2.8 Sand and Organic Filters

Above-ground Austin Sand Filter and sand filtration chamber.

Description

Sand filters utilize a sedimentation chamber and a filtration chamber to treat stormwater. The first chamber (sedimentation) removes large particles from stormwater by allowing them to settle out of suspension, while the second chamber (filtration) removes finer particles by filtering stormwater through a bed composed of sand or a combination of sand and organic material overlying a drain system.

Sand filters provide good treatment for pollutants except nitrates. Since these facilities attenuate the peak flows of common storm events, they are expected to reduce the potential for downstream channel erosion.

Conditions Where Practice Applies

Sand filters can be applied on most types of sites, but are most often implemented on ultra-urban sites dominated by impervious area or where space is a consideration. Sand filters also achieve a relatively constant effluent concentration of 7.5 mg/L TSS regardless of influent concentration. Therefore, sand filters, if maintained frequently enough to prevent clogging, are effective at treating stormwater "hot spots" with atypically high particulate loads, such as commercial parking lots, fueling stations, auto recycling facilities, industrial rooftops, commercial nurseries, outdoor loading/unloading facilities, and vehicle or equipment washing facilities.

Sand filters are appropriate on sites where contamination of groundwater may be a concern. In most instances, sand filters are constructed with impermeable basin or chamber bottoms that help to collect, treat, and release runoff to a storm drainage system or directly to surface water with no contact between runoff and groundwater. Sand filters can be used in areas where a permanent pool cannot be maintained for a wet pond. Sand filters should not receive runoff from active construction areas and are not appropriate for continuously disturbed areas that could cause premature clogging of the sand/media bed.

The two most common types of sand filters used in the United States, the Austin Sand Filter (Figure 2.8.3) and the Delaware Perimeter Sand Filter (Figure 2.8.4). The Austin Sand Filter is built at or below grade and is most commonly used for larger drainage areas that have both impervious and pervious surfaces. Delaware sand filter systems are installed underground, and thus are most commonly used for highly impervious areas where land available for structural controls is limited.

Planning Considerations

Size and Condition of Contributing Drainage Area – Sand filters are best suited to treat drainage areas of up to 25 acres for Austin aboveground sand filters and up to 1 acre for Delaware perimeter or underground units. Aboveground sand filters have been used for drainage areas up to 100 acres, but require larger pretreatment basins, additional distribution of water across the filter bed, and/or more frequent maintenance to prevent clogging. Because of clogging concerns, sand filters should not be used on sites where soils are permanently disturbed, and no stormwater should enter the filter system while the site is under construction.

Slopes – Sand filters can be used on sites with up to 6 percent slope. Austin aboveground sand filters require an elevation drop (head) of about 4 to 8 feet to allow runoff to flow through the system, while Delaware Perimeter Sand Filters typically require only 2 feet of head. The top of the filter bed must be completely level and stormwater must enter the filtration chamber as sheet flow.

Climate – The filter bed and internal conveyance structures may freeze in aboveground and perimeter sand filters unless the filter bed is placed below the frost line. Alternative conveyance systems such as a weir system between the sediment chamber and the filter bed may prevent the filter bed from freezing in more mild cold climates.

Design Criteria

The design of sand filters can be altered to fit a variety of site constraints or community preferences. Due to this flexibility, several sand filter designs have been developed. This manual provides the design criteria for two common configurations of sand filters: the Austin Aboveground Sand Filter and the Delaware Perimeter Sand Filter. Other manuals should be consulted for other design variations. The design steps will generally follow those laid out in Figure 2.8.1 for both aboveground and perimeter sand filters.

1) Determine overall treatment volume (WQv)
2) Divert flows exceeding treatment volume
3) Size and configure sedimentation chamber
4) Size and configure filtration chamber
5) Size outlet structure

Figure 2.8.1 Overall Design Process

Sand filters are usually constructed inside a concrete shell or built directly into the terrain over an impermeable liner. Where possible, the filter bed should be constructed below the frost line to prevent freezing. Although most Austin Sand Filters are open, they have been installed underground in parking areas, along the perimeter of parking lots, and in medians or landscaped areas.

