of Portland. (2016). *2016 City of Portland stormwater management manual.*

Clary, J., Jones, J., Leisenring, M., Hobson, P., & Strecker, E. (2017). *International Stormwater BMP Database: 2016 summary statistics*. Alexandria, VA: Water Environment and Reuse Foundation.

Hirschman, D. J., Seipp, B., & Schueler, T. (2017). *Performance enhancing devices for stormwater best management practices*. Prepared for the Chesapeake Stormwater Network.

King, D., & Hagan, P. (2011). *Costs of stormwater management practices in Maryland counties*. University of Maryland Center for Environmental Science.

Maryland Department of the Environment (MDE). (2009). *2000 Maryland stormwater design manual*.

Massachusetts Department of Environmental Protection (MassDEP). (2008). *Massachusetts stormwater handbook and stormwater standards.*

New Jersey Department of Environmental Protection (NJDEP). (2014). *Stormwater BMP manual: Sand filters*.

Seattle Public Utilities (SPU). (2017). *City of Seattle stormwater manual* (Vol. 2).