
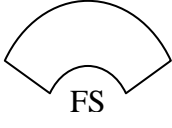

	Bowling Green, Kentucky Stormwater Best Management Practices (BMPs) Stormwater Pollution Treatment Practices (Structural)	PTP-01
PLANNING CONSIDERATIONS: Design Life: Life Acreage Needed: Minimal Estimated Unit Cost: Moderate Annual Maintenance: Moderate to High; Low (Bio-retention)		
	Target Pollutants; Pollutant Removal	
	Total Suspended Solids (TSS): 80% Nutrients – Total Phosphorous/Total Nitrogen: 50/25% Metals – Cadmium, Copper, Lead, and Zinc: 50% Pathogens – Coliform, Streptococci, E.Coli: 40%	
Description	<p>Filtration systems are structural water quality control devices that capture and temporarily store, treat, and release stormwater runoff. Filtration systems consist of two main components: a pretreatment basin and filtration chamber. The pretreatment basin removes floatable materials and heavy sediments, and helps reduce flow velocities. The filtration chamber traps and strains pollutants, and allows the microbial removal of pollutants. Target pollutants for filtrations systems include suspended solids, suspended particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and others. Filtration devices may also employ organic materials such as peat or compost combined with sand, and others add plantings and mulch to the surface layer. This may allow additional pollutant removal via bacterial decomposition and vegetation uptake of nutrients. The two main structures of filtration systems (the pretreatment basin and filtration chamber) may include or be enhanced by the following components:</p> <ul style="list-style-type: none"> ➤ Grass buffer strips ➤ Ponding area ➤ Surface of mulch and plantings ➤ Sand bed ➤ Organic layer ➤ Plant material ➤ Exfiltration zone or collection system to return stormwater to a conveyance system <p>Filtration systems documented in this fact sheet include:</p> <ul style="list-style-type: none"> ➤ Surface sand filters ➤ Underground sand filters ➤ Perimeter sand filters ➤ Organic sand filters ➤ Pocket sand filters ➤ Bioretention systems (shown above) 	

Suitable Applications

Filtration systems are often used to manage stormwater runoff from urban areas where space is limited, and can be applied to areas where retrofit is needed, and are typically suitable in the following applications:

- Small drainage areas (2 to 10 acres maximum)
- Typically requires 2 to 6 feet of head
- Impervious area runoff
- Retrofit applications

Filtration systems should only be applied to stabilized drainage areas, as heavy sediment loads from construction areas will clog and disable the filter. Likewise, they should not be used in areas where stormwater has potential for high silt or clay content, and areas with a high water table. As a guide, sites implementing filtration systems should have over 50% impervious cover in the drainage area.

Filtration systems should typically be designed for off-line use to capture the first flush of runoff. A diversion structure such as a flow splitter or weir may be necessary to separate and route the first flush to the filtration system for water quality control, and route the remaining stormwater to a water quantity control device downstream. Filtration systems are most effective when turbulent flow is minimized and the flow is spread uniformly across the filter media.

Approach**➤ Surface Sand Filters**

A surface sand filter is intended to accommodate treatment of up to approximately 10 acres of drainage area. Designs vary widely; surface sand filters can be constructed from riprap, an excavation with earthen embankments, or concrete blocks. These types of sand filters should not be used in residential applications.

➤ Underground Sand Filters

An underground sand filter is intended for small drainage areas up to approximately 2 acres. These systems are constructed below ground and can be applied in ultra urban areas where space is limited, such as parking lots. The design consists of a chambered concrete vault, with limited access via manholes or grates.

➤ Perimeter sand filters

A perimeter sand filter is intended for small drainage areas up to approximately 2 acres. Perimeter sand filters consume a small amount of surface space, and are ideal for small impervious areas, particularly hot spot applications. The below-ground trench-style design of a perimeter sand filter does not consume surface space, and is ideal for the perimeter of parking lots.

➤ Organic sand filters

An organic sand filter is an above ground filter system intended for drainage areas up to approximately 5 acres. This system functions similarly to a surface sand filter, but uses an organic filter medium.

➤ Pocket sand filters

A pocket sand filter is intended to accommodate treatment of up to approximately 5 acres of drainage area. Its simplified design includes pretreatment by a flow spreader, grass filter strip, and plunge pool, followed by a shallow basin containing the sand filter layer. Pea gravel windows allow runoff into the filter if the surface becomes clogged.

**Approach
(cont.)****➤ Bioretention systems**

A bioretention system is intended to accommodate treatment of up to approximately 5 acres of drainage area. They are designed for intermittent flow such that between rainfall events, the system is fully drained and re-aerated. These systems should not be used on sites with a continuous flow from surface water, groundwater, sump pumps, or other sources.

**Installation
Procedures**

In general, the following installation procedures should be followed for filtration systems:

- Site slope should be less than 6% across the filter location
- The minimum head (or elevation difference on the site from the point of inflow to point of outflow) required is:
 - 5 feet for surface sand filters
 - 2-3 feet for perimeter sand filters
- Allow at least 2 feet between the bottom of the sand filter to the high water table elevation
- Variable soils can be used, but Group A soils generally require exfiltration (surface sand filter earthen structures)
- Hotspot runoff requires an impermeable liner to protect groundwater
- In karst areas, an impermeable membrane should be used to seal the bottom of an earthen surface sand filter, or alternatively, a watertight filtration system structure may be used

Maintenance

Maintenance access should be provided for appropriate equipment, vehicles, and personnel. Filtration systems installed below grade should have access grates available to inspect and maintain the filter bed. For bioretention systems, additional landscaping and maintenance considerations are listed in the Bioretention section of this fact sheet.

Monthly

- Remove trash or debris
- Inspect the filter for clogging (sand filters – rake the first inch of sand)

Quarterly/After Major Storm Events

- Monitor water level in sand filter chamber (underground sand filter)

Annually

- Remove sediment as necessary
- Repair or replace any damaged structural parts
- Stabilize any eroded areas
- Bioretention systems should be re-mulched annually in areas where mulch is depleted.

Activity: Filtration Systems

PTP-01

**Maintenance
(cont.)****As Needed**

- Ponding of water on the surface for more than 72 hours indicates that the filtering capacity is substantially diminished. Replace sand filter media or filter fabric by removing the top few inches of discolored material, and adding fresh material. The removed sediment should be disposed of properly, such as in a landfill.
- Silt or sediment should be removed from the filter bed at the accumulation of approximately one inch.
- Clean out sedimentation chamber when sediment depth reaches 12 inches (underground sand filter)
- Remove accumulated oil and floatables from the sedimentation chamber (underground sand filter)
- For clogged or partially clogged sand beds, remove the first 3 inches of sand from the surface, till, or cultivate the bed, and replace with fresh sand meeting the appropriate design specifications
- Properly dispose of any material generated during maintenance activities.
- Organic sand filters or surface filters with a grass cover should be mowed a minimum of 3 times per growing season, with a maximum grass height less than 12 inches.

**Inspection
Checklist****Monthly**

- Contributing area, facility, inlets, and outlets are clear of debris
- Contributing area is stabilized and mowed, with clippings bagged or removed
- Filter surface is not clogging – also inspect after moderate/major storm events
- Activities in the drainage area minimize oil/grease and sediment entering the system
- Permanent water level is not present (for perimeter sand filter)
- For filtration systems utilizing a permanent pool, chamber or vault does not leak, and normal pool water surface elevation is retained

Annually

- Filter bed is clean of sediment, and the sediment chamber contains no more than 6 inches or 50% depth of sediment, whichever is less (or 12 inches for underground sand filters)
- No evidence of deterioration, spalling, or cracking is present on concrete
- Inspect grates, where applicable
- Inlets, outlets, and overflow spillways or diversion structures show no evidence of erosion or deterioration
- Flow is not bypassing the filtration system
- No noticeable odors are detected outside of the facility

As Needed

- Filtration system (sand bed, filter fabric, etc.) is not clogged or partially clogged

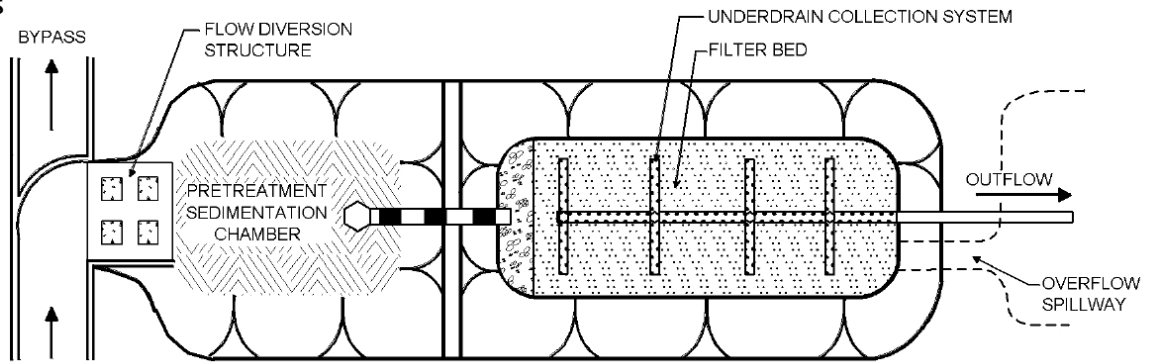
**Surface Sand
Filters****Surface Sand Filter**

Showing the sedimentation (foreground) and the filter bed (background)
Source, *Stormwater Managers Resource Center*, www.stormwatercenter.net

Surface sand filters are open-air structures constructed level with the grade primarily to serve as off-line water quality systems. The two main system components include a pretreatment sediment forebay and filter bed chamber. Flow is routed to the sediment forebay where settlement of heavier sediment particles occurs. A perforated standpipe is used to move pretreated runoff to the filtration chamber. The runoff passes through the filter bed and is collected by the perforated pipe and gravel underdrain system.

Drainage areas can range up to 10 acres for surface sand filters to effectively remove pollutants. Designs vary from riprap to an excavation with earthen embankments to a concrete or block structure. See Figures PTP-01-01 and PTP-01-02 for the typical surface sand filter schematics. Surface Sand Filters should not be used for residential applications.