1. Determine the Treatment Volume (Water Quality Volume)

The water quality volume (WQv) is the volume of runoff that is treated by a sand filter system. The sand filter should be designed to capture and store the entire WQv within the sedimentation chamber with a weir, perforated riser, or other outlet structure used to gradually release the captured runoff into the filtration basin over a 24-hour period. The filtration basin is designed to provide a filtration time of no less than 24 hours (when the filter media is new) and no more than 40 hours (when the filter media is clogged and requires maintenance). A total drawdown time of 40 hours is used for facility design. The water quality volume is calculated using equation 1 below. This is required by the Ohio EPA NPDES general permit (OHC00005 for construction activities.

$$WQv\ (ac\text{-}ft) = Rv * 0.90 * A / 12 \qquad \text{(Equation 1)}$$

Where:

Rv = volumetric runoff coefficient

A = area draining into the BMP in acres

The volumetric runoff coefficient, Rv, is calculated using the following equation or alternatively values provided in the Ohio EPA NPDES general permit (OHC00005) for construction activities.

$$Rv = 0.05 + 0.9\ (i) \qquad \text{(Equation 2)}$$

Where:

i = watershed imperviousness ratio, the percent imperviousness divided by 100

Note: The Ohio EPA NPDES stormwater general permit for construction activities requires that the water quality volume be increased by 20% for capacity lost over time due to sediment accumulation.

2. Divert Flows Exceeding Treatment Volume

In most cases flows into the sand filter are limited to the water quality volume (WQv). Therefore other measures may be necessary to meet flood control detention requirements either (1) by diverting all runoff exceeding the water quality volume to separate facilities or (2) by increasing the size of the sedimentation basin and placing a second outlet sized to meet flood control requirements above the stage of the water quality volume. Figure 2.8.2 shows a device that utilizes a weir to divert the water quality volume to a sand filter.

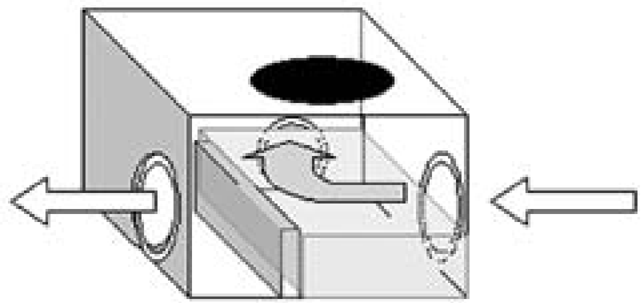

Figure 2.8.2 A weir inside the junction box of the storm sewer system diverts initial flows to sand filter.

3. Designing the Sedimentation Chamber (Basin)

The sedimentation chamber is the first stage of treatment within a sand filter. The chamber provides pretreatment of runoff by settling out coarser particles from runoff in order to prevent clogging and to reduce regular maintenance of the sand filter.

a) The Austin Sand Filter - Sedimentation chamber

The sedimentation chamber within an Austin Sand Filter is designed to completely empty between storms. This requires a somewhat larger size in order to minimize re-suspension of settled material, but also minimizes potential mosquito breeding conditions that exist within Delaware Perimeter Sand Filters and other designs that retain water between storms.

Basin Dimensions – The volume of the sedimentation basin equals the WQv plus an additional 20% of the WQv for sediment storage. The water depth in the sedimentation basin when full should be at least 2 feet and no greater than 10 feet. The minimum surface area of the sedimentation basin is determined by using the equation:

$$As = (1.2 * WQv)/(ds + freeboard) \qquad \text{(Equation 3)}$$

Where:

As = Minimum surface area of sedimentation chamber (cubic feet)
WQv = Water Quality Volume (cubic feet)
ds = Basin depth (feet)
freeboard = 0.5 feet

The sedimentation chamber should be configured so that it has a minimum length-to-width ratio of 2:1 between inlet(s) and the outlet, otherwise baffles may be necessary within the sedimentation chamber. A fixed vertical sediment depth marker should be installed in the sedimentation basin to indicate when 20% of the basin volume has been lost because of sediment accumulation.

