Chapter 7
Filtration BMPs

Filtration BMPs have shown to be very effective at removing a wide range of pollutants from stormwater runoff, particularly organic soil filter medias. They can be constructed in combination with infiltration practices, or with an underdrain filter, where infiltration is not feasible. Soil filters can be designed and constructed using common materials. Some manufacturers have developed proprietary filter medias and structures that may also be used with DEP approval. This chapter discusses the design and construction of underdrained soil filters, as well as proprietary soil filters that have been approved by DEP. Contents include:

- Underdrained Soil Filters and Bioretention Cells
- Proprietary Systems

7.1 Underdrained Soil Filters and Bioretention Cells

7.1.1 Description

IMPORTANT

Underdrained soil filters provide quality control and are designed to provide channel protection. The underdrain provides for the slow release of runoff, which protects streams from channel erosion associated with more frequent increased flow volumes. It also cools the runoff, reducing thermal impacts to receiving streams. If flood control is also required, a detention structure for that purpose will also be needed.

Underdrained soil filters control stormwater quality by capturing and retaining runoff and passing it through a filter bed comprised of a specific soil media. Various

Chapter Contents:

filter medias may be used, the most common including sand filters and organic filters. Soil filters having a mixture of sand, topsoil and organic matter achieve the highest removal rates, therefore are the focus of this Chapter and are the only filters currently approved by DEP. These filters can remove a wide range of pollutants from stormwater, including suspended sediment, phosphorus, nitrogen, metals, hydrocarbons and some dissolved pollutants.

Once through the soil media, the runoff is collected in a perforated underdrain pipe and discharged to the receiving water. The filter and underdrain provides for slow release of smaller storm events, minimizing stream channel erosion, as well as cooling the discharge. Figures 7-1 and 7-2 show two options for constructing a vegetated underdrained soil filter meeting DEP's criteria. The options allow for two different soil filter bed and pipe bedding designs. Either soil filter bed can be used with either pipe bedding. These options are discussed further below.

A bioretention cell is a type of underdrained filter designed to collect, infiltrate/filter, and treat moderate amounts of stormwater runoff using conditioned planting soil beds, gravel beds and vegetation within shallow depressions. The major difference between an underdrained soil filter and bioretention cell is the vegetation. A typical underdrained soil filter may be planted with grass, whereas a bioretention cell is planted with a variety of shrubs and perennials whose roots assist with the passing of water and uptake of pollutants. Studies have shown that bioretention cells are capable of reducing sediment, nutrients, oil and grease, and trace metals.

Bioretention cells are usually located in close proximity to the origin of the stormwater runoff and it is anticipated that these facilities would most often be scattered throughout a residential area, along the downhill edge of smaller parking areas, or below the down spouts of roof drains.

Bioretention cells can be designed to infiltrate water into the groundwater below, or to filter the water through the bioretention soil media and collect it in an underdrain located beneath the soil media. In Maine, the most typical use of bioretention areas or cells will be with an underdrained soil filter structure because natural soils are rarely suitable for infiltration. Figures 7-3 and 7-4 show two options for constructing a bioretention cell meeting DEP's criteria. The options allow for two different soil filter bed and pipe bedding designs. Either soil filter bed can be used with either pipe bedding. These options are discussed further below.

IMPORTANT

DEP strongly encourages the use of Low Impact Development (LID) techniques and recommends the dispersed use of underdrained soil filters throughout a site with a maximum drainage area of 0.75 to 1.0 acre for each individual filter.

IMPORTANT

When used to meet phosphorus allocations in lake watersheds, adjust the sizing of the underdrain filter in accordance with Volume II of this manual.

7.1.2 Site Suitability Criteria

1. **Drainage Area:** The drainage area contributing to an underdrained soil filter is sized based on the storage capacity over the filter and within the detention structure.

2. **Depth to Groundwater:** The bottom of the underdrain soil filter shall be one foot above the seasonal high groundwater table.

3. **Bedrock:** Bedrock close to the surface may prevent excavation.

7.1.3 General Design and Construction Criteria

The following design criteria apply to all underdrained soil filters. Specific criteria associated with grassed underdrained soil filters and bioretention cells are provided below.

IMPORTANT

Underdrained soil filters must detain a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area.

1. **Treatment Volume:** An underdrained soil filter must detain a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area. See specific underdrained soil filter and bioretention cell criteria provided below for storage and impoundment depth criteria specific to each type of filter.

2. **Outlet:** The treatment volume must be discharged solely through an underdrained vegetated soil filter having a single outlet with a diameter no greater than eight inches, or through a proprietary filter system approved by the Department.