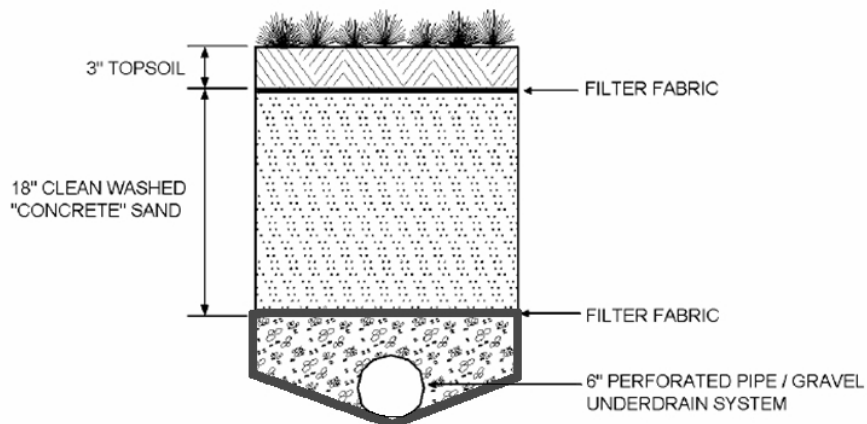
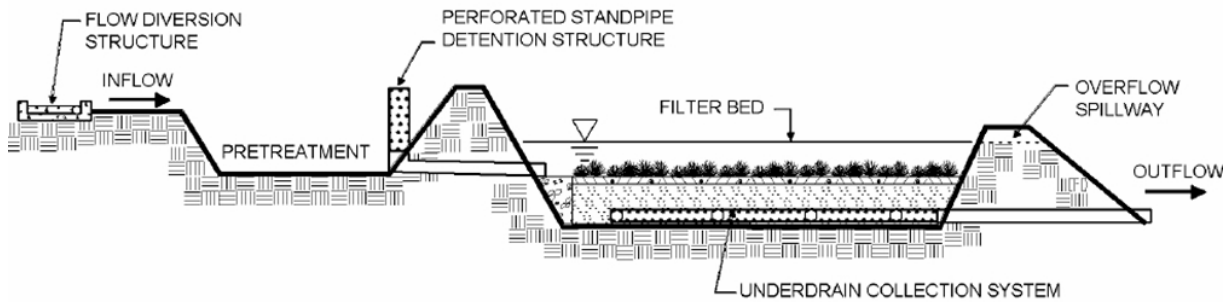
Surface Sand Filters



PLAN VIEW

Figure PTP-01-01

Source, Georgia Stormwater Management Manual



TYPICAL SECTION

PROFILE

Figure PTP-01-02

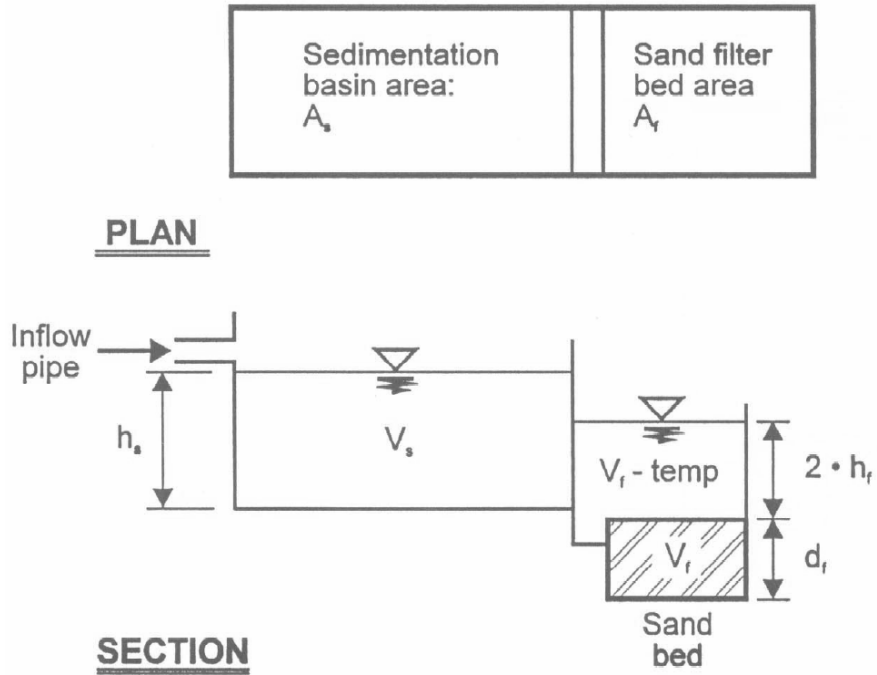
Source, Georgia Stormwater Management Manual

Surface Sand Filters (cont.)

Design Criteria

- Contributing drainage area should be less than 10 acres
- Typically requires 2-6 feet of head
- Use in areas with urban land uses and high percentage of impervious area (greater than 50% impervious)
- Disturbed areas draining to the sand filter should be identified and stabilized as soon as possible as they may clog the filter bed
- Surface sand filters should be configured off-line, so that flows greater than the water quality volume (WQ_v) capacity can be diverted downstream
- Flow should not be continuous, and the filter should be designed to drain completely and reaerate between rainfall events
- The filtration system must be designed to temporarily hold a capacity equal to or greater than 75% of the water quality volume (WQ_v) of the system prior to filtration. Figure PTP-01-03 shows the distribution of treatment volume (0.75 WQ_v).
- The sedimentation chamber must have a capacity to hold 25% of the water quality volume (WQ_v), and have a ratio of 2:1 (H:V)
- Inlet and outlet structures should be constructed at opposite ends of the sedimentation chamber
- Use Darcy's law to size the filter bed area, using a coefficient of permeability, k, of 3.5 ft/day for sand. Typically, filter beds should drain within 40 hours.
- The filter media should be placed around the underdrain system, and should include an 18-inch layer of clean, washed, medium sand (ASTM C-33 concrete sand). A layer of permeable filter fabric should be placed both above and below the sand layer to prevent clogging of the sand filter and underdrain system.
- The surface sand filter should incorporate a 6-inch perforated PVC pipe (AASHTO M 252) underdrain in a gravel layer. Requirements for the underdrain include:
 - A minimum grade of 1/8-inch per foot (1% slope)
 - Holes spaced approximately 6 inches apart with diameters of 3/8-inch
 - Gravel specifications are clean, washed aggregate at a diameter no greater than 3.5 inches and no less than 1.5 inches. Voids should make up approximately 40% of space. Do not use gravel that has been contaminated with soil.
- The outer structure of the surface sand filter can vary. Concrete or earthen embankments are common. If earthen embankments are used, a permeable filter fabric should be used to line the bottom and side slopes of the earthen walls before installing the underdrain and other filtration system components.

Surface Sand Filters (cont.)



- V_s = Sedimentation basin volume
- V_r = Volume of voids in the filter bed
- V_{r-temp} = Temporary volume stored above the filter bed
- A_s = Surface area of the sedimentation basin
- A_r = Surface area of the filter media
- h_s = Depth of water in the sedimentation basin
- h_r = Average depth of water above the filter media
- d_r = Depth of the filter media

Figure PTP-01-03

Source, Georgia Stormwater Management Manual

Perimeter Sand Filter



Perimeter Sand Filter

Source, Stormwater Managers Resource Center, www.stormwatercenter.net



Perimeter Sand Filter

Showing pre-cast concrete form with 2 chambers

Source, Stormwater Managers Resource Center, www.stormwatercenter.net

Perimeter sand filters are constructed just below grade with two enclosed parallel chambers. Typically, perimeter sand filters are installed along the perimeter of a parking lot for off-line treatment. Runoff from impervious area enters the sedimentation chamber via an inlet grate and spills through a weir and into the filtration chamber. The sand bed filters runoff, and runoff is then collected by the perforated pipe and gravel underdrain system. See Figures PTP-01-04 and PTP-01-05 for typical perimeter sand filter schematics.

Perimeter Sand Filter (cont.)

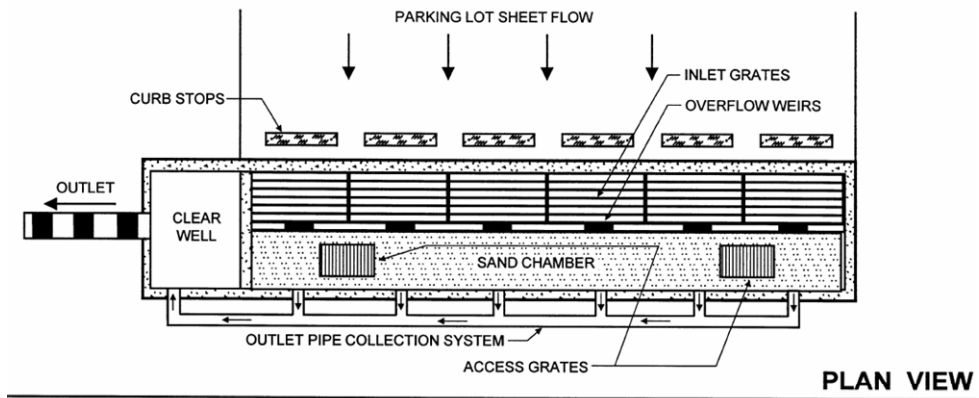
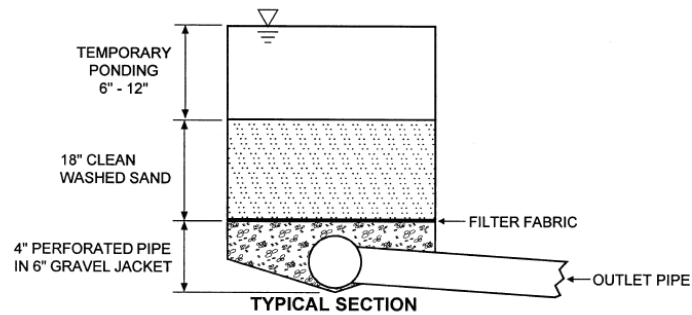
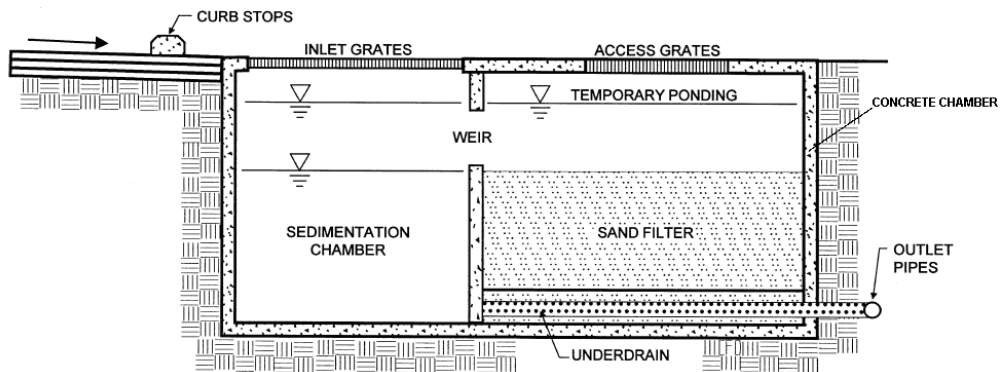