Sedimentation Chamber Inlet – The WQv should be discharged uniformly into the sedimentation chamber at a velocity of no more than 2 ft/sec in order to maintain near quiescent conditions. A drop inlet structure is recommended to allow more efficient collection of sediment and other suspended solids that settle out within the sedimentation chamber. Energy dissipation devices may be necessary in order to reduce inlet velocity to 2 ft/sec or less.

Sedimentation Chamber Outlet – The outlet of the sedimentation basin conveys the WQv into the filtration chamber. The outlet structure should consist of a weir or a perforated riser pipe with a trash rack discharging to a weir acting as the inlet to the filtration chamber (Figure 2.8.3):

- Any weirs shall extend across the full width of the facility such that no short-circuiting of flows can occur.
- The riser pipe shall have a minimum diameter of 6 inches with four 1-inch perforations per row. The vertical spacing between rows should be 4 inches (on centers). To prevent clogging, it is recommended that the bottom half of the riser pipe be wrapped with geotextile fabric and that a cone of 1 to 3 inch diameter gravel be placed around the riser pipe.
- If a riser pipe is used to connect the sedimentation and filtration basins a valve shall be included to isolate the sedimentation basin in case of a hazardous material spill in the watershed. The control for the valve must be accessible at all times, including when the basin is full.
- Openings in the trash rack should not exceed one-third the diameter of the riser pipe.

Liners – For sedimentation basins built directly on the terrain of the site, they must be built on an impermeable liner, particularly in areas where groundwater protection is of primary importance. The liner may consist of either compacted clay with a hydraulic conductivity of 1 x 10-6 cm/sec or less, or nonwoven geotextile fabric meeting the specifications of ASTM D-751 and ASTM D-1682 and a minimum US Standard Sieve size of 80.

b.) The Delaware Perimeter Sand Filter Sedimentation Chamber

The sedimentation basin within the Delaware Perimeter Sand Filter system is usually a narrow 24” deep trough parallel to; and the same length and width as, the filtration basin, separated by a weir that runs the entire basin width with an elevation equal to the elevation of the top of sand in the filtration basin (see Figure 2.8.4). This weir results in a permanent pool 24 inches deep, the depth of the filtration bed, within the sedimentation basin. Although this dead storage serves to prevent the re-suspension of settled particulates, it may serve as a breeding ground for mosquitoes.

Sedimentation Chamber Surface Area – To meet Ohio EPA permit requirements, the WQv must fit within the volume of the sedimentation basin and the filtration basin between the top of the filter media and an overflow weir designed to divert flows in excess of the WQv to conveyance and/or detention facilities sized to meet local drainage criteria. The following equation may be used to calculate the surface area of the sedimentation basin:

$$A_s = WQv/2h - A_f \qquad \text{(Equation 4)}$$

Where:

A_s = Surface area of the sedimentation basin (square feet)

WQ_v = Water quality volume (cubic feet)

$2h$ = Maximum allowable depth of water over the filter (feet)

A_f = Surface area of the filtration basin (square feet)

The surface area of the sedimentation basin and the filtration basin are usually equal in a Delaware Perimeter Sand Filter, allowing the following equation to be used to determine the maximum allowable depth of water over the filter:

$$2h = WQv / 2^*A_f \qquad \text{(Equation 5)}$$

Solve this equation simultaneously with Equation 4 to calculating the surface area of the filter bed.

Establishing Basin Width and Length – Once the area of each chamber is calculated, the dimensions of the facility must be established. Although typical sediment trenches and filter trenches are 18 to 30 inches wide, site constraints dictate the width. In addition, other factors such as available grate widths also may dictate final widths. Standard grate width is 26 inches.

Floatable Control – The standard Delaware Sand Filter design does not provide a means to prevent floatables or hydrocarbon sheens from passing through to the filtration chamber. If installing a Delaware Sand Filter in a situation where floatables or hydrocarbons are a concern, long-term maintenance plans should reflect the increased maintenance needs of the sand filter. In addition, large storm overflow weirs should be equipped with a 10-gauge aluminum hood or commercially available catch basin trap. The hood or trap covers should extend a minimum of 1 foot into the permanent pool.