3. **Construction Components:** Underdrained filters are constructed in an excavated hole at least 3 ft deep and consist of, from bottom up:

   - A geotextile fabric between natural soils and constructed media

   - A base of coarse clean stone in which a 4 to 6-inch perforated underdrain is usually installed

   - A layer of lightly compacted soil media at least 18 inches thick

   - Vegetation consisting of either grass (grassed underdrain soil filter) or dense plantings of woody shrubs, herbaceous perennials and, if the soil media is deep enough for the roots, small trees (bioretention cells). The plants should be native if possible and must be both drought and flood tolerant

   - A cover of 2-3 inches of aged, fibrous bark mulch for bioretention cells

   - Depression for surface stormwater storage

4. **Filter Shape:** Underdrained filters can be designed as pond shaped or linear structures to fit specific site conditions.

5. **Underdrain Pipe:** Proper layout of the pipe underdrain system is necessary to effectively drain the entire filter area. There must be at least one line of underdrain pipe for every eight feet of the filter area's width. The slope of the installed underdrain pipe must be 1% or greater. The underdrain piping should be 4" to 6" slotted, rigid schedule 40 PVC or SDR35.

IMPORTANT
Design Tips

- Bioretention areas may be constructed as infiltration or underdrained soil filters depending on site soils. The design standards provided for these techniques must also be followed.

- If used with infiltration, soil must be able to infiltrate pooled water within 3-4 hours. This requires an infiltration rate of greater than 1.5 in/hr. In tighter soils, an underdrain filter may be used to collect and discharge the treated water.

- See Appendix B of Volume I for appropriate plant species for Maine. A landscape designer or architect should be involved to select the appropriate plants for site conditions.

6. **Pipe Bedding and Transition Zone:** The 4 to 6 inch diameter perforated underdrain pipe(s) must be bedded in 12 to 14 inches of underdrained material with at least 4 inches of material beneath the pipe and 4 inches above. Two options for pipe bedding are provided below:

   Option 1: The underdrain bedding material must consist of crushed stone meeting the MEDOT specification 703.22 Underdrain Type C for Underdrain Backfill Material (see Table 7-1). As a transition zone, the crushed stone bedding material must be covered with a 6 inch layer of well graded, clean, coarse gravel meeting the MEDOT specification 703.22 Underdrain Type B for Underdrain Backfill Material (see Table 7-1). Fines passing the #200 sieve in the gravel should be no more than 5% (preferably 2%). Underdrain pipes must be placed no further than 8 feet apart.

   Option 2: This is a less preferable design, but one that requires 6 inches less depth. It will be acceptable for areas where the head or depth to high seasonal water table is problematic.The underdrain material consists of well graded, clean, coarse gravel meeting the MEDOT specification 703.22 Underdrain

   Type B for Underdrain Backfill (see Table 7-1). The material must contain no more than 5% (preferably 2% or less) fines passing the #200 sieve. No transition zone is necessary since the drainage pipe is bedded in less pervious gravel. Underdrain pipes must be placed no further than 4 feet apart.

IMPORTANT
Design Tips -
All Underdrained Soil Filters

- The soil filter should be designed to drain in 24 hours or less.

- Provide a maintenance right-of-way to the filter for access by heavy equipment. Maintenance access shall be planted with grass and at least 10 feet wide with a maximum slope of 15% and a maximum cross slope of 3%.

Table 7-1
ME DOT Specifications for Underdrains (MEDOT #703.22)

Sieve Size	% by Weight
Underdrain Type B	
1”	90-100
1/2”	75-100
#4	50-100
#20	15-80
#50	0-15
#200	0-5
Underdrain Type C	
1”	100
3/4”	90-100
3/8”	0-75
#4	0-25
#10	0-5

7. **Soil Filter Bed:** The soil filter must be at least 18 inches deep on top of the gravel underdrain pipe bedding and must extend across the bottom of the entire filter area. This soil mixture shall be a uniform mix, free of stones, stumps, roots, or other similar objects larger than two inches. No other materials or substances that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations can be mixed within the filter. The resultant mixture should have minimal clay content with between 5% and 15% fines passing the #200 sieve. During construction, care should be taken to avoid compaction of both the gravel and soil filter. Compaction should be by saturation only, unless special low compaction equipment is available.

NOTE: Care should be taken, especially in areas where the predominant soil and overburden contains marine clay, to be sure that the sand and topsoil used in the mixture have very little or no clay content. Use of soils with more than 2 % clay content could cause failure of the system.