Figure PTP-01-04
Source, Georgia Stormwater Management Manual



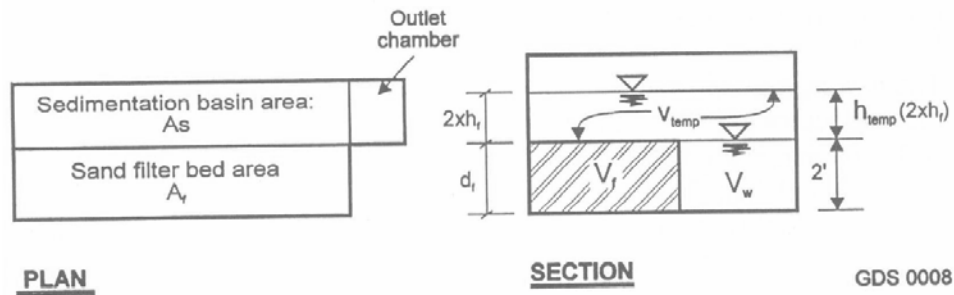
PROFILE

Figure PTP-01-05
Source, Georgia Stormwater Management Manual

Perimeter Sand Filter (cont.)

Design Criteria

- Contributing drainage area should be less than 2 acres
- Use in areas with urban land uses and high percentage of impervious area (greater than 50% impervious)
- Disturbed areas draining to the sand filter should be identified and stabilized as soon as possible as they may clog the filter bed
- Perimeter sand filters should be configured off-line, so that flows greater than the water quality volume (WQ_v) capacity can be diverted to an overflow conveyance
- Construct perimeter sand filters along the boundary, or perimeter, of an impervious area, i.e., a parking lot
- Flow should not be continuous, and the filter should be designed to drain completely and reaerate between rainfall events
- The filtration system must be designed to temporarily hold a capacity equal to or greater than 75% of the water quality volume (WQ_v) of the system prior to filtration. Figure PTP-01-06 shows the distribution of treatment volume ($0.75 WQ_v$).
- The sedimentation chamber should be sized to accommodate at least 50% of the calculated WQ_v .
- Use Darcy's law to size the filter bed area, using a coefficient of permeability, k , of 3.5 ft/day for sand. Typically, filter beds should drain within 40 hours.
- The filter media should be placed above the underdrain system, and should include a 12- to 18-inch layer of clean, washed, medium sand (ASTM C-33 concrete sand). See Figure PTP-01-07 for a typical perimeter sand filter cross section of media placement.



- V_w = Wet pool volume of the sedimentation basin
- V_f = Volume of voids in the filter bed
- V_{temp} = Temporary volume stored above the filter bed
- A_s = Surface area of the sedimentation basin
- A_f = Surface area of the filter media
- h_s = Depth of water in the sedimentation basin
- h_f = Average depth of water above the filter media ($\frac{1}{2} h_{temp}$)
- d_f = Depth of the filter media

Figure PTP-01-06

Source, Georgia Stormwater Management Manual

Perimeter Sand Filter (cont.) Design Criteria (cont.)

- The perimeter sand filter should incorporate a 4-inch perforated PVC pipe (AASHTO M 252) underdrain in a gravel layer. Requirements for the underdrain include:
 - A minimum grade of $\frac{1}{8}$ -inch per foot (1% slope)
 - Holes spaced approximately 6 inches apart with diameters of $\frac{3}{8}$ -inch
 - A permeable filter fabric should be placed between the gravel layer and the filter bed material.
 - Gravel specifications are clean, washed aggregate at a diameter no greater than 3.5 inches and no less than 1.5 inches. Voids should make up approximately 40% of space. Do not use gravel that has been contaminated with soil.

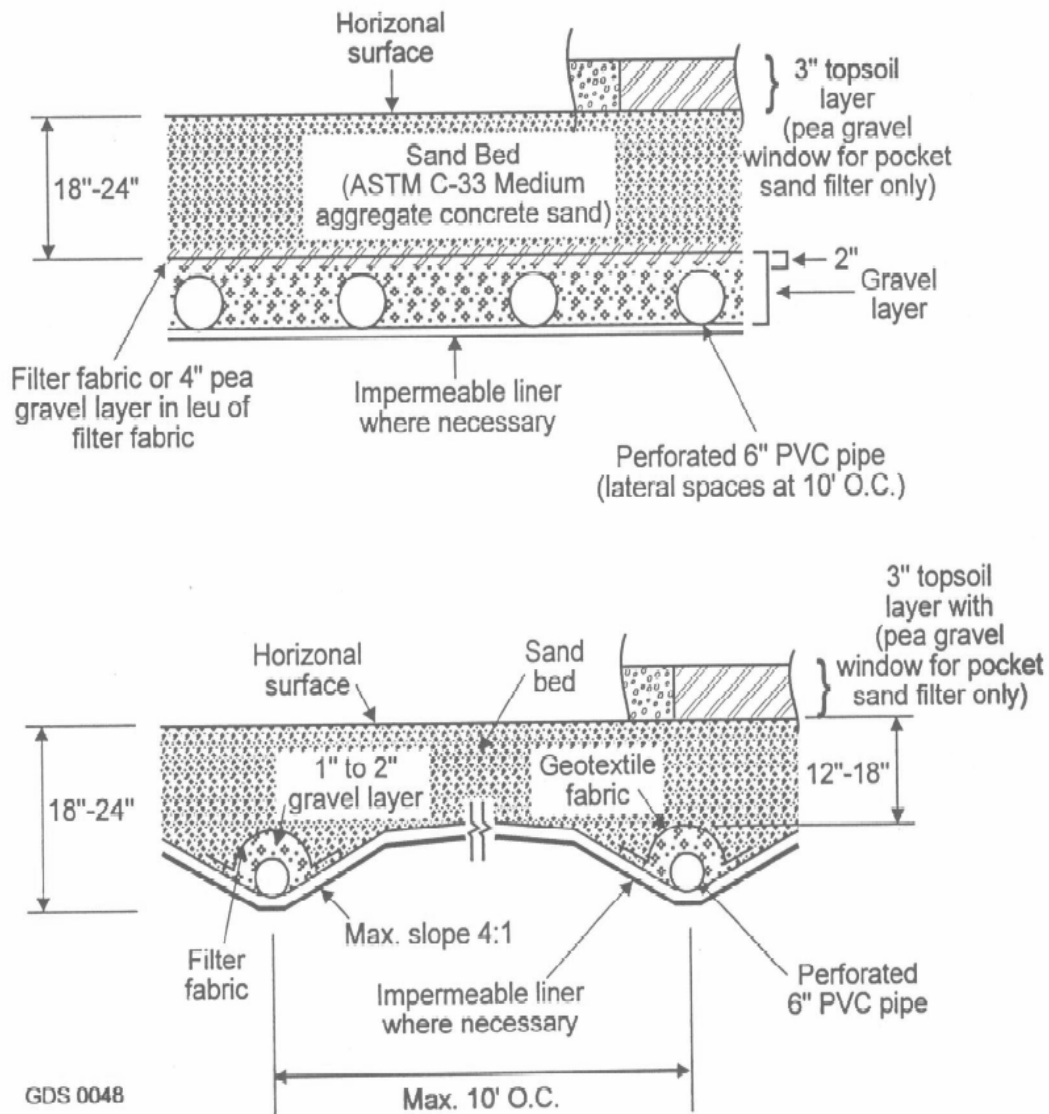


Figure PTP-01-07

Source, Georgia Stormwater Management Manual

Underground
Sand Filter

Underground Sand Filter

Source, University of Virginia Stormwater and Watershed Group,

<http://www.people.virginia.edu/~engstorm>

Underground sand filters are designed for applications with extreme space constraints or high density areas where a surface sand filter cannot be constructed due to space limitations. They are typically used as on-line systems for impervious areas of 1 acre or less. An underground sand filter should not be designed to treat a drainage area greater than 5 acres.

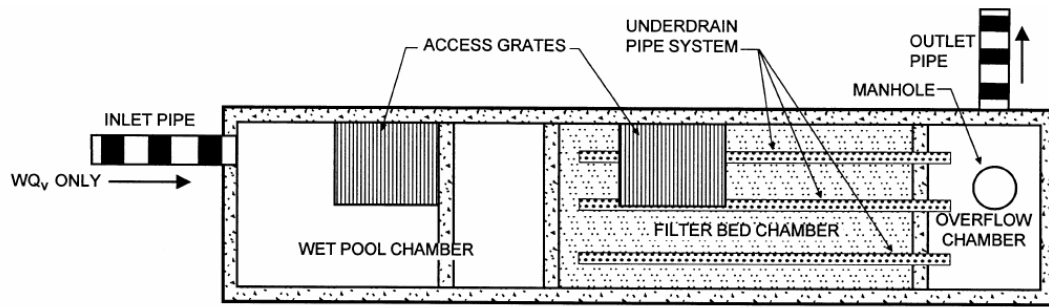
This type of filtration system utilizes a three-chamber vault, where the first two chambers temporarily store and treat runoff, and the third chamber collects filtered runoff. This first chamber is a sedimentation chamber with a wet pool that stores and pretreats runoff. This is connected to the second chamber, the sand filter, by a submerged wall which provides an obstruction for oil and floatables. The filter bed should be approximately 18 to 24 inches deep. Permeable geotextiles or a gravel screen can be used to prevent clogging of the sand bed. The second chamber also contains a perforated drain pipe to collect the filtered runoff. This underdrain system transfers the filtered runoff to the third chamber, where runoff is collected. An overflow weir is necessary to divert excess flow through the system. See Figures PTP-01-08 and PTP-01-09 for schematics of a typical underground sand filter.