Dewatering Drain – A 6-inch diameter dewatering drain with gate valve should be installed at the top of filter bed elevation through the partition separating it from the clear-well chamber.

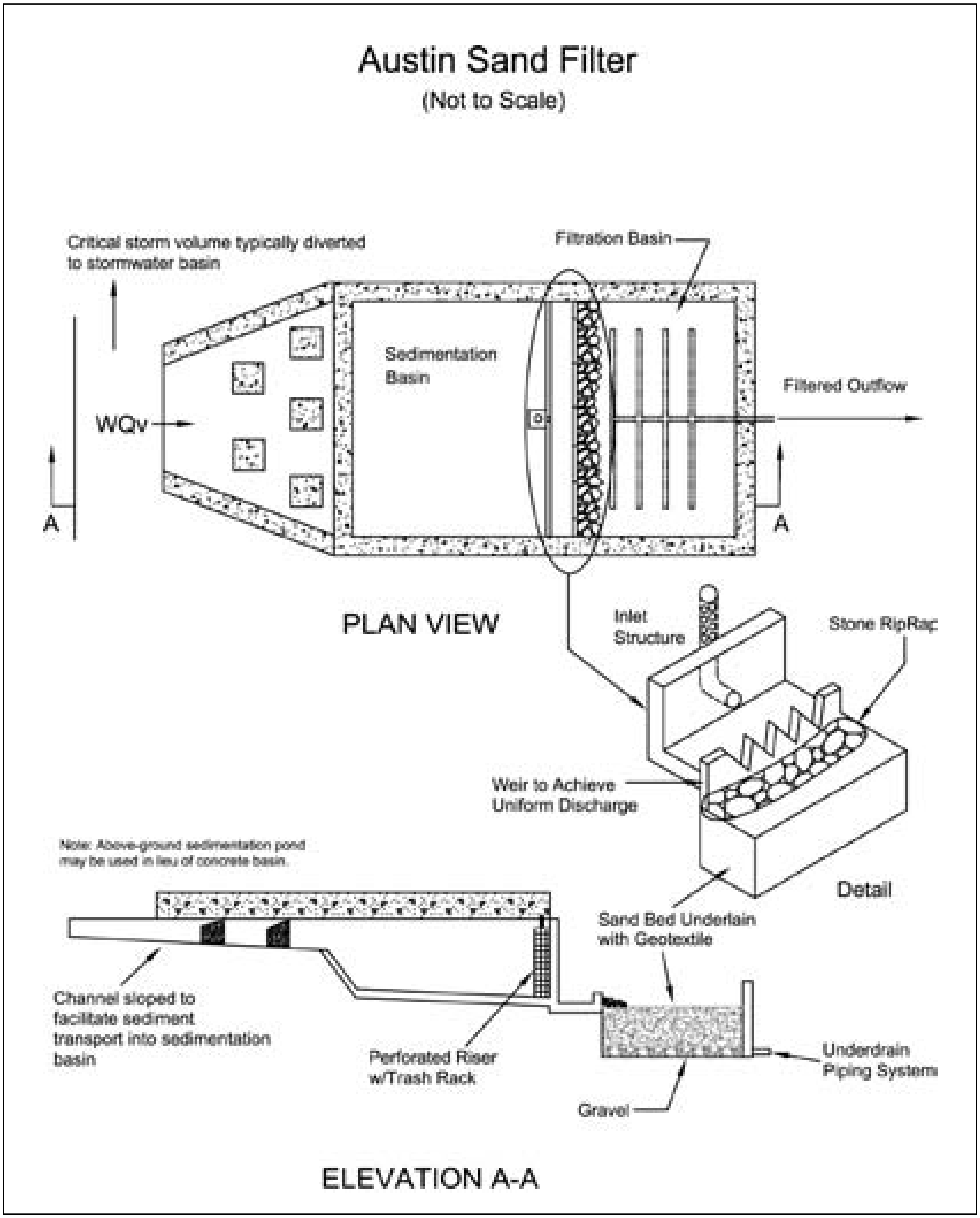

Figure 2.8.3 Austin Sand Filter, (City of Austin, TX. 1996).