Two options are provided for materials used in the construction of the filter bed:

Option 1: The soil filter media must be composed of a thoroughly blended mixture of materials meeting the specifications in Table 7-2 below:

Table 7-2
Soil Filter Media (Option 1)

Filter Media	Mixture by Volume	Specification
Sand	50%-55%	MEDOT specification #703.01 Fine Aggregate for Concrete (see Table 7-3)
Topsoil	20%-30%	Loamy sand topsoil with minimal clay content and between 15 to 25% fines passing the #200 sieve
Mulch	20%-30%	Moderately fine, shredded bark or wood fiber mulch with less than 5% passing the 200 sieve

Table 7-3
ME DOT Specifications for Aggregate (MEDOT #703.01)

Sieve Size	% by Weight
3/8”	100
#4	95-100
#8	80-100
#16	50-85
#30	25-60
#60	10-30
#100	2-10
#200	0-5

Adjust the proportions based on the organic content and amount of fines of each component. If the sand is very clean or the topsoil is relatively coarse, use more topsoil and less sand while staying within the established ranges. If the sand is silty or the topsoil loamy, use more sand and less topsoil.

Option 2: The soil filter media must consist of a mixture of a coarse loamy sand soil with 20 to 30% by volume of moderately fine shredded bark or wood fiber mulch that has no more than 5% fines passing the #200 sieve. The coarse loamy sand used in the mixture should meet the sieve analysis specification provided in Table 7-4.

Table 7-4
Coarse Loamy Sand Sieve Analysis Specification (Option 2)

Sieve #	% Passing by Weight
10	85-100
20	70-100
60	15-40
200	8-15

8. **Geotextile Fabric:** A geotextile fabric with suitable characteristics must be placed between the gravel filter layer and adjacent soil. The fabric will prevent the surrounding soil from migrating into the filter and clogging the outlet. Use an appropriate geotextile design manual to choose a fabric that is compatible with the surrounding soil for the purposes stated above. Overlap seams a minimum of 12 inches. Do not wrap fabric over the top of the pipe bedding as it will cause clogging and will prevent flows out of the filter.

9. **Underdrain Outlet:** Each underdrain system must discharge to an area capable of withstanding concentrated flows and saturated conditions without eroding.

10. **Drainage:** The soil filter should be designed to completely drain in 24 hours or less.

11. **Sediment Pretreatment:** Pretreatment devices such as grassed swales, grass or meadow filter strips and sediment traps shall be provided to minimize the discharge of sediment to the underdrained soil filter. Pretreatment structures shall be sized to hold an annual sediment loading. An annual sediment load shall be calculated using a sand application rate of 500 lbs/acre for sanding of roadways, parking areas and access drives within the subcatchment area, a sand density of 90 lbs per cubic foot and assuming a minimum frequency of ten sandings per year.

12. **Access:** Maintenance access shall be planted with grass and at least 10 feet wide with a maximum slope of 15% and a maximum cross slope of 3%. This access should never cross the emergency spillway, unless the spillway has been designed for that purpose.

7.1.4 Grassed Underdrained Soil Filters Design Criteria

IMPORTANT
Design Tips - Grassed Underdrained Soil Filters

- The peak storage depth within the filter area may not exceed 18 inches if grassed.
- The soil filter should be designed to drain in 24 hours or less.
- The underdrained soil filter must be planted with a species tolerant of frequent inundation.

In addition to the general design and construction criteria, the following criteria apply to grassed underdrained soil filters.

1. **Treatment Volume:** The treatment volume of 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area must be stored on the surface of the grassed filter. No credit may be taken for storage within the soil media.

2. **Impoundment Depth:** The peak surface storage depth within the filter area for the water quality volume may not exceed 18 inches.

3. **Vegetation:** The underdrained soil filter must be planted with a species tolerant of frequent inundation. An example would include a wetland seed mix containing the following:

Wetland Seed Mix

Scientific Name	Common Name
Carex vulpinoidea	Fox Sedge
Carex comosa	Bearded Sedge
Carex lurida	Lurid Sedge
Juncus effusus	Soft Rush
Euthamia graminifolia	Grass-leaved Goldenrod
Eupatorium perfoliatum	Boneset
Carex lupulina	Hop Sedge
Verbena hastata	Blue Vervain
Carex gynandra	Nodding Sedge
Scirpus atrovirens	Green Bulrush
Onoclea sensibilis	Sensitive Fern
Iris versicolor	Blue Flag Iris
Scirpus cyperinus	Woolgrass
Eupatorium maculatum	Spotted Joe Pye Weed
Asclepias incarnata	Swamp Milkweed
Mimulus ringens	Monkey Flower
Shoenoplectus tabernaemontani (ex. - S. validus)	Soft-Stem Bulrush
Schoenoplectus acutus (ex. - Scirpus acutus)	Hard-Stem Bulrush
Bidens cernua	Nodding Bur Marigold
Aster umbellatus	Flat-top Aster

To obtain an annual sediment volume, perform the following calculation:

$$\underset{(acres)}{\textit{Area to be sanded}} \times 500\ \frac{pounds}{acre\text{-}storm} \div 90\ \frac{pounds}{ft^3} \times 10\ \frac{storms}{year} = \frac{\textit{cubic feet of}}{\textit{sediment/yr}}$$

7.1.5 Bioretention Cells Design Criteria

In addition to the general design and construction criteria, the following criteria apply to bioretention cells.