Design Criteria

- Contributing drainage area should be less than 5 acres. Underground sand filters are commonly used for impervious areas of approximately 1 acre.
- Typically constructed as on-line systems, but can be off-line systems. Off-line construction omits the overflow structure between the second and third chambers.
- The minimum wet pool volume required in the sedimentation chamber should be calculated using the following equation:

$$V_w = A_s * 3 \text{ feet minimum}$$

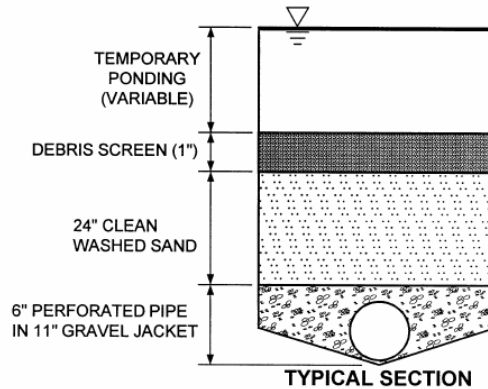
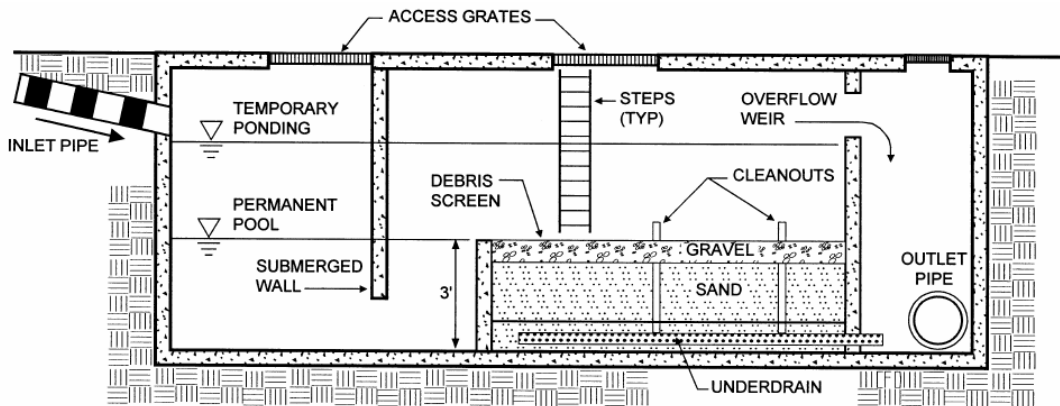
Please reference perimeter sand filter design criteria for remaining requirements of filter sizing and system design.



PLAN VIEW

Figure PTP-01-08

Source, Georgia Stormwater Management Manual

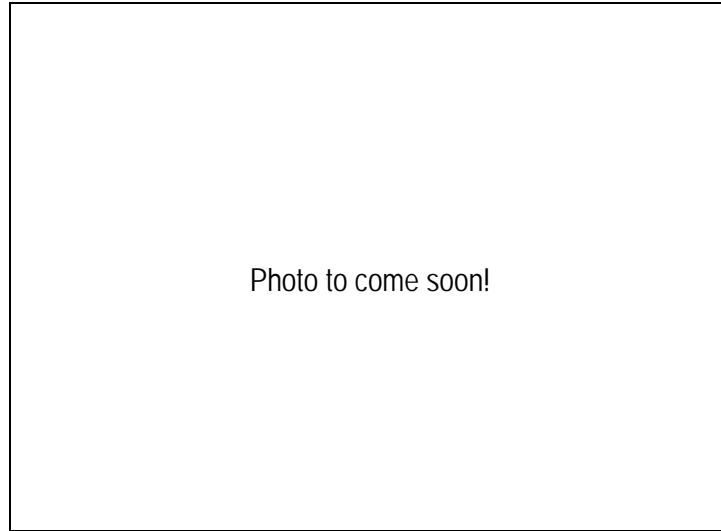


TYPICAL SECTION

PROFILE

Figure PTP-01-09

Source, Georgia Stormwater Management Manual

Organic Sand Filter**Organic Sand Filter**

The organic sand filter is a variation of the surface sand filter, utilizing organic materials in the filter media. Organic materials typically used are leaf compost or a peat/sand mixture. These materials enhance pollutant removal capabilities, absorbing soluble metals, hydrocarbons, and other organic chemicals.

The organic sand filter system is constructed with a layer of organic material placed above permeable filter fabric and the gravel and perforated underdrain system. The filter bed should be separated from soil layer by an impermeable layer such as a concrete structure or impermeable liner to prevent groundwater contamination.

Organic filters, like surface sand filters, are typically used in highly urban areas, most notably where enhanced pollutant removal is needed. Maintenance for organic sand filters is generally more tedious than surface sand filters due to higher propensity to clog and degradation of the organic filter media. Unlike surface sand filters, organic sand filters require basin sizing for the water quality volume to be configured to provide a minimum head to promote permeability rather than the use of known permeability factors. See Figures PTP-01-10 and PTP-01-11 for schematics of a typical organic sand filter.

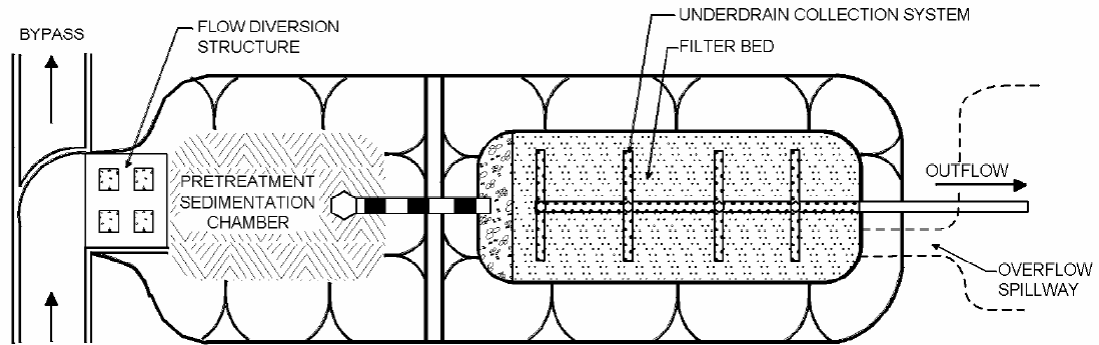
Design Criteria

- Minimum head required is 5 to 8 feet (the difference in elevation between the point of inflow to the point of outflow). Compared to surface sand filters, organic sand filters have a higher head requirement.
- Drainage area should be designed to serve a maximum of 5 acres
- Organic materials can vary, but typical filter media composition are:
 - Peat/sand filter – 18-inch 50/50 ratio of peat/sand mix over a 6-inch layer of sand. Can also be covered by a layer of topsoil and vegetation
 - Compost filter – an 18-inch compost layer

Organic Sand Filter

- Peat types used impact the pollutant removal efficiency of the system. Fibric peat, where undecomposed fibrous organic material is easily seen within the peat mixture, is preferred. Hemic peat, which contains more decomposed material, may also be used. Sapric peat, which is almost fully decomposed matter, should not be used, and is not suited for this application.
- Organic sand filters remove dissolved pollutants more effectively than other sand filters. Pollutant removal capability is listed below:
 - TSS; 80%
 - Nutrients – Total Phosphorous/Total Nitrogen; 60/40%
 - Fecal Coliform; 50%
 - Heavy Metals; 75%
- Organic sand filters are generally constructed as off-line systems, diverting the water quality volume (WQ_v) into the filtration system, and the remaining volume downstream.
- A gravel underdrain system should be utilized. Further specifications are shown in the Surface Sand Filter design criteria.

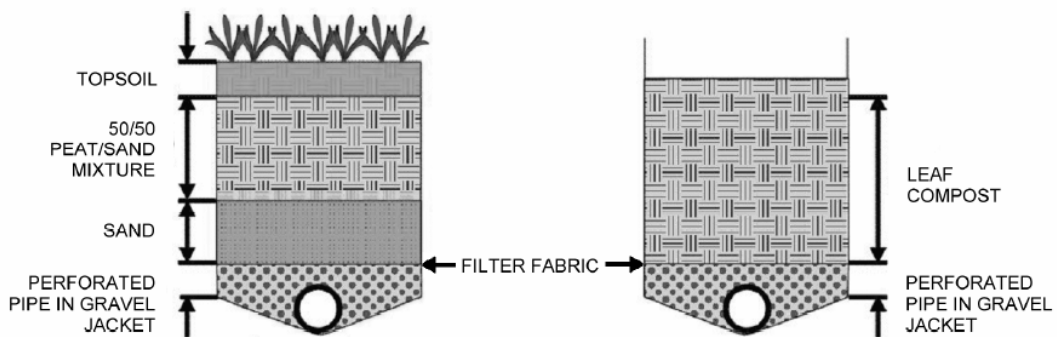
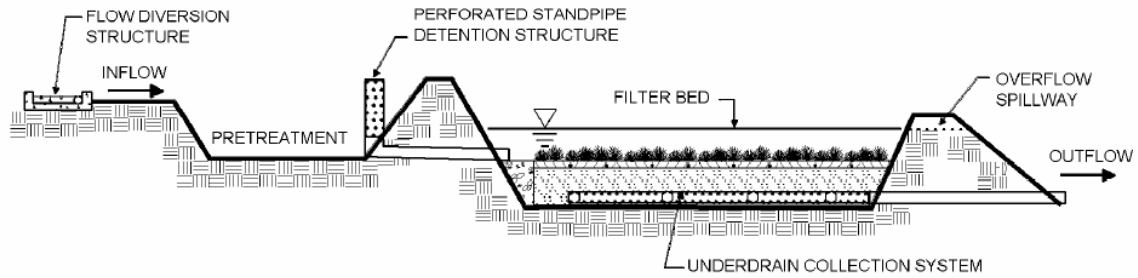
Please reference the design criteria from the Surface Sand Filter for detailed sizing and design requirements.



PLAN VIEW

Figure PTP-01-10

Source, Georgia Stormwater Management Manual



TYPICAL SECTIONS

PROFILE

Figure PTP-01-11

Source, Georgia Stormwater Management Manual

Pocket Sand Filter**Pocket Sand Filter**

Shown adjacent to a small recreational area

Source, Stormwater Managers Resource Center, www.stormwatercenter.net

Pocket sand filters utilize a more simplified design, allowing them to be used on smaller sites. Runoff is typically diverted into the filtration system via a manhole and pipe where the runoff is pretreated by a concrete flow spreader, a grass filter strip, and a plunge pool. The filter bed is constructed by a shallow excavation where the sand layer is placed. On the surface, a soil layer with grasses is placed above the sand layer. A pea gravel "window" should be constructed, as well as a cleanout/observation well to facilitate maintenance and inspection of clogging.