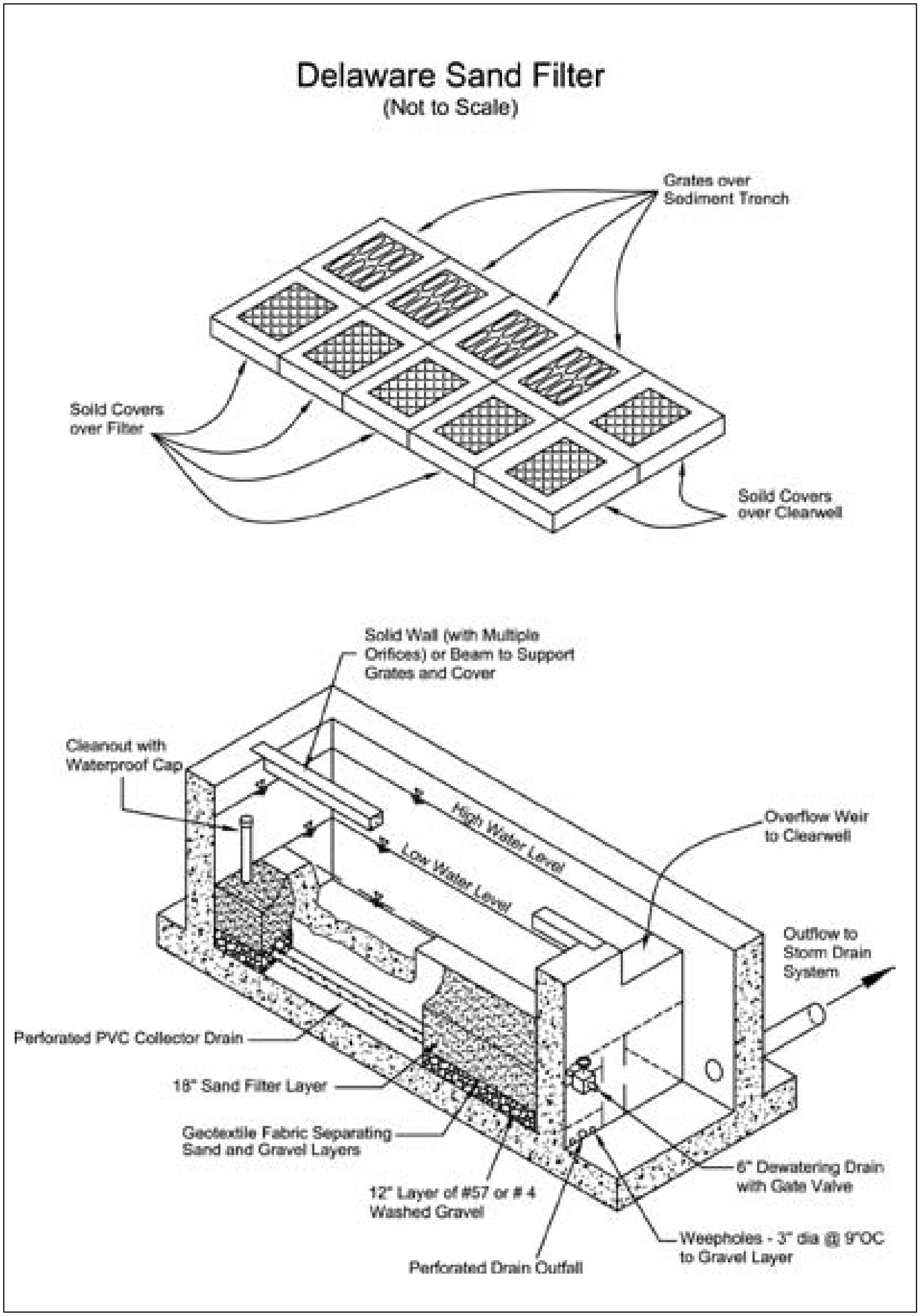

Figure 2.8.4 Delaware sand filter (City of Austin, TX. 1996).