1. **Treatment Volume:** The treatment volume of 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area must be stored within the soil media and on the surface of the filter. One third of the soil filter volume may be included as storage volume when designing bioretention cells. This extra storage capacity is associated with the deeper root zones of the plants and increased evapotranspiration potential.

2. **Impoundment Depth:** The peak surface storage depth within the filter area for the treatment volume may not exceed 6 inches.

3. **Mulch:** Individual planting shall be mulched with 2 to 3 inches of cover. Acceptable mulch must be well aged, uniform in color, and free of foreign material including plant material. Well aged mulch is defined as mulch that has been stockpiled or stored for at least twelve (12) months.

4. **Plant Species:** Native plant species should be chosen based on their toleration of urban stresses such as expected pollutant loading, variable moisture condition, ponding water, soil pH. A list of appropriate plant species has been provided in Appendix B of Volume I. Beware of invasive plant species.

IMPORTANT
Design Tips - Bioretention Cells

- Bioretention areas may be constructed as infiltration or underdrained soil filters depending on site soils. The design standards provided for these techniques must also be followed.
- Due to the deeper root zones of the plants and increased evapotranspiration potential, one third of the soil filter volume may be included as storage volume when designing bioretention cells.
- If used with infiltration, soil must be able to infiltrate pooled water within 3-4 hours. This requires an infiltration rate of greater than 1.5 in/hr. In tighter soils, an underdrain filter may be used to collect and discharge the treated water.
- See Appendix B of Volume I for appropriate plant species for Maine. A landscape designer or architect should be involved to select the appropriate plants for site conditions.

7.1.6 Maintenance Criteria

1. **Maintenance Agreement:** A legal entity should be established with responsibility for inspecting and maintaining any underdrained filter. The legal agreement establishing the entity should list specific maintenance responsibilities (including timetables) and provide for the funding to cover long-term inspection and maintenance.

2. **Soil Filter Inspection:** The soil filter should be inspected after every major storm in the first few months to ensure proper function. Thereafter, the filter should be inspected at least once every six months to ensure that it is draining within 24 hours.

3. **Soil Filter Replacement:** The top several inches of the filter shall be replaced with fresh material when water ponds on the surface of the bed for more than 72 hours. The removed sediments should be disposed in an acceptable manner.

4. **Sediment Removal:** Sediment and plant debris should be removed from the pretreatment structure at least annually.

5. **Mowing:** Filters with grass cover should be mowed no more than 2 times per growing season to maintain grass heights less than 12 inches.

6. **Fertilization:** Fertilization of the under-drained filter area should be avoided unless absolutely necessary to establish vegetation.

7. **Harvesting and Weeding:** Harvesting and pruning of excessive growth will need to be done occasionally. Weeding to control unwanted or invasive plants may also be necessary.