Design Criteria

- Pocket sand filters are off-line systems, constructed with a diversion structure to separate the water quality volume (WQ_v) and route it to the filter, while directing the remaining flow downstream.
- Drainage area should be designed to serve a maximum of 5 acres
- A gravel layer with an underdrain system should be constructed to facilitate drainage.
- A permeable filter fabric should be placed between the filter bed material and soil layer.
- See Figure PTP-01-12 and PTP-01-13 for typical detail

Pocket Sand Filter (cont.)

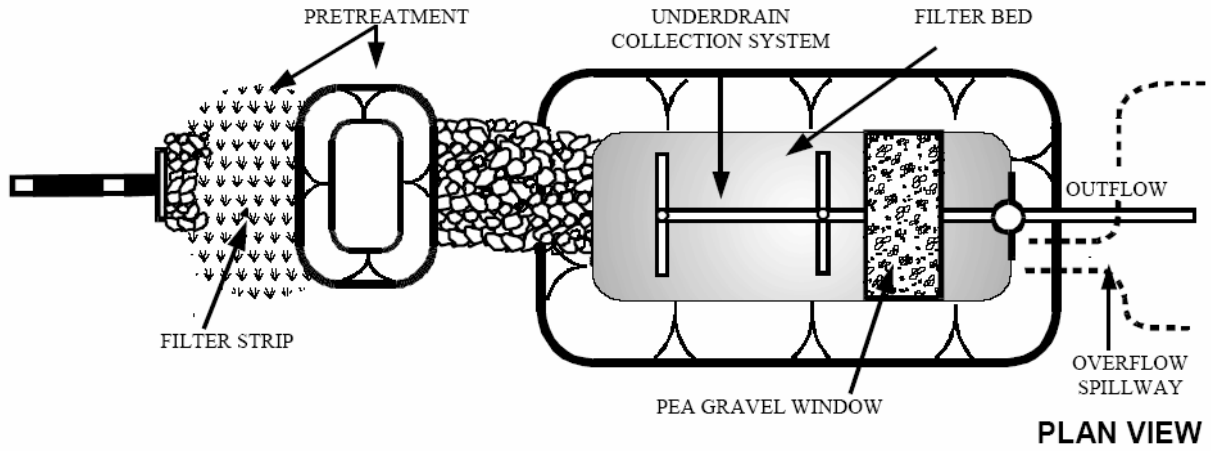


Figure PTP-01-12
Source, Maryland Stormwater Design Manual

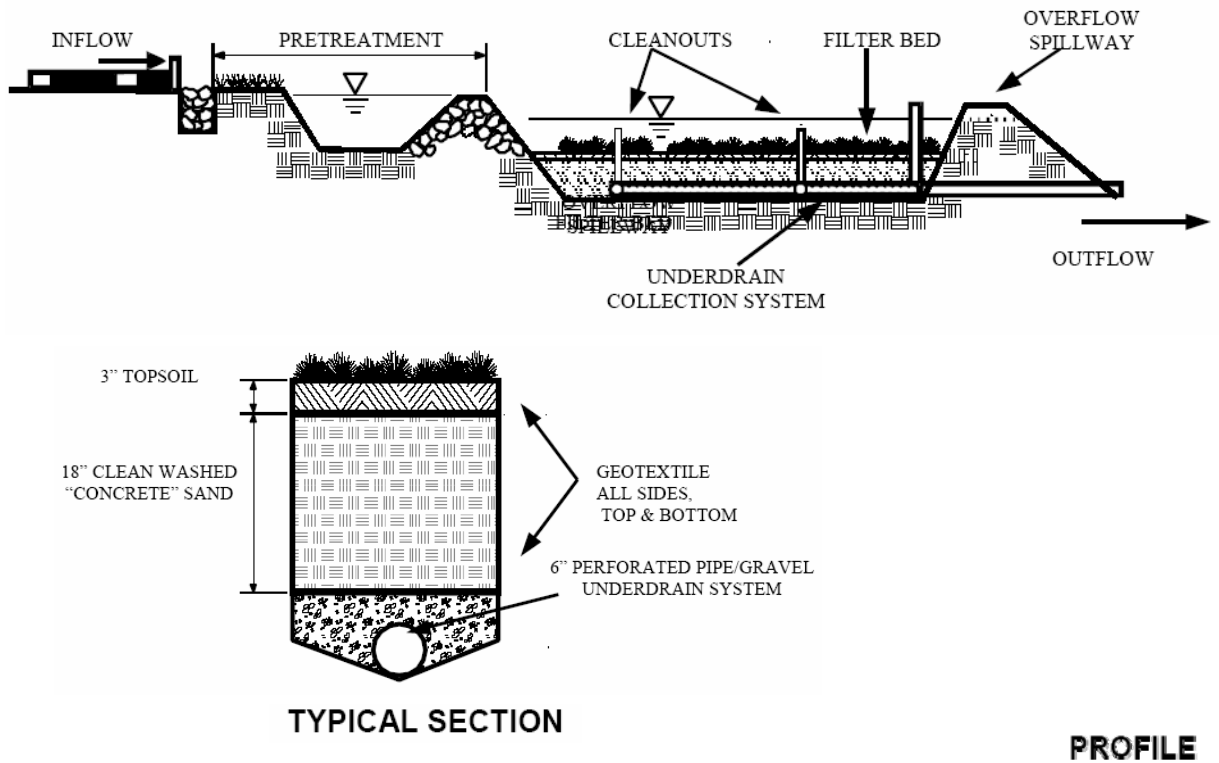


Figure PTP-01-13
Source, Maryland Stormwater Design Manual

**Bioretention
Systems****Bioretention System**

Source, Maryland Department of Natural Resources, www.dnr.state.md.us

Bioretention practices are water quality control devices that capture, temporarily store, treat, and release stormwater runoff. A properly designed area will replicate a small, dense forest floor.

Bioretention is typically used for drainage areas from 1 to 5 acres. Such suitable applications include, but are not limited to:

- off-line facilities adjacent to parking lots
- along road drainage swales
- within larger landscaped pervious areas
- landscaped islands in impervious or high-density environments (i.e. parking lots)
- retrofitting exiting parking lot islands/off-line facilities

Biofiltration systems should **not** be placed in areas with mature trees, sites with slopes greater than 5:1 (H:V), areas that experience continuous or frequent flows, or locations with unstable soil. When considering this control for a karst area, use a collection system to carry flow to another conveyance element.

Design Criteria

- The size of the drainage area typically dictates the size of the bioretention practice. These areas should be limited to a maximum contributing drainage area of five (5) acres. One-half to two acre areas are preferred. Multiple bioretention areas may be required for larger drainage areas.
- Bioretention areas should be at least 10-feet wide and 15 feet long.
- The area should be designed such that it is drained within 48 hours
- The maximum recommended ponding depth is 6-inches.
- See Figure PTP-01-14 and PTP-01-15 for typical detail

Bioretention Systems (cont.)

Design Components

- **Grass Buffer Strip** - Reduces velocity of runoff and filters particles in the stormwater.
- **Sand Bed** – Reduces runoff velocities and spreads over perimeter of basin. The sand bed should be 12 to 18 inches thick, composed of clean sand containing less than 15% fines to adequately filter water.
- **Ponding Area or Pretreatment Basin** – Runoff is detained to settle particulates suspended in stormwater.
- **Organic Layer** – A layer of mulch or another organic cover filters pollutants out of the stormwater and protects soil from eroding. Layer can also sustain a nutrient rich environment with microbes that can break down petroleum-based contaminants. The layer should contain approximately 2 to 3 inches of mulch or other organic cover such as fine shredded hardwood mulch or shredded hardwood chips.
- **Planting Soil Layer** – This layer, which should be at least 4 feet in depth, is used to provide nutrients and store water for the areas plantings. Clay material can absorb heavy metals, hydrocarbons and other pollutants. However, clay should be mixed with sand or topsoil such that the planting soil layer has a clay content ranging from 10 to 25%. Additionally, the layer should have an infiltration rate greater than 0.27 inches per hour and a pH ranging from 5.5 to 6.5. Organic content in the soil should be between 1.5 and 3% with a maximum concentration of soluble salts of 500 parts per million.
- **Plant Material** – Consider surrounding environment, climate, maintenance requirements and types of pollutants that the plants must withstand and treat, while maintaining a positive aesthetic enhancement.
- **Underdrain/Collection System** – Necessary to collect and send flows to a stormwater conveyance system. This system should contain a 6-inch perforated PVC pipe surrounded by an 8-inch thick gravel layer. A permeable filter fabric should be placed between the gravel layer and the planting soil layer. Pipe perforations should be sized approximately 3/8 inch in diameter, spaced at 6-inch intervals on center. At a minimum, 4 holes per row should be used, and pipe grade placement should be at least 0.5%. Pipes should be spaced no more than 10 feet on center.

Landscaping & Maintenance

- Consult with a landscaping professional to select vegetation which fits into the landscape, is appropriate for the hardiness zone, and can tolerate conditions found in bioretention areas (short durations of 6 inch ponding water)
- A dense and vigorous vegetative cover should be established over the contributing pervious drainage areas **BEFORE** runoff can be accepted into the facility.
- The bioretention area should be vegetated to resemble a terrestrial forest ecosystem, with a mature tree canopy, sub canopy of under story trees, scrub layer, and herbaceous ground cover. Three species each of both trees and scrubs are recommended to be planted. Other typical landscape plants can be used, such as day lilies, landscape grasses, or other native plantings.
- The tree-to-shrub ratio should be 2:1 to 3:1. On average, the trees should be spaced 8 feet apart. Plants should be placed at regular intervals to replicate a natural forest. Woody vegetation should not be specified at inflow locations.
- After the trees and shrubs are established, the ground cover and mulch should be established.

Bioretention Systems (cont.)

- Choose plants based on factors such as resistance to drought and inundation, cost aesthetics, maintenance, etc. Planting recommendations for bioretention facilities are as follows:
 - Native plant species should be specified over non-native species.
 - Vegetation should be selected based on a specified zone of hydric tolerance.
- A selection of trees with an under story of shrubs and herbaceous materials should be provided.
- Pruning and weeding to maintain appearance.
- Mulch replacement when erosion is evident.
- Remove trash and debris.

As needed

- Inspect inflow points for clogging (off-line systems). Remove any sediment.
- Inspect filter strip/grass channel for erosion or gulying. Re-seed or sod as necessary.