4. Designing the Filtration Chamber

Once the WQv passes through the sedimentation chamber, it enters the filtration chamber where the stormwater passes through a sand filter for treatment. Surface area is the primary design parameter.

Filter Surface Area – The filter surface area is calculated using the following formula:

$$A_f = \frac{WQv * d_f}{k * (h + df) * t_f} \qquad \text{(Equation 6)}$$

Where:

A_f = Filter surface area ($feet^2$)
d_f = Sand bed depth (feet)
k = Coefficient of permeability for sand filter (feet/day)
= 3.5 ft/day for clean concrete sand (0.02" to 0.04" diameter) satisfying AASHTO M-6 or ASTM C-33
h = One-half the maximum allowable water depth over filter (feet)
t_f = Time required for runoff volume to pass through filter (days) or 1.67 days (40 hours) per Ohio EPA requirement

Filter Basin Inlet – Storm water must be spread uniformly across the surface of the filter media. To assure a uniform flow, stormwater must enter the filtration chamber using flow spreaders, weirs or multiple orifice openings, and the receiving end of the sand filter protected (splash pad, riprap, etc.) such that erosion of the sand media does not occur.

Sand Bed – The sand filter is constructed with at least 18 inches of sand overlying at least 6 inches of very coarse gravel (0.5 to 2 inch diameter). The sand and gravel media shall be separated by a permeable geotextile fabric meeting ASTM D-751 and ASTM D-1682, and the gravel layer shall be placed on drainage matting made of geotextile fabric meeting ASTM D-2434, ASTM D-1682, and ASTM D-1117. Figures 2.8.3, 2.8.4 and 2.8.5 present schematic representations of a standard sand beds.

Underdrain and Outlet Requirements – The underdrain piping consists of 4 inch diameter perforated PVC pipe (Schedule 40 PVC or greater), configured as a main collector pipe and, for Austin Sand Filters, two or more lateral branch pipes placed no more than 10 ft apart or 5 ft from the basin wall. Perforations should be 3/8 inch in diameter, with at least 6 holes per row and a maximum spacing between rows of perforations of no more than 6 inches. Each underdrain pipe should be wrapped in a geotextile fabric meeting ASTM D-751 and ASTM D-1682, with a minimum of 2 inches of gravel covering the top surface of the PVC pipe. Each pipe must have a minimum slope of 1% (1/8 inch per foot), and each individual underdrain pipe shall have a cleanout access location.

Weepholes – Weepholes between the filter chamber and the shell may be provided as a backup in case of underdrain pipe clogging. If used, weepholes should be 3 inches in diameter with a minimum spacing of 9 inches center to center. The openings on the filter side of the dividing wall should be covered to the width of the trench with 12-inch high plastic hardware cloth of 1/4-inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, number 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded 6 inches back under the bottom stone.

Maintenance of Sand Filters

Filter systems require frequent maintenance. Two design considerations that can help reduce maintenance problems are:

1. Providing access to the filtering system
2. Addressing confined space issues for underground systems

Where observation wells and grates are used, lifting rings or threaded sockets should be provided to allow for easy removal by lifting equipment. Access for the lifting equipment must be provided. Any long-term maintenance plan for sand and organic filters should include regular inspections for each of the following items:

Table 2.8.2 Typical maintenance activities.

