Description

Photograph SF-1. The vegetation on the surface of the filter and the shallow design depth of this sand filter, help the BMP blend into its surroundings. Photo courtesy of Fred Bromberger.

A sand filter is a filtering or infiltrating BMP that consists of a surcharge zone underlain by a sand bed with an underdrain system (when necessary). During a storm, accumulated runoff collects in the surcharge zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to a nearby channel, swale, or storm sewer. It is similar to a BMP designed for bioretention in that it utilizes filtering, but differs in that it is not specifically designed for vegetative growth. For this reason, it can have a greater depth and be designed for a larger contributing area. A sand filter is also similar to an extended detention basin (EDB) in that it is a dry basin, which can be easily designed to include the flood control volume above the WQCV or EURV. However, a sand filter does not require a forebay or micropool because the solids that would be deposited in these components in an EDB will be retained on the surface of the sand bed in a sand filter. Sand filters can be vegetated with species that will tolerate both wet and dry conditions and occasional inundation. The rain garden growing media is recommended for sand filters where vegetation is desired. Sand filters can also be placed in a vault. Underground sand filters have additional requirements. See Fact Sheet T-11 for additional discussion on underground BMPs.

Sand/Media Filter	
Functions	
LID/Volume Red.	Yes
WQCV Capture	Yes
WQCV+Flood Control	Yes
Fact Sheet Includes EURV Guidance	No
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Very Good[1]
Nutrients	Good
Total Metals	Good
Bacteria	Moderate
Other Considerations	
Life-cycle Costs[4]	Moderate

[1] Not recommended for watersheds with high sediment yields (unless pretreatment is provided).

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

Site Selection

Sand filters require a stable watershed. When the watershed includes phased construction, sparsely vegetated areas, or steep slopes in sandy soils, consider another BMP or provide pretreatment before runoff from these areas reach the rain garden.

When sand filters (and other BMPs used for infiltration) are located adjacent to buildings or pavement areas, protective measures should be implemented to avoid adverse impacts to these structures. Oversaturated subgrade soil underlying a structure can cause the structure to settle or result in moisture-related problems. Wetting of expansive soils or bedrock can cause swelling, resulting in structural movements. A geotechnical engineer should evaluate the potential impact of the BMP on adjacent structures based on an evaluation of the subgrade soil, groundwater, and bedrock conditions at the site. Additional minimum requirements include:

- In locations where subgrade soils do not allow infiltration, the filter layer should be underlain by an underdrain system.
- Where infiltration can adversely impact adjacent structures, the filter layer should be underlain by an underdrain system designed to divert water away from the structure.
- In locations where potentially expansive soils or bedrock exist, placement of a sand filter adjacent to structures and pavement should only be considered if the BMP includes an underdrain designed to divert water away from the structure, and is lined with an impermeable geomembrane liner designed to restrict seepage.

Benefits

- Filtering BMPs provide effective water quality enhancement including phosphorus removal.

Limitations

- This BMP may clog and require maintenance if a moderate to high level of silts and clays are allowed to flow into the facility.
- This BMP should not be located within 10 feet of a building foundation without an impermeable membrane. See *Bioretention* (BMP Fact Sheet T-3) of this manual for additional information.
- The sand filter should not be put into operation while construction or major landscaping activities are taking place in the watershed.

Designing for Maintenance

Recommended maintenance practices for all BMPs are provided in Chapter 6 of this manual. During design the following should be considered to ensure ease of maintenance over the long-term:

- Do not put a filter sock on the underdrain. This is not necessary and can cause the BMP to clog.
- Install cleanouts. Cleanouts can be used for inspection (by camera) immediately following construction to ensure that the underdrain pipe was not crushed during construction. They can also be used to for ongoing maintenance practices. Consider locating cleanouts in the side slopes of the basin and above the depth of ponding.
- Provide vegetated side slopes to pre-treat runoff by filtering (straining). This will reduce the frequency of maintenance.

Design Procedure and Criteria

The following steps outline the design procedure and criteria for a sand filter.

1. **Basin Storage Volume**: Provide a storage volume above the sand bed of the basin equal to the WQCV based on a 24-hour drain time. Although the BMP will be designed to drain in 12 hours, sizing the basin for a longer drain time will ensure containment of the WQCV as infiltration through the filter layer slows over time.