7.2 Proprietary Systems

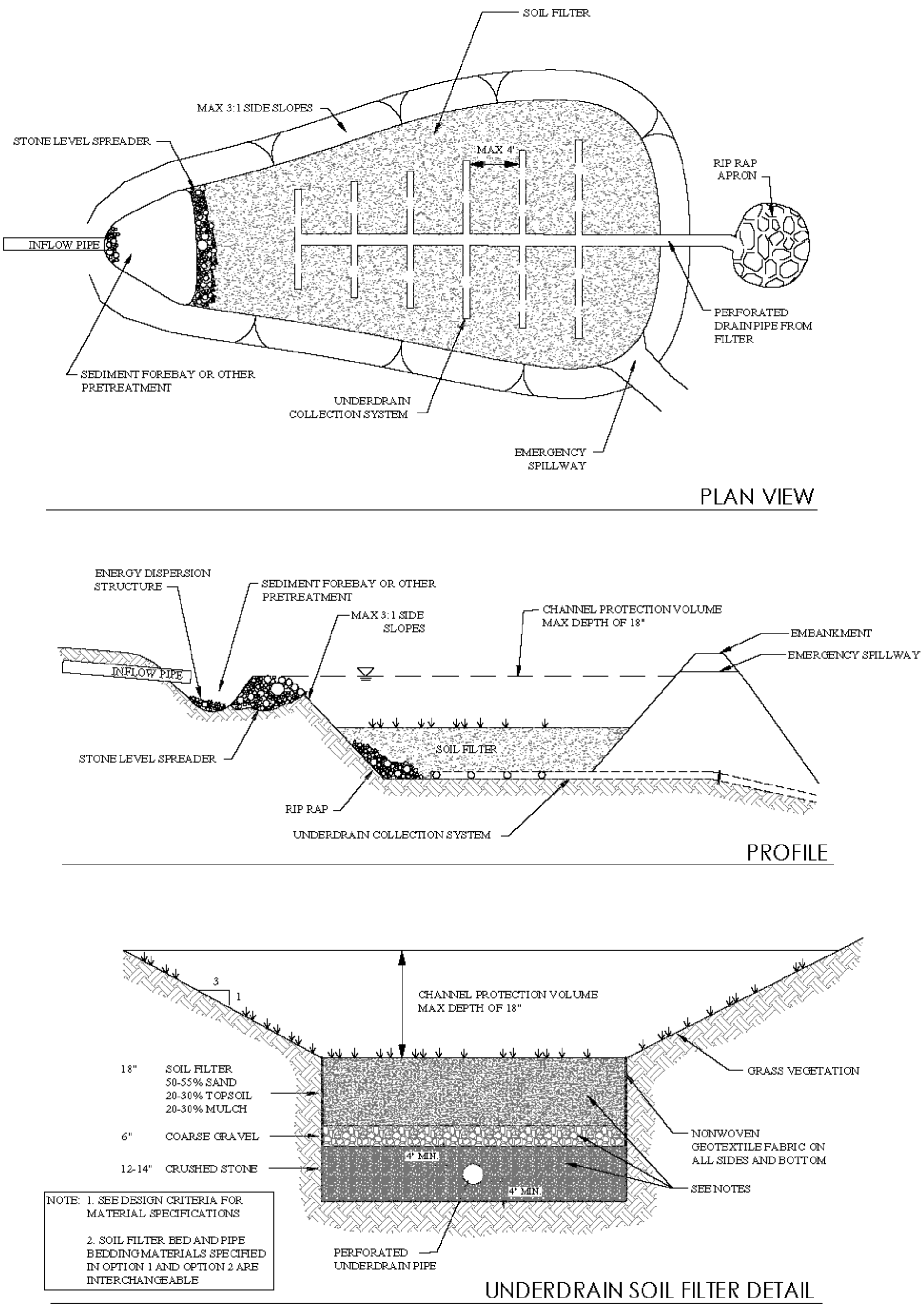

FIGURE 7-1. VEGETATED UNDERDRAIN SOIL FILTER FIELD (OPTION 1)