Schedule	Activity
Monthly	Debris Removal Check for clogging and sediment accumulation on the filter surface – remove and place areas where clogging is occurring or likely If sediment chamber is more than half full of sediment, clean out Vegetation Control for surface systems (if applicable) • Mowing • Fertilization • Repair erosion
Semi-annual	Check for cracks and leakage Inspect, repair grates Replenish media
Annual and/or after major storms	Remove accumulated sediment from sedimentation chamber Rake and/or remove sediment from surface of filter bed Inspect spillways and repair if necessary

Delaware Sand Filter

(Not to Scale)

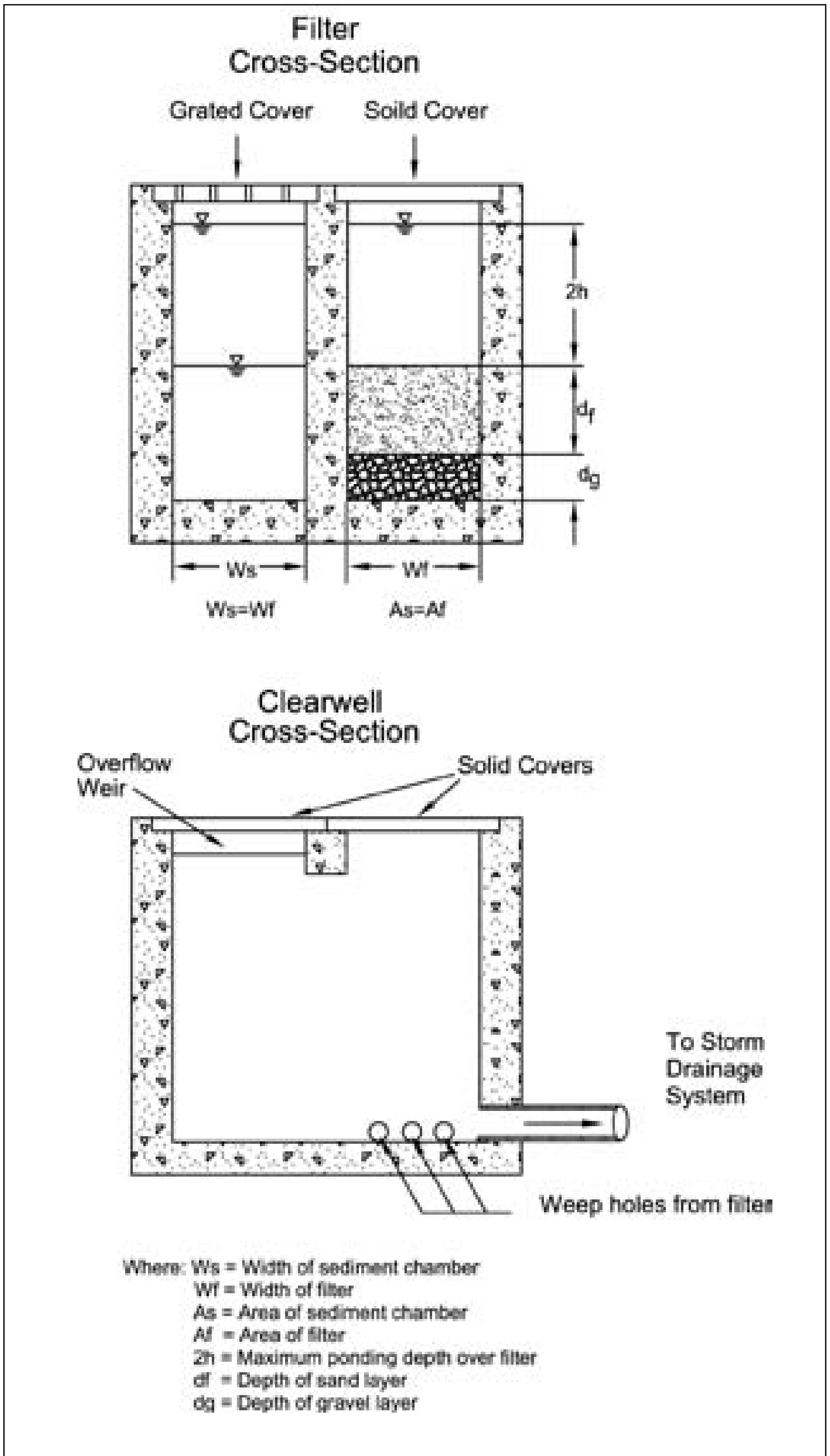

Figure 2.8.5 Delaware filter cross sections.

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