- Determine the imperviousness of the tributary area (or effective imperviousness where LID techniques are implemented). Determine the required WQCV (watershed inches of runoff) using Figure 3-2 in Chapter 3 of this manual. The volume should be based on a drain time of 24 hours.

- Calculate the design volume as follows:

$$V = \left[\frac{\text{WQCV}}{12}\right] A \qquad \text{Equation SF-1}$$

Where:

V = design volume (ft^3)

A = watershed area tributary to the sand filter (ft^2)

2. **Basin Geometry:** Use equation SF-2 to calculate the minimum filter area, which is the flat surface of the sand filter. Sediment will reside on the filter area of the sand filter. Therefore, if the filter area is too small, the filter may clog prematurely. If this is of particular concern, increasing the filter area will decrease the frequency of maintenance. The following equation provides the minimum filter area allowing for some of the volume to be stored beyond the area of the filter. **Note that the total volume must also equal or exceed the design volume.**

   The side slopes of the basin should be stable and maintainable. For vegetated side slopes, a 4:1 (horizontal: vertical) minimum slope is recommended. Use vertical walls where side slopes are steeper than 3:1

$$A = \frac{2\text{V}}{9} \qquad \text{Equation SF-2}$$

Where:

A = minimum filter area (flat surface area) (ft^2)

V = design volume (ft^3)

3. **Filter Material**: Provide, at a minimum, an 18-inch layer of CDOT Class C filter material (see Table SF-1). Maintain a flat surface on the top of the sand bed.

Table SF-1. Gradation Specifications for CDOT Class C Filter Material
(Source: CDOT Table 703-7)

Sieve Size	Mass Percent Passing Square Mesh Sieves
19.0 mm (3/4")	100
4.75 mm (No. 4)	60 – 100
300 µm (No. 50)	10 – 30
150 µm (No. 100)	0 – 10
75 µm (No. 200)	0 - 3

4. **Underdrain System**: Underdrains are typically required for sand filters and should be provided if infiltration tests show rates slower than 2 times that required to drain the WQCV over 12 hours, or where required to divert water away from structures as determined by a professional engineer. Percolation tests should be performed or supervised by a licensed professional engineer and conducted at a minimum depth equal to the bottom of the sand filter. Additionally, underdrains are required where impermeable membranes are used. There are three basic types of sand filters:

   - **No-Infiltration:** This section includes an underdrain and an impermeable liner that does not allow for infiltration of stormwater into the subgrade soils. It is appropriate to use a no-infiltration system when any of the following is true:

     - Land use or activities could contaminate groundwater when stormwater is allowed to infiltrate, or

     - The BMP is located over potentially expansive soils or bedrock or is adjacent (within 10 feet) to structures.

   - **Partial Infiltration:** This section does not include an impermeable liner, allowing for some infiltration. Stormwater that does not infiltrate will be collected and removed by an underdrain system.

   - **Full Infiltration:** This section is designed to infiltrate all of the water stored into the subgrade below. UDFCD recommends a minimum infiltration rate of 2 times the rate needed to drain the WQCV over 12 hours.

   When using an underdrain system, provide a control orifice sized to drain the design volume in approximately 12 hours or more (see Equation SF-3). Use a minimum orifice size of 3/8 inch to avoid clogging. This will provide detention and slow release of the WQCV to offset hydromodification. Provide cleanouts to allow inspection of the drainpipe system during and after construction to ensure that the pipe was not crushed or disconnected during construction and to allow for maintenance of the underdrain. Space underdrain pipes a maximum of 20 feet on-center.

$$D_{12 \text{ hour drain time}} = \sqrt{\frac{V}{1414\, y^{0.41}}} \qquad \text{Equation SF-3}$$

   Where:

   D = orifice diameter (in)

   y = distance from the lowest elevation of the storage volume (ft) (i.e., surface of the filter) to the center of the orifice

   V = volume to drain in 12 hours (WQCV) (ft^3)

   In previous versions of this manual, UDFCD recommended that the underdrain be placed in an aggregate layer and that a geotextile (separator fabric) be placed between this aggregate and the growing medium. This version of the manual replaces that section with materials that, when used together, eliminate the need for a separator fabric.