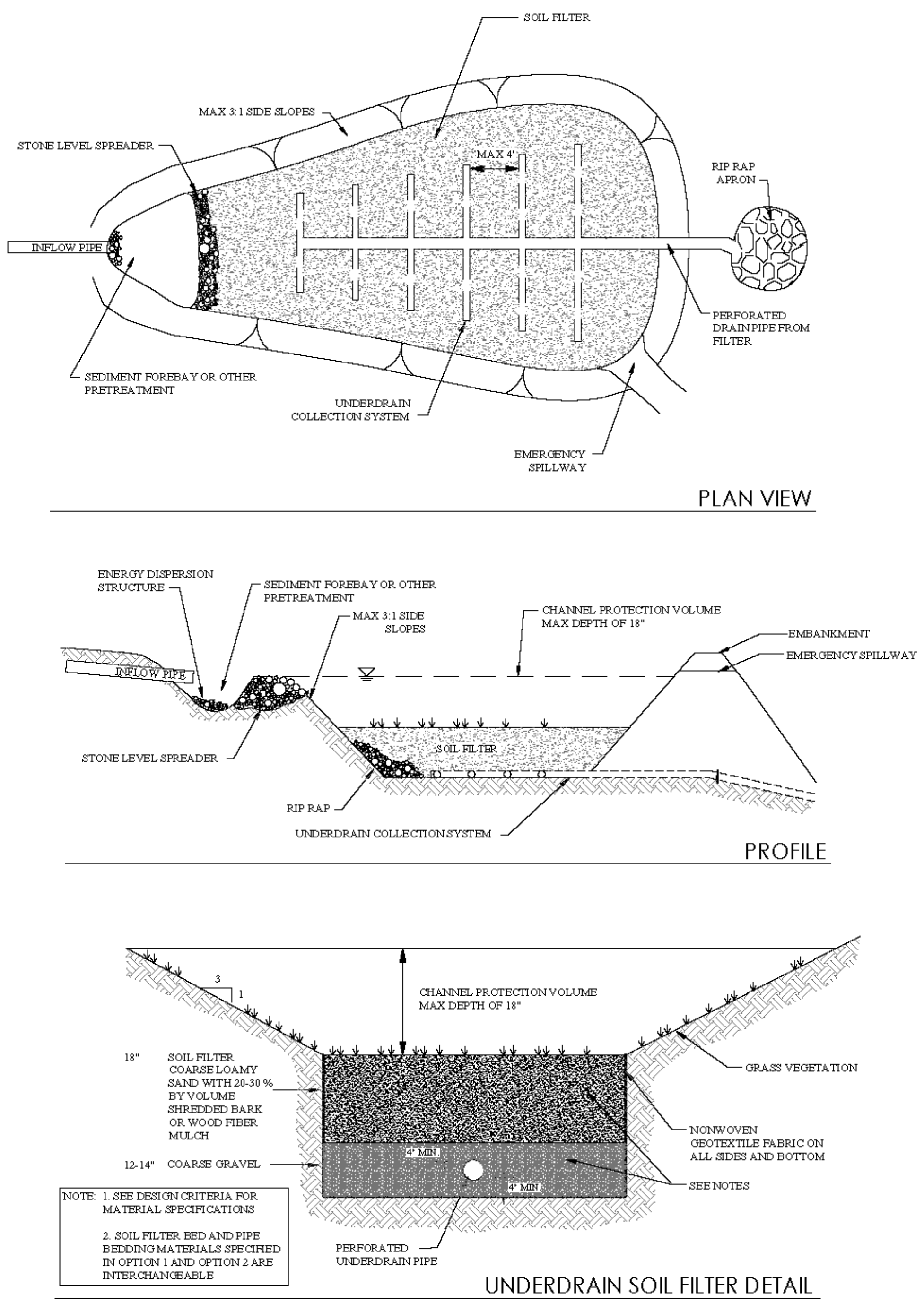

FIGURE 7-2. VEGETATED UNDERDRAIN SOIL FILTER FIELD (OPTION 2)