Trees and shrubs should be inspected to evaluate their health and remove any dead or severely diseased vegetation.

Semi-annually

- The planting soils should be tested for pH to establish acidic levels. If the pH is below 5.2, limestone should be applied. If the pH is above 7.0 to 8.0, then iron sulfate plus sulfur can be added to reduce the pH.

Annually

- Replace mulch over the entire area.
- Replace pea gravel diaphragm if warranted every 2 to 3 years.

Cost Considerations

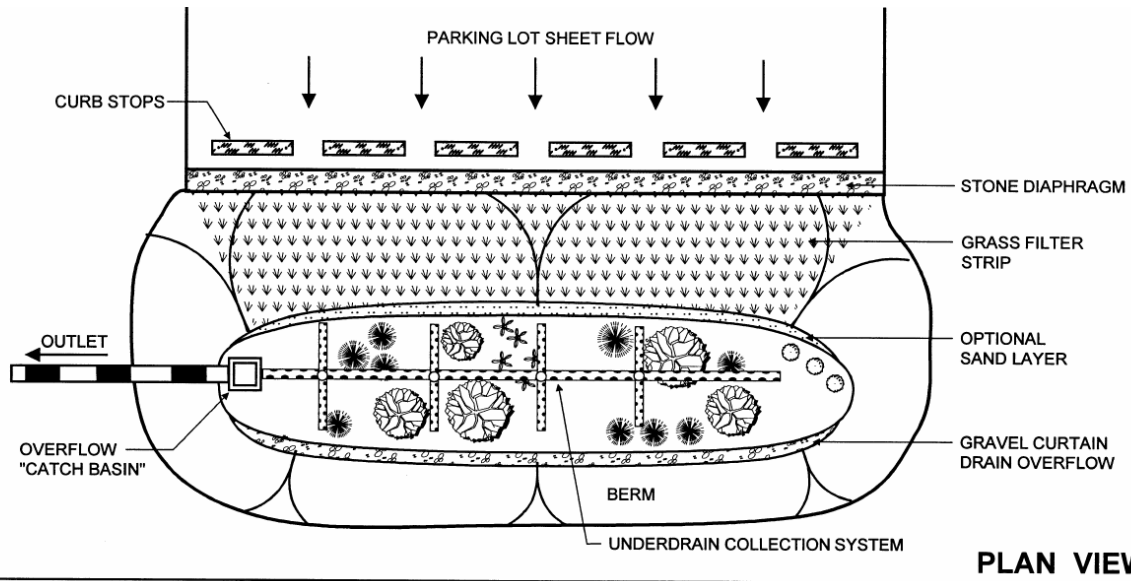
Bioretention areas can be expensive. However, costs can be offset if the bioretention area meets multiple uses, such as open space requirements or landscaping requirements. The following equation has been used to calculate and approximate cost for this practice.

$$C = 7.30 V^{0.99}$$

Where,

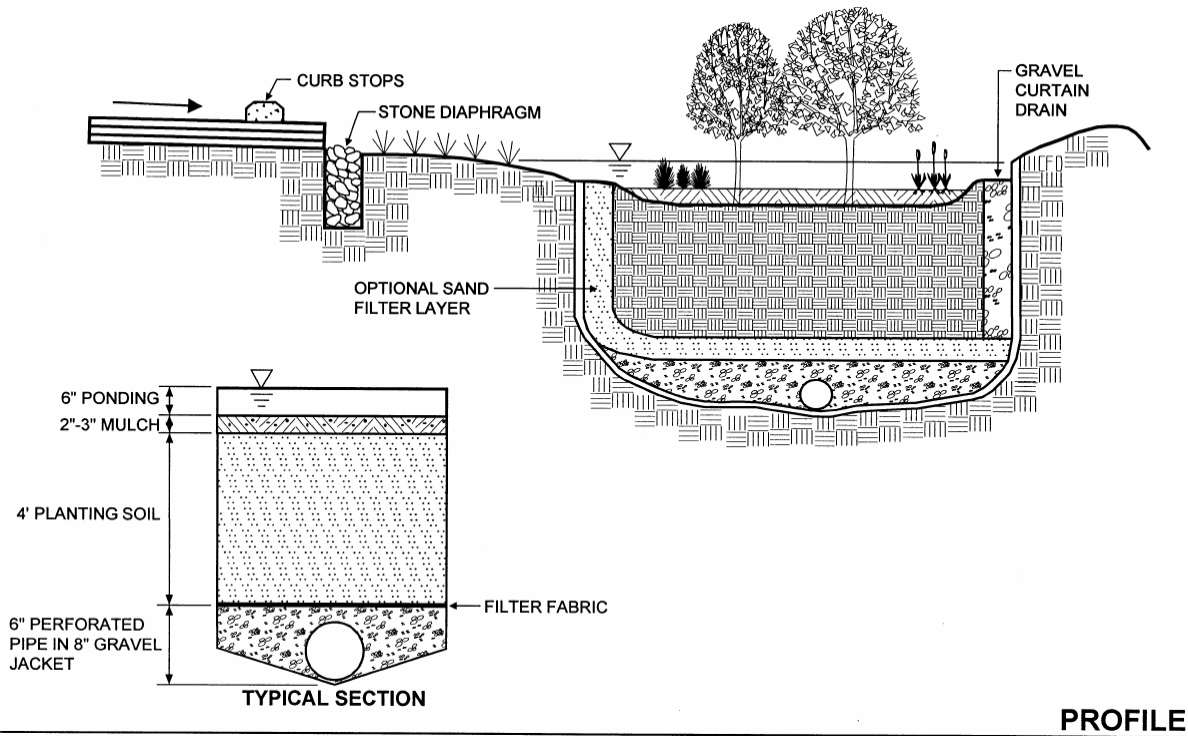
C = Construction, design, and permitting cost (\$)

V = Volume of water treated by the practice (ft³)



PLAN VIEW

Figure PTP-01-14
 Typical Bioretention Area
 (Source, Georgia Stormwater Management Manual)



PROFILE

Figure PTP-01-15
 Typical Bioretention Area
 (Source, Georgia Stormwater Management Manual)

**Surface/
Perimeter Sand
Filter Design
Procedures**

Step 1. Compute runoff control volumes.

Calculate the Water Quality Volume (WQ_v), Channel Protection Volume (Cp_v) Overbank, Flood Protection Volume (Q_p), and Extreme Flood Volume (Q_f). See Section 1.6.

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

- Soil Type
- % Impervious Area
- Intermittent Flow
- Sufficient Flow Elevation Difference
- Is development commercial, industrial, or institutional

Step 3. Confirm local design criteria and applicability

Consider any special site-specific design conditions/criteria. Check with local officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Compute WQ_v peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures. See Section 1.6.

- Using WQ_v , compute CN
- Compute time of concentration using TR-55 method
- Determine appropriate unit peak discharge from time of concentration
- Compute Q_{wq} from unit peak discharge, drainage area, and WQ_v .

Step 5. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQ_v to the sand filter facility.

Size low flow orifice, weir, or other device to pass Q_{wq} .

Step 6. Size filtration basin chamber

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

$$A_f = (WQ_v) (d_f) / [(k) (h_f + d_f) (t_f)]$$

where:

A_f = surface area of filter bed (ft²)

d_f = filter bed depth (typically 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 ≤ 6 feet)

t_f = design filter bed drain time (days); (1.67 days or 40 hours is recommended maximum)

**Surface/
Perimeter Sand
Filter Design
Procedures
(cont.)**

Set preliminary dimensions of filtration basin chamber. See Design Criteria for filter media specifications.

Step 7. Size sedimentation chamber

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

$$A_s = - (Q_o/w) * \ln (1-E)$$

Where:

- A_s = sedimentation basin surface area (ft²)
- Q_o = rate of outflow = the WQ_v over a 24-hour period
- 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:

$$A_s = (0.066) (WQ_v) \text{ ft}^2 \text{ for } I < 75\%$$

$$A_s = (0.0081) (WQ_v) \text{ ft}^2 \text{ for } I \geq 75\%$$

Set preliminary dimensions of sedimentation chamber.

Perimeter sand filter: The sedimentation chamber should be sized to at least 50% of the computed WQ_v . Use same approach as for surface sand filter.

Step 8. Compute V_{min}

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

Step 9. Compute storage volumes within entire facility and sedimentation chamber orifice size

Surface sand filter:

$$V_{min} = 0.75 WQ_v = V_s + V_f + V_{f-temp}$$

- Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$, where: n = porosity = 0.4 for most applications
- Compute V_{f-temp} = temporary storage volume above the filter bed = $2 * h_f * A_f$
- Compute V_s = volume within sediment chamber = $V_{min} - V_f - V_{f-temp}$
- Compute h_s = height in sedimentation chamber = V_s/A_s
- 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.
- Size orifice from sediment chamber to filter chamber to release V_s within 24-hours average release rate with 0.5 h_s as average head.

Surface/
Perimeter Sand
Filter Design
Procedures
(cont.)

- Design outlet structure with perforations allowing for a safety factor of 10.
- Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

Perimeter sand filter:

- Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
- Where: n = porosity = 0.4 for most applications
- Compute V_w = wet pool storage volume $A_s * 2$ feet minimum
- Compute V_{temp} = temporary storage volume = $V_{min} - (V_f + V_w)$
- Compute h_{temp} = temporary storage height = $V_{temp} / (A_f + A_s)$
- Ensure $h_{temp} \geq 2 * h_f$, otherwise decrease h_f and re-compute. Ensure dimensions fit available head and area – change as necessary in design iterations until all site dimensions fit.
- Size distribution slots from sediment chamber to filter chamber.

Step 10. Design inlets, pretreatment facilities, underdrain system, and outlet structures according to Design Criteria.

Step 11. Compute overflow weir sizes

Surface sand filter:

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

Perimeter sand filter: Size overflow weir at end of sedimentation chamber to handle excess inflow, set at WQ_v elevation.

Sand Filter Design Example

The following demonstrates the process for the design of a sand filter BMP.

Site Specific Data

Happy Land is an activity center located in Bowling Green, Kentucky. The site area and drainage area to the proposed stormwater management facility is 3.0 acres. The project consists of constructing the activity center and parking for a total impervious area of 1.9 acres. Existing ground at the restaurant is 500' above mean sea level (MSL). Soil borings indicate that the seasonally high water table is at elevation 491'. The adjacent creek invert is at 490'. The underlying soils are clays with a Hydrologic Soil Group of D.