The underdrain system should be placed below the 18-inch (minimum) filter layer. The underdrain system should be placed within an 5-inch-thick section of CDOT Class C filter material meeting the gradation in Table SF-1. Areas of the underdrain layer may be deeper due to the slope of the underdrain. If no underdrain is required, the minimum section can be reduced to the 18-inch filter layer. Use slotted pipe that meets the slot dimensions provided in Table SF-2.

Table SF-2. Dimensions for Slotted Pipe

Pipe Size	Slot Length[1]	Maximum Slot Width	Slot Centers[1]	Open Area[1] (per foot)
4"	1-1/16"	0.032"	0.413"	1.90 in^2
6"	1-3/8"	0.032"	0.516"	1.98 in^2

[1] Some variation in these values is acceptable and is expected from various pipe manufacturers. Be aware that both increased slot length and decreased slot centers will be beneficial to hydraulics but detrimental to the structure of the pipe.

Table SF-3. Physical Requirements for Separator Fabric[1]

Property	Class B		Test Method
	Elongation < 50%[2]	Elongation > 50%[2]	
Grab Strength, N (lbs)	800 (180)	510 (115)	ASTM D 4632
Puncture Resistance, N (lbs)	310 (70)	180 (40)	ASTM D 4833
Trapezoidal Tear Strength, N (lbs)	310 (70)	180 (40)	ASTM D 4533
Apparent Opening Size, mm (US Sieve Size)	AOS < 0.3mm (US Sieve Size No. 50)		ASTM D 4751
Permittivity, sec^{-1}	0.02 default value, must also be greater than that of soil		ASTM D 4491
Permeability, cm/sec	k fabric > k soil for all classes		ASTM D 4491
Ultraviolet Degradation at 500 hours	50% strength retained for all classes		ASTM D 4355

[1] Strength values are in the weaker principle direction
[2] As measured in accordance with ASTM D 4632

5. **Impermeable Geomembrane Liner and Geotextile Separator Fabric:** For no-infiltration sections, install a minimum 30-mil thick PVC geomembrane liner, per Table SF-4, on the bottom and sides of the basin, extending up at least to the top of the underdrain layer. Provide at least 9 inches (12 inches if possible) of cover over the membrane where it is attached to the wall to protect the membrane from UV deterioration. The geomembrane should be field-seamed using a dual track welder, which allows for non-destructive testing of almost all field seams. A small amount of single track and/or adhesive seaming should be allowed in limited areas to seam around pipe perforations, to patch seams removed for destructive seam testing, and for limited repairs. The liner should be installed with slack to prevent tearing due to backfill, compaction, and settling. Place CDOT Class B geotextile separator fabric above the geomembrane to protect it from being punctured during the placement of the filter material above the liner. If the subgrade contains angular rocks or other material that could puncture the geomembrane, smooth-roll the surface to create a suitable surface. If smooth-rolling the surface does not provide a suitable surface, also place the separator fabric between the geomembrane and the underlying subgrade. This should only be done when necessary because fabric placed under the geomembrane can increase seepage losses through pinholes or other geomembrane defects. Connect the geomembrane to perimeter concrete walls around the basin perimeter, creating a watertight seal between the geomembrane and the walls using a continuous batten bar and anchor connection (see Figure SF-3). Where the need for the impermeable membrane is not as critical, the membrane can be attached with a nitrile-based vinyl adhesive. Use watertight PVC boots for underdrain pipe penetrations through the liner (see Figure SF-2).

Table SF-4. Physical Requirements for Geomembrane

Property	Thickness 0.76 mm (30 mil)	Test Method
Thickness, % Tolerance	±5	ASTM D 1593
Tensile Strength, kN/m (lbs/in) width	12.25 (70)	ASTM D 882, Method B
Modulus at 100% Elongation, kN/m (lbs/in)	5.25 (30)	ASTM D 882, Method B
Ultimate Elongation, %	350	ASTM D 882, Method A
Tear Resistance, N (lbs)	38 (8.5)	ASTM D 1004
Low Temperature Impact, °C (°F)	-29 (-20)	ASTM D 1790
Volatile loss, % max.	0.7	ASTM D 1203, Method A
Pinholes, No. Per 8 m^2 (No. per 10 sq. yds.) max.	1	N/A
Bonded Seam Strength, % of tensile strength	80	N/A

6. **Inlet Works**: Provide energy dissipation at all inlet points into the sand filter. Use an impact basin for pipes and a baffle chute or grouted sloping boulder drop if a channel or swale is used, or install a Type VL or L riprap basin underlain with geotextile fabric at the inlet (see Figure SF-1). Fill all rock voids with the filter material specified in Table SF-1.