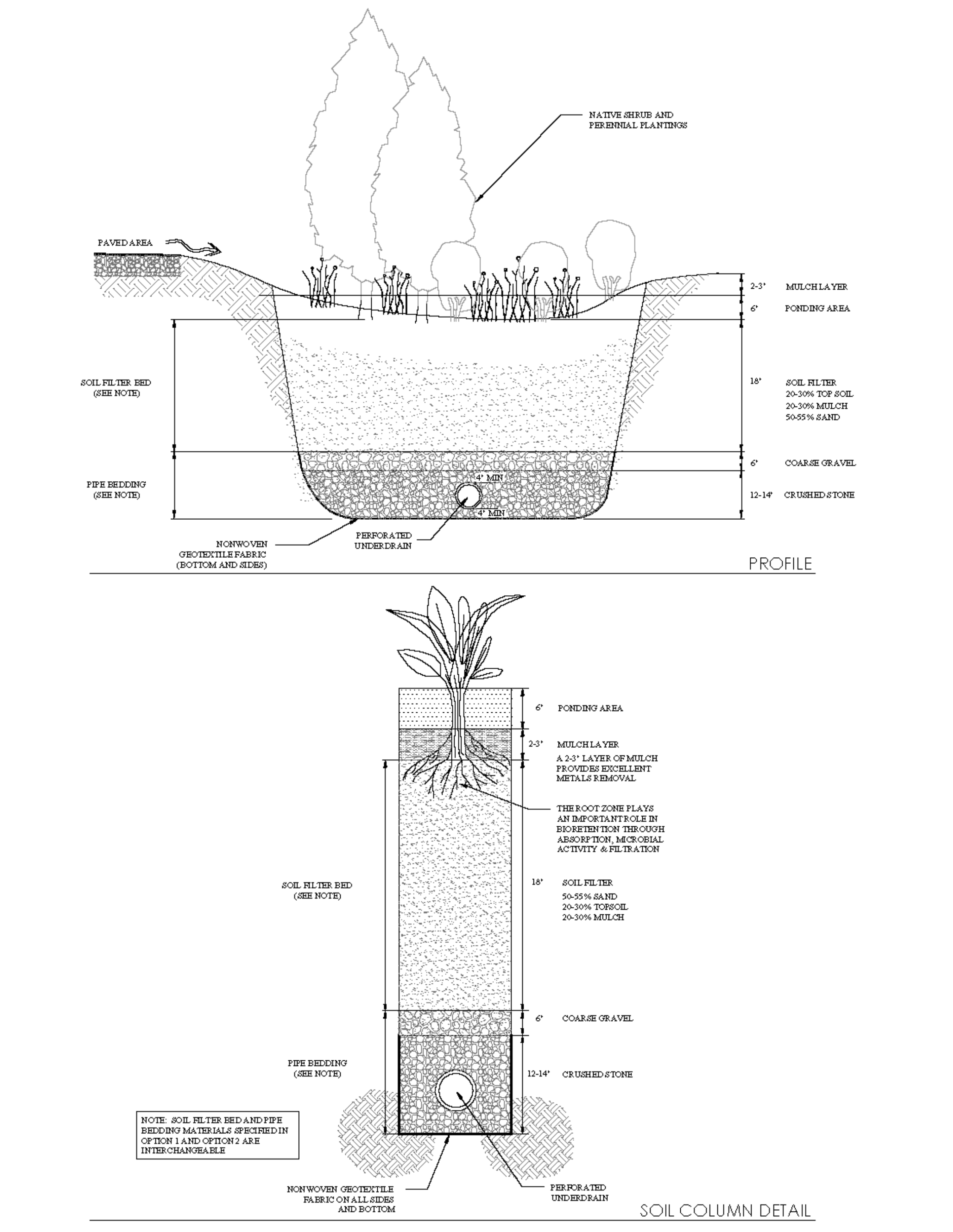

FIGURE 7-3. TYPICAL BIORETENTION CELL (OPTION 1)

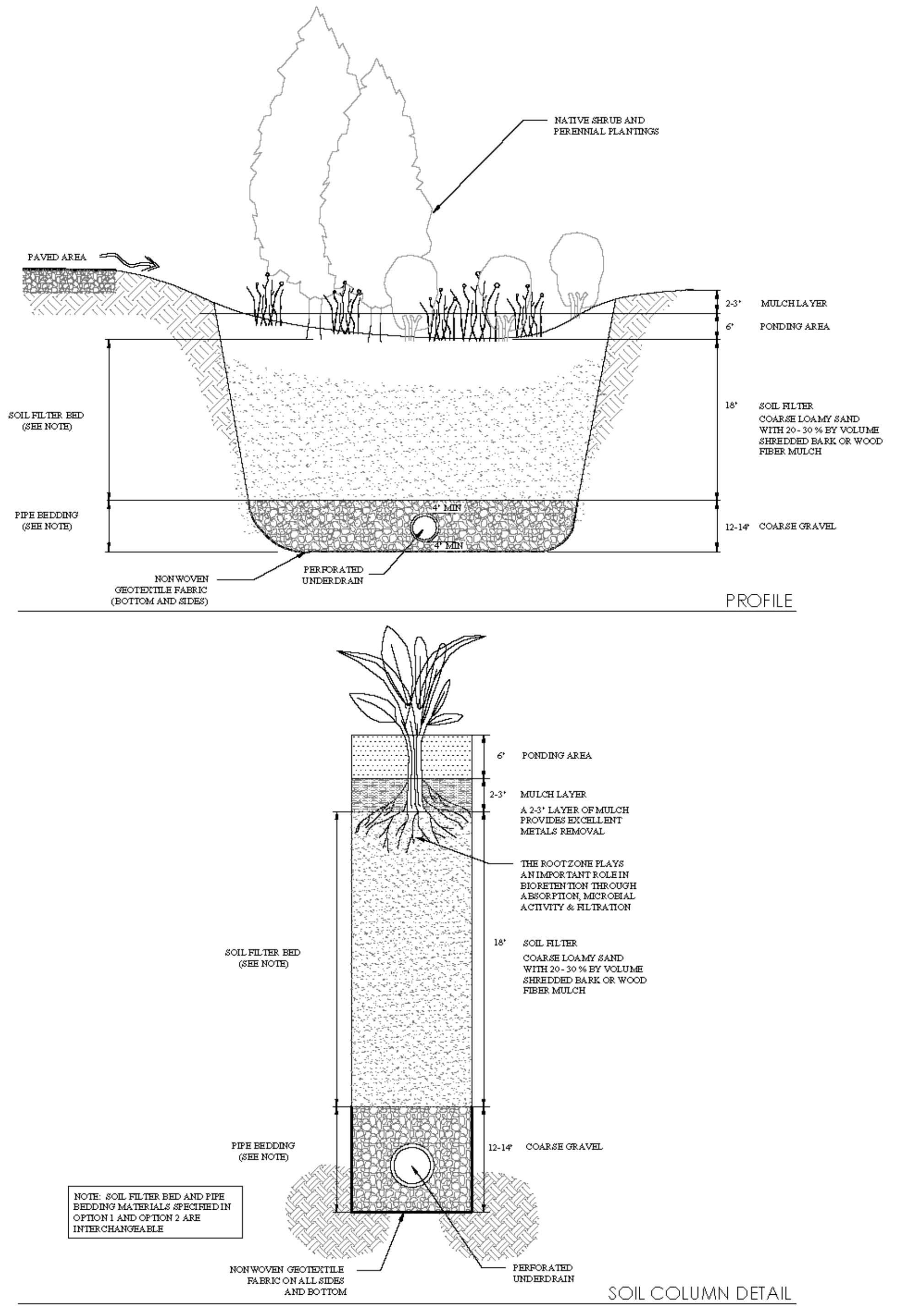

FIGURE 7-4. TYPICAL BIORETENTION CELL (OPTION 2)