Step 1. Compute runoff control volumes

Step A. Compute WQ_v

Compute Volumetric Runoff Coefficient (R_v)

$$R_v = 0.05 + (0.009)(I); I = 1.9 \text{ acres} / 3.0 \text{ acres} = 0.633 \text{ or } 63.3 \% \\ = 0.05 + (0.009)(63.3) = 0.62$$

Compute WQ_v

$$WQ_v = [(P)(R_v)(A)]/12 = [(0.64\text{"})(0.62)(3.0 \text{ acres})]/12 \\ P = \text{rainfall depth in inches} = \underline{0.099 \text{ ac-ft}} \text{ (4312 cf.)}$$

Step B. Compute Cp_v

It is assumed that the proposed activity center is located within a USE I watershed, therefore an extended detention time (T) of 24 hours for the one-year storm event. From a computer analysis (TR-55) the time of concentration (t_c) and one-year runoff (Q_a) are 0.15 hours and 1.9 inches, respectively.

Initial Abstraction (I_a) for CN of 83 is 0.41: ($I_a = 200/CN-2$)

$$I_a/P = 0.41/3.6\text{"} = 0.11; \quad P = \text{Rainfall Depth for 1 yr, 24 hour storm event}$$

$$q_u = 875 \text{ csm/in} \quad (\text{See Figure PTP-01-16})$$

$$q_o/q_i = 0.02 \quad (\text{See Figure PTP-01-17})$$

Compute V_s/V_r for a Type II rainfall distribution.

$$V_s/V_r = 0.683 - 1.43(q_o/q_i) + 1.64(q_o/q_i)^2 - 0.804(q_o/q_i)^3 = 0.66$$

$$V_s = [(V_s/V_r)(Q_a)(A)]/12 = [(0.66)(1.9\text{"})(3.0 \text{ acre})]/12 = 0.314 \text{ ac-ft (13,677 cf)}$$

Compute the Cp_v release rate.

The above volume is to be released over 24 hours

$$(0.314 \text{ ac-ft} \times 43560 \text{ ft}^2/\text{ac}) / (24 \text{ hours} \times 3600 \text{ secs/hr}) = 0.16 \text{ cfs}$$

Sand Filter Design Example (cont.)

Step C. Compute Q_{p25} Storage Volume

For this example, TR-55 was utilized to calculate the storage volume. An inflow of 17 cfs and an allowable outflow of 6 cfs were used, which yielded a volume of storage (V_s) necessary for control of 0.52 ac-ft (22677 cf), with a developed CN of 83. Note that there is 7.9 inches of rainfall during this event with 5.9 inches of runoff. It should be noted that there are other methods for determining storage volumes for a site are available.

Step D. Compute Q_f

For this example, management of Q_f is not required. However, the 100 year storm event must be conveyed safely through the stormwater management practice.

Step 2. BMP Selection Process

Determine the most appropriate BMP for the development site and conditions. For this example, a sand filter would be appropriate.

Step 3. Confirm local design criteria and applicability

Consider any special site-specific design conditions in design criteria. Check with local officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply. For this example, there is not a special site-specific design condition.

Step 4. Compute WQ_v peak discharge (Q_{wq}) & Head

Step A. Determine Water Quality Volume

$WQ_v = 4312$ cf from above.

Step B. Determine available head

Low point at parking lot is 501.5 ft. Subtract 2' to pass Q_{25} discharge (499.5') and a half foot for channel to facility (499.0'). Low point at stream invert is 490.0'. Set outfall underdrain pipe 2' above stream invert and add 0.5' to this value for drain (492.5'). Add to this value 8" for the gravel blanket over the underdrains, and 18" for the sand bed (494.67'). The total available head is $499.0 - 494.67 = 4.33$ ft. Therefore, the average depth, h_f , is $h_f = 4.33/2 = 2.17'$.

Find modified CN.

$$P = 0.64''$$

$$Q = WQ_v/area = (4312 \text{ cf})(12 \text{ in/ft})/[(3 \text{ ac})(43560 \text{ ft}^2/\text{ac})] = 0.40''$$

$$CN = 1000/[10+5P+10Q-10(Q^2+1.25QP)^{1/2}] = 97$$

For $CN = 97$ and $t_c = 0.15$ hours, compute Q_p for a 0.64" storm. With the $CN = 97$, a 0.64" storm will produce 0.38" of runoff (SCS Hydrologic Method). $I_a = 0.062$, therefore $I_a/P = 0.062/0.64 = 0.097$. $q_u = 900$ csm/in, therefore $Q_{wq} = (900 \text{ csm/in})(3.0 \text{ ac}/640 \text{ ac/sq mile})(0.38'') = 1.6$ cfs.

Sand Filter Design Example (cont.)

Step 5. Size flow diversion structure

Size a low flow orifice to pass 1.6 cfs with 1.5' of head using the orifice equation:

$$Q = CA\sqrt{2gh}; 1.6 \text{ cfs} = (0.6)(A)\sqrt{(2)(32.2)(1.5)}$$

$$A = 0.27 \text{ sq ft} = \frac{\pi d^2}{4}; d = 0.59' (7.1"); \text{ Use 9 inches.}$$

Size the 25-year overflow as follows: the 25-year water surface elevation is set at 501.0'. Use a concrete weir to pass the 25-year flow (17 cfs) into a grassed overflow channel using the Weir equation. Assume 2' of head to pass this event. Overflow channel should be designed to provide sufficient energy dissipation so that there will be non-erosive velocities.

$Q = CLH^{3/2} \Rightarrow 17 \text{ cfs} = (3.1)(L)(2')^{3/2} \Rightarrow L = 1.94'$; use $L = 2.0'$ which sets flow diversion chamber dimension.

Weir wall elevation = 499.0.

Set low flow invert at $499.0 - [1.5' + (0.5)(9")/(12)] = 19.13'$

Step 6. Size filtration bed chamber

From Darcy's Law: $A_f = \frac{WQ_v(d_f)}{k(h_f + d_f)(t_f)}$

where $d_f = 18"$

$k = 3.5 \text{ ft/day}$

$h_f = 2.17'$

$t_f = 40 \text{ hours}$

$A_f = 302.1 \text{ sq ft}$; using a 2:1 ratio, say filter is 13' x 26' (338 sq ft)

Step 7. Size sedimentation chamber

From Camp-Hazen equation, for $I < 75\%$: $A_s = 0.066(WQ_v)$

$A_s = 284.6 \text{ sq ft}$; with width = 13', the length will be $284.6/13 = 21.8$
(Use 13.0' x 22.0')

Step 8. Compute V_{min}

$$V_{min} = \frac{3}{4}(WQ_v) = 3234 \text{ cf}$$

Step 9. Compute storage volumes within entire facility and sedimentation chamber orifice size.

Volume within filter bed (V_f): $V_f = A_f(d_f)(n)$

$n = 0.35$ for clays (NAVFACS 7.1-22)

$V_f = 177 \text{ cf}$

Temporary storage above filter bed (V_{f-temp}): $V_{f-temp} = 2h_f A_f$

$V_{f-temp} = 1467 \text{ cf}$

Sand Filter
Design
Example
(cont.)

Compute remaining volume for sedimentation chamber (V_s):

$$V_s = V_{\min} - [V_f + V_{f\text{-temp}}] = 1590 \text{ cf}$$

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

$$h_s = 5.56' \text{ which is larger than the head available (4.33')};$$

increase the size of the settling chamber, using 4.33' design height

$$(1590 \text{ cf})/(4.33) = 367.2 \text{ sq ft}; 367.2/13' \text{ yields length of } 29'$$

New sedimentation chamber dimensions are 13' x 29'

With adequate preparation of the bottom of the settling chamber (rototil earth, place gravel, then surge stone), the bottom can infiltrate water into the substrate. The runoff will enter the groundwater directly without treatment. The stone will eventually clog without protection from settling solids, so use a removable geotextile to facilitate maintenance.

Provide perforated standpipe with orifice sized to release volume over a 24 hr period. Average release rate equals $1590 \text{ cf}/24 \text{ hr} = 0.018 \text{ cfs}$.

Equivalent orifice size can be calculated using orifice equation:

$$Q = CA\sqrt{2gh}; \text{ where } h = 2.17' \text{ (average head)}$$

$$A = 0.0025 \text{ ft}^2 = \frac{\pi d^2}{4}; \text{ therefore equivalent orifice diameter equals } 1''.$$

Recommended design is to cap stand pipe with low flow orifice sized for 24 hr detention. Over-perforate pipe by a safety factor of 10 to account for clogging.

Step 10. Design inlets, pretreatment facilities, underdrain system, and outlet structures.

This example problem does not require an inlet or outlet structure, pretreatment facility, or underdrain system.

Step 11. Compute overflow weir sizes.

Assume overflow that needs to be handled is equivalent to the 9" orifice discharge under a head of 3.5 ft.

$$Q = CA\sqrt{2gh} \text{ with } h = 3.5', A = 0.44 \text{ sq ft}, C = 0.6$$

$$Q = 3.96 \text{ cfs, use } 4.0 \text{ cfs.}$$

For the overflow from the sediment chamber to the filter bed, size to pass 4 cfs.

Sand Filter
Design
Example
(cont.)

Weir equation: $Q = CLh^{3/2}$, assume maximum allowable head of 0.5'
Where $Q = 4.0$ cfs
 $C = 3.1$
 $H = 0.5'$

$L = 3.65$ ft, Use $L = 3.75'$

Similarly, for the overflow from the filtration chamber to the outlet of the facility, size to pass 4.0 cfs.

Weir equation: $Q = CLh^{3/2}$, assume maximum allowable head of 0.5'
 $L = 3.65$ ft, Use $L = 3.75$ ft

Adequate outlet protection and energy dissipation should be provided for the downstream overflow channel.