7. **Outlet Works**: Slope the underdrain into a larger outlet structure. As discussed in Step 4, use an orifice plate to drain the WQCV over approximately 12 hours. Flows exceeding the WQCV should also drain into the outlet structure. Additional flow restrictions may be incorporated to provide Full Spectrum Detention, as discussed in the *Storage* chapter of Volume 2, or peak reduction for other specific storm events.

   For Full Spectrum Detention, perform reservoir routing calculations to design the outlet structure. The *UD-Detention* workbook, available at www.udfcd.org, can be used for this purpose. The design could include a second orifice located at the WQCV elevation or could include a downstream point of control designed to drain the full excess urban runoff volume (EURV) in approximately 72 hours.

Construction Considerations

Proper construction of sand filters involves careful attention to material specifications and construction details. For a successful project, do the following:

- Protect area from excessive sediment loading during construction. The portion of the site draining to the sand filter must be stabilized before allowing flow into the sand filter.

- When using an impermeable liner, ensure enough slack in the liner to allow for backfill, compaction, and settling without tearing the liner.

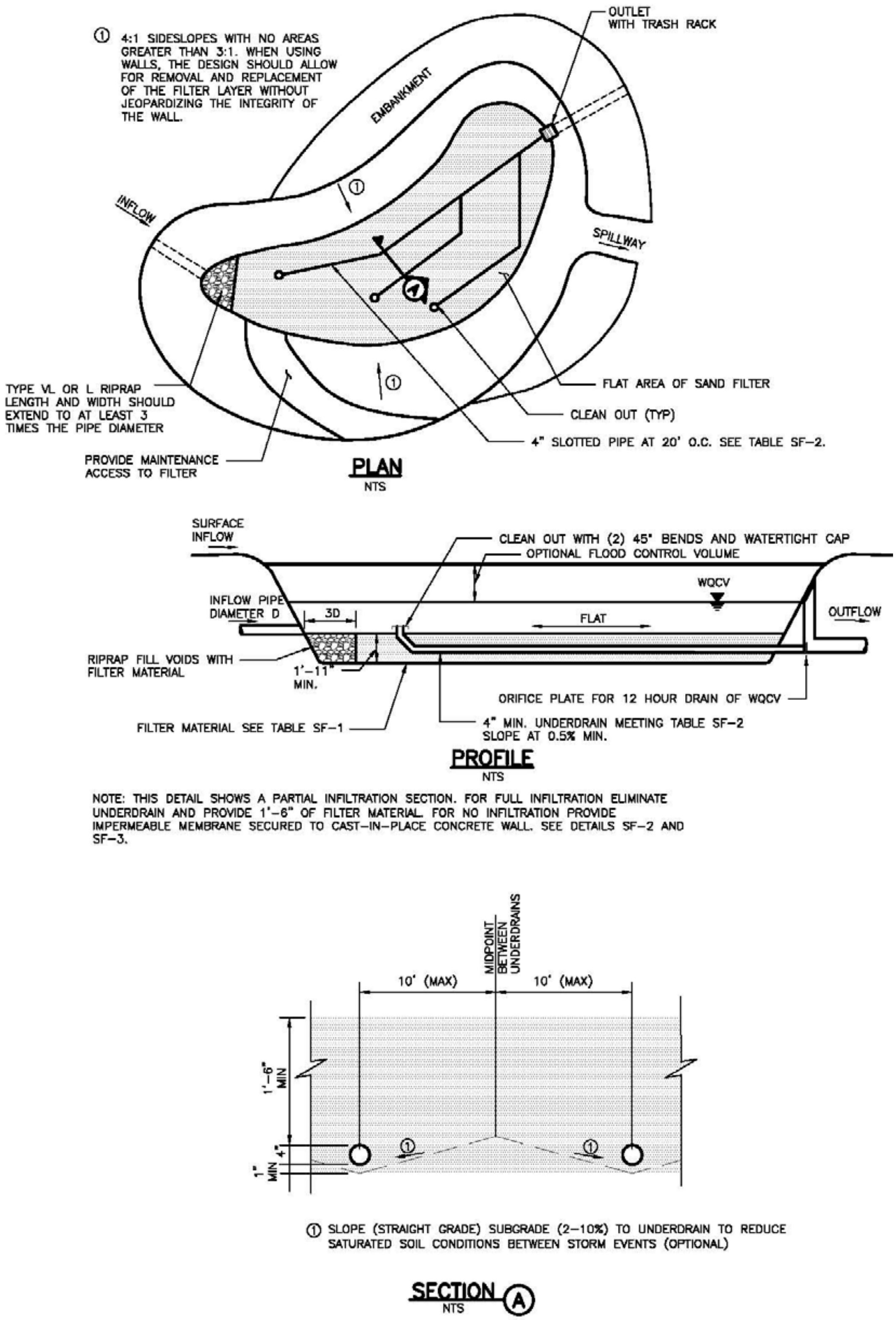

Figure SF-1. Sand Filter Plan and Sections

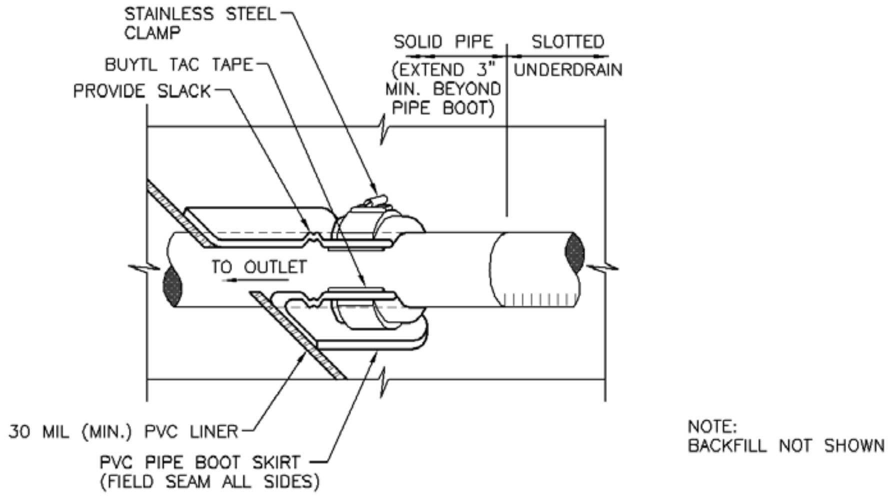