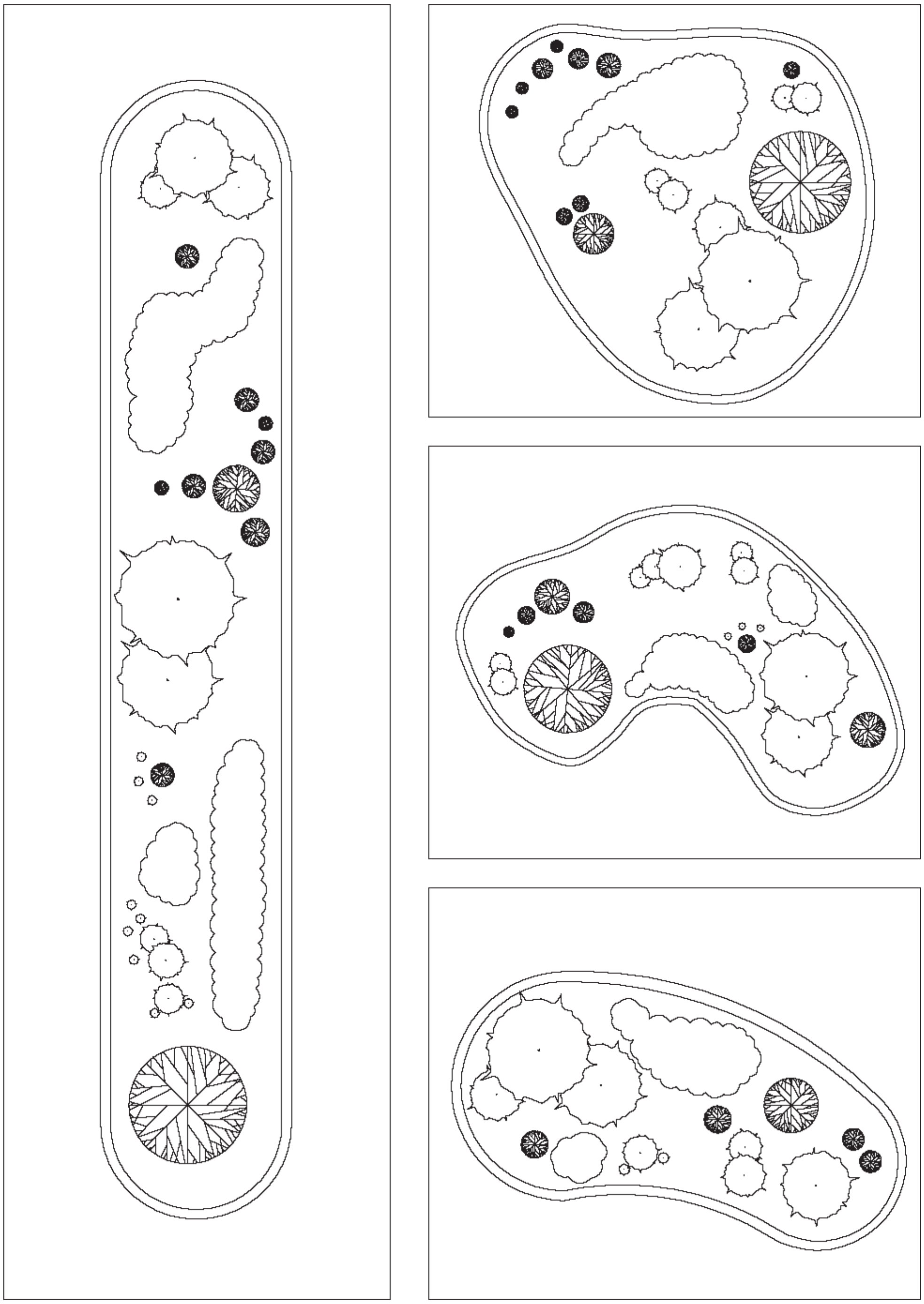

FIGURE 7-5. ALTERNATIVE SOIL FILTER LAYOUTS

NOTE: ALTERNATIVE LAYOUTS CAN BE USED FOR BOTH VEGETATED UNDERDRAIN SOIL FILTER FIELDS AND BIORETENTION CELLS