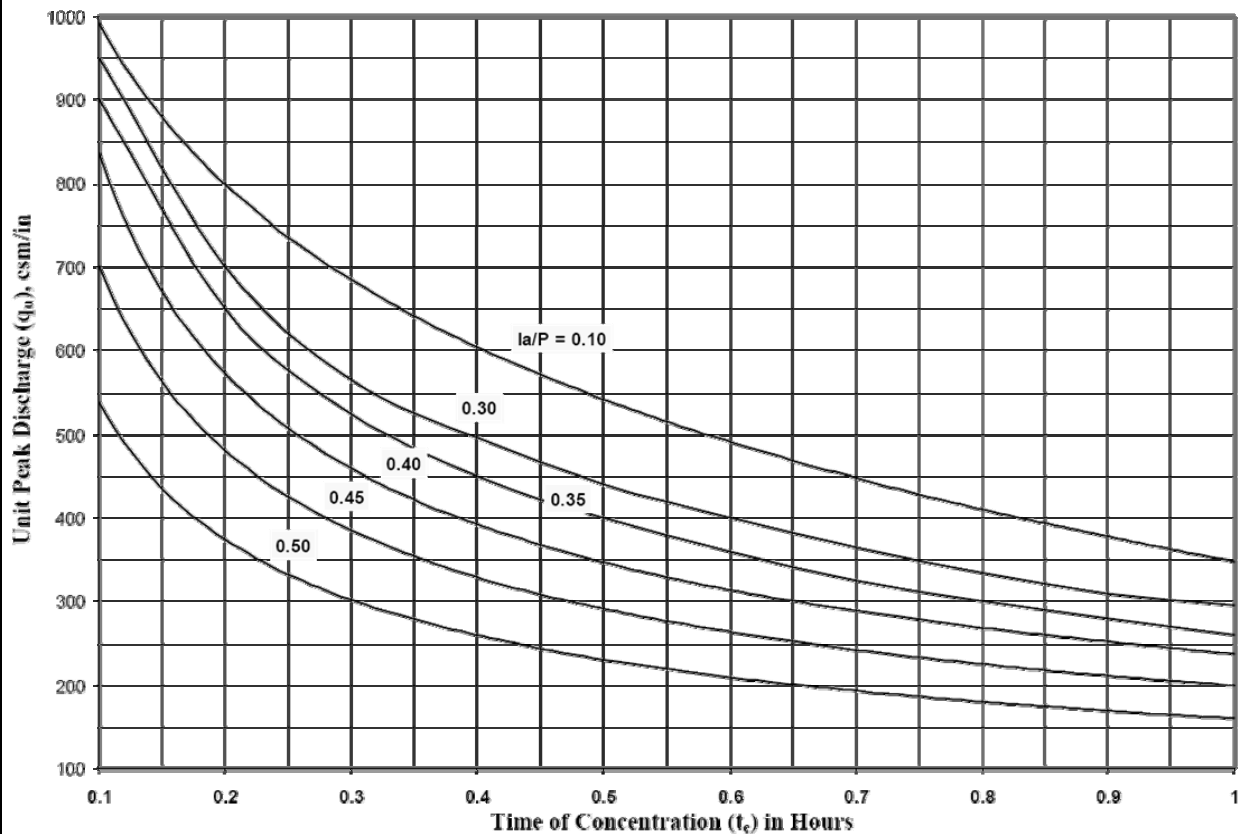


Figure PTP-01-16
SCS Graphical Method of Determining Peak Discharge for 24-Hour Type II Storm Distribution
Source, Maryland Stormwater Design Manual

Sand Filter
Design
Example
(cont.)

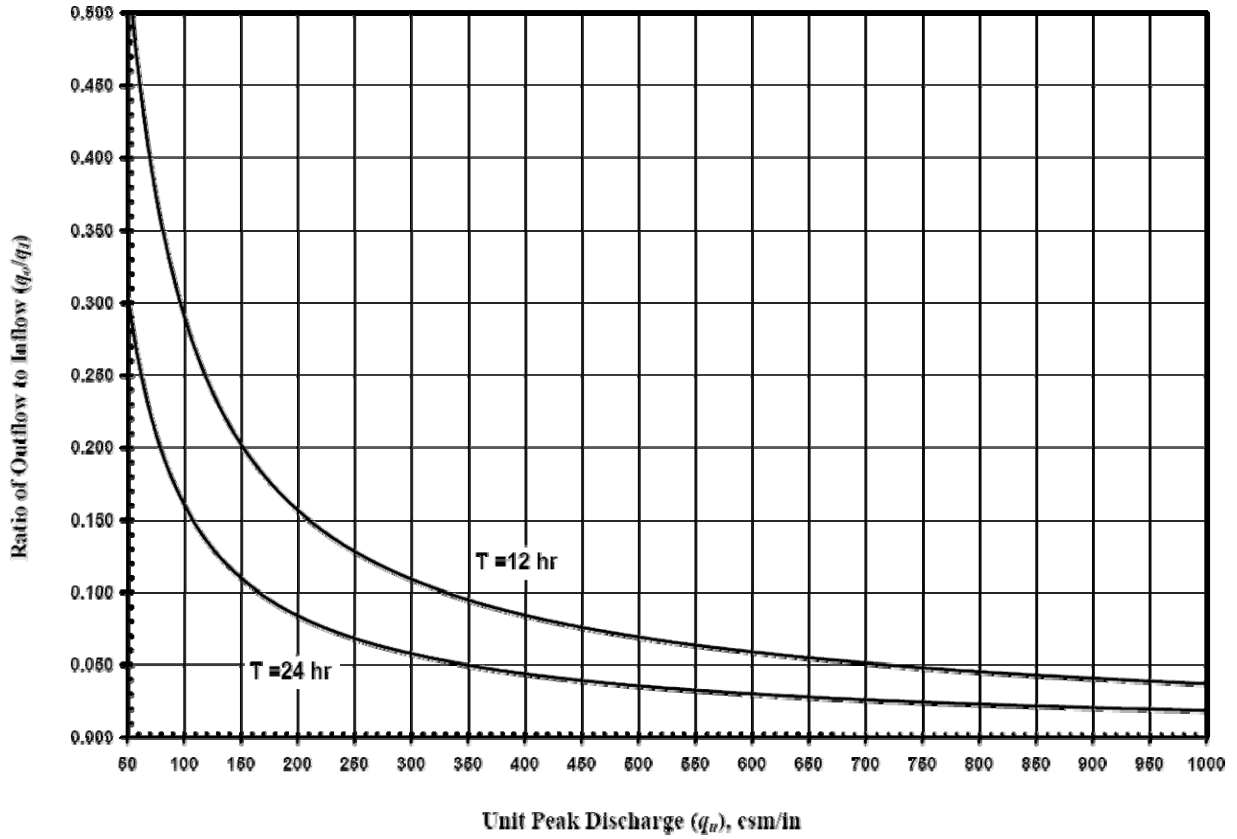


Figure PTP-01-17
Detention Time vs. Discharge Ratios (q_o/q_i)
Source, Maryland Stormwater Design Manual

Sand Filter
Design
Example
(cont.)

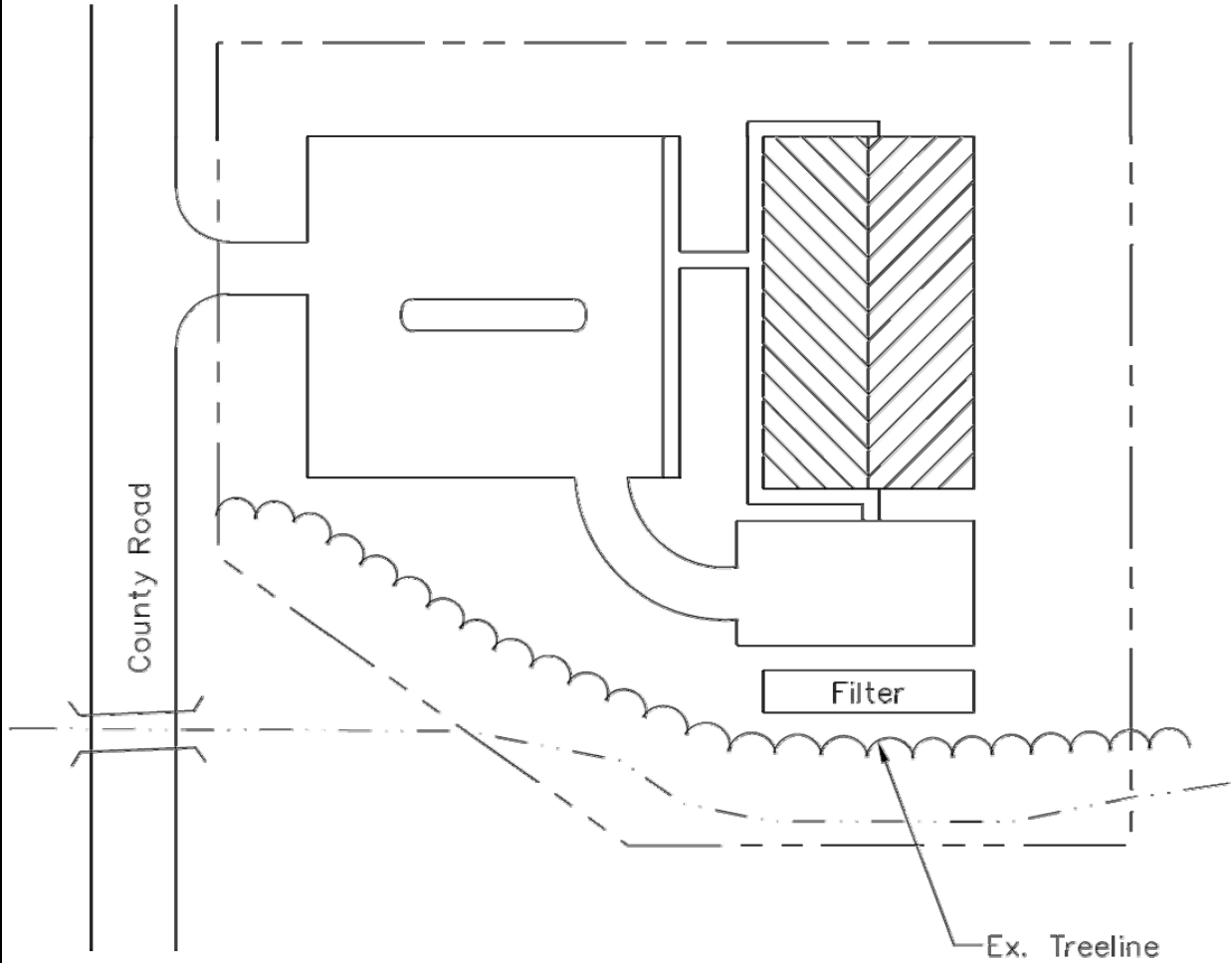


Figure PTP-01-18
Design Example - Happy Land Activity Center Site Plan
Sand Filter