Figure SF-2. Geomembrane Liner/Underdrain Penetration Detail

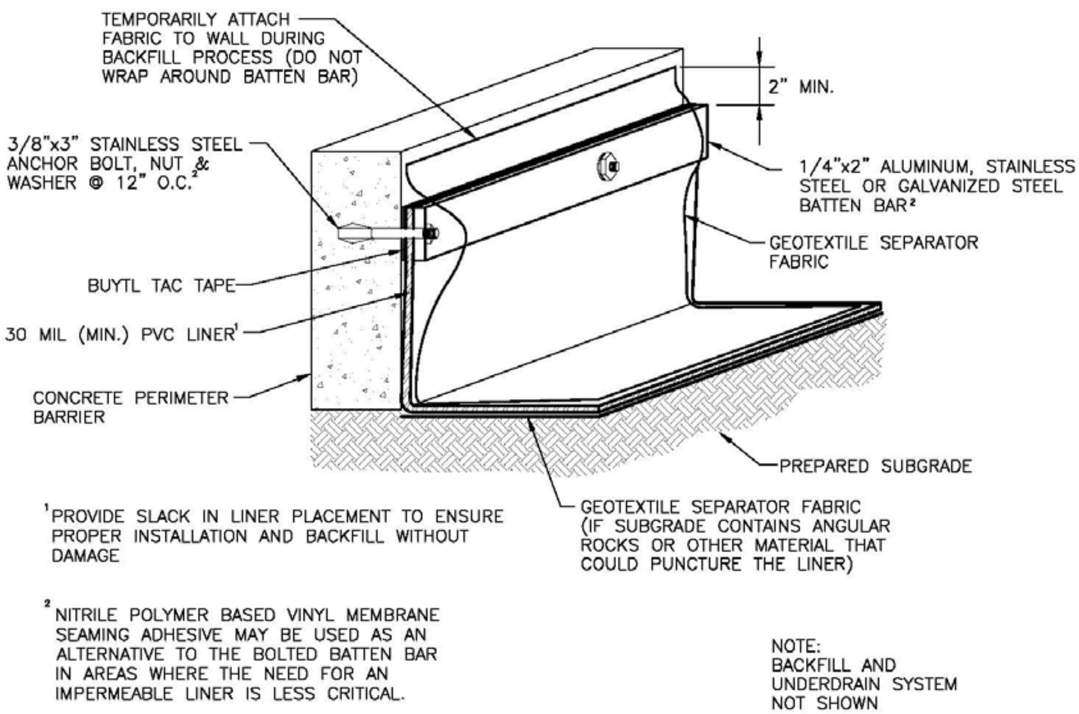

Figure SF-3. Geomembrane Liner/Concrete Connection Detail

Design Examples

The *UD-BMP* workbook, designed as a tool for both designer and reviewing agency is available at www.udfcd.org. This section provides a completed design form from this workbook as an example.

Design Procedure Form: Sand Filter (SF)

Sheet 1 of 2

Designer:	**T. Chio**
Company:	**BMP, Inc.**
Date:	**November 29, 2010**
Project:	**Shops at 67th**
Location:	**SE Corner of 67th Ave. and 104th St.**

1. Basin Storage Volume	
A) Effective Imperviousness of Tributary Area, I_a (100% if all paved and roofed areas upstream of sand filter)	I_a = 75.0 %
B) Tributary Area's Imperviousness Ratio ($i = I_a/100$)	i = 0.750
C) Water Quality Capture Volume (WQCV) Based on 24-hour Drain Time $WOCV= 0.9 * (0.91* i^3 - 1.19 * i^2 + 0.78 * i)$	WQCV = 0.27 watershed inches
D) Contributing Watershed Area (including sand filter area)	Area = 217,800 sq ft
E) Water Quality Capture Volume (WQCV) Design Volume V_{WQCV} = WQCV / 12 * Area	V_{WQCV} = 4,893 cu ft
F) For Watersheds Outside of the Denver Region, Depth of Average Runoff Producing Storm	d_6 = ____ in
G) For Watersheds Outside of the Denver Region, Water Quality Capture Volume (WQCV) Design Volume	$V_{WQCV\ OTHER}$ = ____ cu ft
H) User Input of Water Quality Capture Volume (WQCV) Design Volume (Only if a different WQCV Design Volume is desired)	$V_{WQCV\ USER}$ = ____ cu ft
2. Basin Geometry	
A) WQCV Depth	D_{WQCV} = 3.2 ft
B) Sand Filter Side Slopes (Horizontal distance per unit vertical, 4:1 or flatter preferred). Use "0" if sand filter has vertical walls.	Z = 4.00 ft / ft
C) Mimimum Filter Area (Flat Surface Area)	A_{Min} = 1087 sq ft
D) Actual Filter Area	A_{Actual} = 1625 sq ft
E) Volume Provided	V_T = 4893 cu ft
3. Filter Material	Choose One: (●) 18" CDOT Class C Filter Material; ( ) Other (Explain):
4. Underdrain System	
A) Are underdrains provided?	Choose One: (●) YES; ( ) NO
B) Underdrain system orifice diameter for 12 hour drain time	
i) Distance From Lowest Elevation of the Storage Volume to the Center of the Orifice	y = 2.8 ft
ii) Volume to Drain in 12 Hours	Vol_{12} = 4,893 cu ft
iii) Orifice Diameter, 3/8" Minimum	D_O = 1.51 in

Design Procedure Form: Sand Filter (SF)

Sheet 2 of 2

Designer:	**T. Chio**
Company:	**BMP, Inc.**
Date:	**November 29, 2010**
Project:	**Shops at 67th**
Location:	**SE Corner of 67th Ave. and 104th St.**

5. Impermeable Geomembrane Liner and Geotextile Separator Fabric A) Is an impermeable liner provided due to proximity of structures or groundwater contamination?	Choose One ○ YES ◉ NO
6-7. Inlet / Outlet Works A) Describe the type of energy dissipation at inlet points and means of conveying flows in excess of the WQCV through the outlet	At grade type VL riprap pad at both inlet locations.

Notes: