CHAPTER 10
STORMWATER BEST MANAGEMENT PRACTICES FOR WATER QUANTITY AND WATER QUALITY CONTROL

10.1 Introduction

Non-point source pollution is now responsible for up to 80 percent of pollution in waters of the U.S., which include streams, lakes, rivers, and wetlands. This is true, in part, due to significant reductions in direct discharges of pollutants by industry that have been achieved since passage of the Clean Water Act (CWA) of 1972. In urban areas, non-point source pollution occurs because stormwater runoff collects impurities while passing over rooftops, streets, parking lots, landscaping and gutters. This polluted stormwater runoff typically enters a storm drain system and is rapidly conveyed to a lake, stream, or river. The percentage of impervious land cover in urban and suburban watersheds generally indicates the level of pollutant impact on receiving waters. In most cases, impervious cover in excess of 30 percent results in streams that are considered "degraded," while impervious cover between 10 and 30 percent causes "impacts" on the receiving streams. Typical residential development results in approximately 35 percent of a watershed being impervious, which is more than enough to degrade the receiving waters. Realization of this fact is important, because healthy (non-impacted) streams are important for a healthy ecosystem, and a healthy ecosystem is important for all living creatures including people.

To protect our natural resources, the CWA of 1972, as amended in 1987, prohibits the discharge of pollutants to waters of the U.S. and mandates that stormwater not be discharged unless it is in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. LFUCG is responsible for ensuring that discharges of stormwater from public stormwater systems into waters of the state comply with CWA requirements. The implementation of the requirements contained in this manual will be a primary mechanism for accomplishing this objective.

Stormwater management in Fayette County shall include management for quality as well as quantity (flood protection). The general policies for control of quality and quantity were given in Chapter 1. This chapter gives detailed design information on the structural water quality and water quantity best management practices (BMPs) to implement these policies.

Permanent water quality treatment measures described in this chapter should not be confused with erosion and sediment controls required during construction, which are described in Chapter 11.

10.2 General Design Criteria

Stormwater management in Fayette County shall include management for quality and quantity. This section provides the general design criteria for both.

10.2.1 Water Quantity Control

Water quantity controls shall be implemented so that post-development peak discharges do not exceed pre-development discharges for those storms listed in Table 5-1.

10.2.2 Water Quality Controls

Research has indicated that capturing and treating 90 percent of the total annual runoff volume provides effective water quality treatment volume based on removal of particulates. Effective removal of solid particles in the runoff also provides for removal of significant amounts of nitrogen, phosphorus, and oil and grease. Ninety percent of the annual runoff seems to be a large volume, but the storm events that cumulatively produce this runoff volume in Fayette County produce less than 1.6 inches of runoff each. Using historical rainfall records, typical soil parameters, and the SWMM model, the runoff depth necessary for 90 percent runoff capture was approximated as a function of percent impervious area. These values, which are shown in Table 10-1, represent the water quality depth that shall be treated for each development. For example, a 20-acre development that is 40 percent impervious has a water quality depth of 0.7 inches over the whole area (not just the impervious area), resulting in a water quality volume (WQV) of 50,820 cubic feet.

In addition to carrying pollutants, stormwater runoff from developed areas increases the frequency and duration of bankfull flows in the receiving streams, causing increased erosion of the stream banks and further degradation of in-stream water quality. On-site infiltration, designed for the increased runoff due to development, is the preferred solution to this impact.

TABLE 10- 1
WATER QUALITY DEPTH VERSUS PERCENT IMPERVIOUS SURFACE

% Impervious Surface	Water Quality Depth (inches)
0 to 9	0
10	0.4
20	0.5
30	0.6
40	0.7
50	0.85
60	1.0
70	1.15
80	1.3
90	1.45
100	1.6

Notes:
1) The Water Quality Volume (WQV) is the volume resulting from applying the prescribed Water Quality Depth to the drainage area to be developed.
2) For % impervious values between those given use linear interpolation.
3) Water quality controls are not required for sites that are less than 10% impervious.

10.3 Bioretention Systems

Bioretention is a practice to treat stormwater runoff using a conditioned planting soil bed and planting materials to filter runoff stored within a shallow depression. The method combines physical filtering and adsorption with biological processes. The system consists of a structure to spread flow, a pretreatment filter strip or grass channel, a sand bed, pea gravel overflow curtain drain, a shallow ponding area, a surface organic layer of mulch, a planting soil bed, plant material, a gravel underdrain system, and an overflow system. Figure10-1 shows a diagram of a bioretention system designed to receive runoff from a paved area.

10.3.1 Applicability

Bioretention systems are very effective for water quality treatment. Bioretention systems are particularly well suited for use in parking lot islands, roadside swales, and median strips.

10.3.2 Design Criteria

Size the area of the filter bed in accordance with the design WQV corresponding to the area draining to it. (See the next section for procedure).

Design the bioretention system to be on-line with an overflow catch basin, as shown in Figure 10-1, to handle volumes exceeding the design WQV.

Design the bioretention system to have a longitudinal slope of 0 to 1 percent.

Provide a pretreatment system composed of a pea gravel diaphragm and a grassed filter strip. The pea gravel diaphragm also serves as a flow spreader. Dimensions of the gravel diaphragm and grass filter strip shown in Figure 10-1 are minimums. When flow into a bioretention system is parallel to its long dimension (i.e., from a drainage swale), omit the gravel diaphragm shown in Figure 10-1 and provide a berm across the downstream end of the system to impede the flow. The top of the berm shall be level across the base of the bioretention system and be 12 to 18 inches high in the center.

Provide a planting soil bed with a minimum width of 4 feet and a minimum depth of 4 feet (including a 12-inch sand bed). The planting soil bed can be as wide as 15 feet. The area of the system is determined by the required area of the filter bed. The minimum length is 15 feet.

For widths greater than 10 feet, maintain at least a 2:1 length to width ratio.

Provide a pea gravel curtain drain, as shown in Figure 10-1. The minimum width of the curtain drain is 8 inches.

Provide a 2 to 3 inch thick mulch layer above the planting soil bed.

Grade the top of the planting soil bed to provide a shallow ponding area with a maximum depth of 6 inches.

Provide an underdrain system of gravel and perforated pipe. Design the gravel bed to be at least 8 inches deep. Connect the underdrain to the storm drainage system or design it to daylight to a suitable non-erosive outfall.

10.3.3 Design Procedures

Size the filter bed using the following equation:

$A_f = V*(d_f)/[k*(h_f + d_f)(t_f)]$
where:
A_f = surface area of the sand filter bed (ft^2)
V = treatment or infiltration volume (ft^3)
d_f = planting bed depth (ft)
k = coefficient of permeability for planting bed (ft/day)
h_f = average height of water above the planting bed (ft); $h_f = 0.5 * h_{max}$
t_f = time required for V to filter through the planting bed (days).

Note:
d_f = 4 feet (including sand filter) unless it is increased by designer
k = 0.5 feet/day (median value of a silt loam)
$h_f = 0.5 * h_{max}$ = 3 inches = 0.25 feet
t_f = 3 days.

Design the bioretention system to provide the minimum filter area required and to meet the design criteria.

10.3.4 Specifications

Provide planting soil with the following characteristics:

- pH of 5.2 to 7.0
- organic content of 1.5 to 4 percent
- magnesium of 35 pounds per acre minimum
- phosphorus (as P_2O_5) of 75 pounds per acre minimum
- potassium (as K_2O) at 85 ponds per acre minimum
- soluble salts less than 500 ppm
- clay content of 10 to 25 percent by volume
- silt content of 30 to 55 percent by volume
- sand content of 35 to 60 percent by volume
- free of stones, stumps, roots, or other woody material greater than 1 inch in diameter

Place planting soil in lifts of 12 to 18 inches and loosely compact or tamp lightly with backhoe bucket.

Provide shredded hardwood mulch aged at least 2 months. Place mulch layer 2 to 3 inches deep.

Provide clean river pea gravel for the curtain drain and diaphragm sized to meet ASTM D-448 size no. 6 with diameter ranging from 1/8 to ¼ inch.

Provide gravel for the underdrain sized to meet AASHTO M-43 with size range of ½ to 2 inches in diameter.

Provide PVC piping for the underdrain satisfying AASHTO M-278 standard for rigid schedule 40 pipe. Provide 3/8 inch diameter perforations on 6-inch centers with four holes per row.

Plant base of bioretention system (planting soil bed) in herbaceous ground cover and shrubs. Plant side slopes of bioretention system in herbaceous ground covers, vines, and shrubs. Trees may also be used in the bioretention system. Use direct seeding for herbaceous varieties and nursery stock for vines, shrubs, and trees.

Areas to be seeded with herbaceous varieties shall be roughened with a rake or similar tool. Seeding rates shall be minimum of 10 pounds of seed mix per 1000 square feet of area.

Bare root or containerized stock shall be planted at the same depth as planted in the nursery. The stock should be planted in a hole large enough to accommodate the root system when well spread. Shrubs and vines shall be planted at a minimum density of 1,700 stems per acre (one stem per 25 square feet at 5 feet on center).

Select herbaceous species for the planting soil bed from the following list. Use a minimum of two species.

Common Name	**Scientific Name**
Barnyard grass	*Echinochloa crusgalli*
Switch Grass	*Panicum virgatum*
Swamp Milkweed	*Asclepias incarnata*
Giant Cane	*Arundinaria gigantea*
Jewelweed	*Impatiens capensis*
River oats	*Chasmanthium latifolia*
Deertongue	*Panicum clandestinum*
Boneset	*Eupatorium perfoliatum*

Select herbaceous species for the side slopes from Table 9-1 in Chapter 9. Also, select vines, shrubs, and trees from Table 9-1.

10.4 Infiltration Systems

Infiltration practices and/or bioretention systems reduce the adverse impacts on the receiving waters that result from increasing the impervious area. This chapter describes several infiltration practices that can be used in many different situations. Many of the practices cannot function as the sole water quality infiltration and treatment device, but will provide significant "credits" toward reducing the magnitude of the runoff that must be detained and treated.

Infiltration practices include a variety of practices such as directing downspouts to grassed areas and using modular pavement. Infiltration practices also include swales, terraforming, infiltration, and vegetative filters. Terraforming is a term for special grading practices such as terracing and berming that are intended to promote infiltration. This section presents infiltration practices and describes the minimum requirements that must be met to obtain credits to reduce water quality treatment volumes.

The infiltration volume credit listed for each practice can be used to satisfy an equal amount of water quality volume.

10.4.1 Downspouts to Grass

Discharging downspouts from roofs onto grassed yards encourages infiltration and reduces direct discharge to impervious areas such as driveways. The grass area shall be greater than or equal to the roof area.

Infiltration Credit
When downspouts are discharged onto grass, the infiltration credit is 0.225 acre-feet per acre of roof area.

Design Criteria
The lot must be graded so that the downspout discharge travels at least 30 feet over grass before reaching a driveway, roadway, paved ditch, or any other impervious conveyance.

10.4.2 Modular Pavement

Modular pavement consists of strong structural materials, typically concrete, having regularly interspersed void spaces that are filled with pervious materials such as sand, gravel, or sod. These pavements can be used as driveways or as overflow parking in areas that are used less frequently than the main parking areas for civic, commercial, and industrial facilities. Modular pavement can be used for any portion of parking up to that amount allowed by the LFUCG Planning Commission.

Infiltration Credit
Any area that is paved using modular pavement can be treated as pervious for purposes of calculating WQV and post-development peak runoff, as long as appropriate design criteria and construction specifications are satisfied.

Design Criteria
Large void spaces in modular pavement shall represent at least 30 percent of the total surface area of the pavement.

Voids shall be filled with silty soil and vegetated with permanent grass. If vegetation is inappropriate, voids may be filled with sand or gravel, but the material shall be clean and uniform (poorly graded) to ensure high permeability.

Construction Specifications
Install all modular pavements following manufacturer's specifications.

To prevent premature clogging and/or failure, modular pavements shall not be placed into service until the entire contributing surface drainage area has been completely stabilized.

Clearly mark the planned area for modular pavement to prevent heavy equipment from compacting the underlying soils.

Excavate the subgrade soil using equipment with tracks or oversized tires to minimize compaction.

10.4.3 Swales

Swales are typically vegetated parabolic or trapezoidal channels with a large width to depth ratio that are used for conveying stormwater runoff. Swales can act both as vegetated filters and infiltration practices because they tend to slow runoff rates and allow for both particle settling and stormwater infiltration. Swales are encouraged wherever they can be used as an alternative to narrower, deeper channels that tend to convey flow at higher velocities. Swales are especially effective in reducing water quality impacts when used for roadside drainage instead of the traditional curb inlet/storm sewer system. In this application, curb cuts are used instead of drop inlets in the gutter. See Figure 10-2.

Swales can be even more effective when constructed using berms or infiltration beds to encourage additional ponding and infiltration. These cases are discussed in subsequent sections.

Infiltration Credits
When swales are used, the infiltration credit is 0.25 acre-feet per acre of swale. To obtain this credit, the area draining to the swale must be at least three times the area of the swale considering that the swale itself is part of the drainage area.

To calculate the area of the swale, the width will be the average water surface width corresponding to the flowrate associated with the 100-year storm.

Design Criteria

To be considered a swale, a channel must have a width to depth ratio of at least 6:1, have a bed slope of not greater than 4 percent, and be vegetated. When swales are used for roadside drainage, curb cuts shall be provided no less frequently than one per each 100 feet of curb.

Drop inlets in swales shall be spaced no closer than once per each 300 feet in order to obtain the infiltration credit.

Grassed channels that do not satisfy the design criteria to be considered swales may be given an infiltration credit only for the channel bottom, if the bed slope does not exceed 4 percent.

10.4.4 Bermed Swales

A bermed swale or infiltration swale is a grassed swale constructed with berms or swale blocks across the swale to impound shallow pools of water, slowing flow and providing additional opportunities for particle settling and stormwater infiltration.

Infiltration Credit

Infiltration credit for a bermed swale is calculated in the same manner as the credit for a swale, except that the calculated infiltration credit can be increased by 50 percent of the water volume that can be impounded by the berms.

Design Criteria

Swale blocks or earthen berms built across the swale shall be constructed with a 2-inch diameter PVC pipe through the berm to prevent long-term ponding of water.

Berms shall be no taller than 8 inches and spaced no closer than 60 feet.

Drop inlets in swales shall be spaced no closer than once per each 300 feet in order to obtain the infiltration credit.

Grassed channels that do not satisfy the design criteria to be considered swales may be given an infiltration credit only for the channel bottom, if the bed slope does not exceed 4 percent.

10.4.5 Biofiltration Swales

A biofiltration swale is a version of a bioretention system without the pipe underdrain system. This practice encourages infiltration from the swale bottom, through a planting bed, to the underlying soil. See Figure 10-3.

Infiltration Credit

Infiltration credit for a biofiltration swale is 0.50 acre-feet per acre of swale plus 100 percent of the volume of the ponded water, when designed according to the following criteria. If biofiltration swales are designed consistent with the procedures for bioretention systems, the infiltration credit equals the design treatment volume.

Design Criteria
Biofiltration swales shall be designed to have the following characteristics:

- trapezoidal or parabolic shape
- bottom width of 2 feet
- side slopes no steeper than 3:1
- longitudinal slope of 1 to 2 percent (up to 4 percent slope can be used with berms constructed as required for bermed swales)
- length, width, depth, and slope necessary to provide surface storage of the design volume with a maximum ponded depth of 18 inches
- vegetated in accordance with requirements for vegetated channels with grass lining
- capacity to convey the 100-year design storm with at least 6 inches of freeboard
- a soil bed 36 inches deep having the width of the swale bottom

Plan the soil bed to consist of soils that have a permeability of at least 0.5 feet per day (USCS soils ML, SM, or SC). If native soils do not satisfy this criterion, a prepared soil bed can be designed.

An alternative to the above criteria is to size the filter bed (i.e., planting soil bed) for a biofiltration swale consistent with a bioretention system. Then the infiltration credit would be calculated in the same manner as the credit for bioretention.

10.4.6 Terraforming

Terraforming is a term for special grading practices such as terracing and berming that are intended to promote infiltration. Bermed swales are a special case of terraforming. Terraforming can range from a small depression in permeable soil to an extensive series of bermed terraces. A simple example is given in Figure 10-4.

Infiltration Credit
The infiltration credit for terraforming is 0.25 acre-feet per acre of area terraformed plus 100 percent of the impounded water.

10.4.7 Infiltration Basins

Infiltration basins may be used in locations that have at least 5 feet of soil, with a permeability of at least 0.5 inches/hour underlying the device. The underlying 5 feet of soil must also be above the seasonal high water table.

If soils do not meet the permeability requirement, they can be modified by mixing sand and gravel in the top 5 feet of the soil underlying the device. If native soils are to be modified with sand or gravel, provide a design that shows the depth of soil to be modified and the total quantity of gravel or soil to be added. Include soil test data documenting the permeability of the soils before and after modification.

If desired, large infiltration basins can be designed much like an extended detention pond for storm peak control. The outlet structure and detention storage volumes are designed to be above the level needed to store the design WQV. The difference is that an infiltration basin does not have an extended detention outlet. Instead, the WQV is allowed to infiltrate into the soils underlying the basin. If the infiltration basin is not intended for peak flow control, it shall be designed so that volumes exceeding the WQV can discharge through an overflow weir or pipe. For small excavated basins of less than one-fourth acre, volumes exceeding the WQV may be allowed to overflow onto the ground surface without use of an overflow structure, if proper erosion control measures are implemented.

The infiltration credit for an infiltration basin is simply the volume designed to be impounded before overflow or discharge to a spillway.

Design Criteria

Test soils prior to designing an infiltration basin to ensure that the site is capable of infiltration. Obtain a minimum of three soil test borings or test pits to verify that the soil is at least 5 feet deep below the base elevation and has a permeability of at least 0.5 inch/hour.

Design the floor of the basin to be as flat as possible to promote infiltration. Provide side slopes not greater than 3:1 (h:v).

Provide a sediment forebay at the inlet to the basin with a depth of at least 4 feet and a volume of at least 10 percent of the WQV.

Size the basin to store the design WQV before discharging through the peak flow control outlet. If the basin is intended only for water quality treatment, design an outlet that allows volumes in excess of the WQV to discharge to a surface water conveyance.

If a base flow will be discharged into the infiltration basin, design a low flow orifice to allow base flow to pass through.

Adjust the storage depth so that the basin will completely drain the WQV in 72 hours.

When using an infiltration basin for peak flow control, provide a minimum of 1 foot of freeboard above the 100-year design storm high water elevation.

Impoundment depths shall not exceed 15 feet and storage volumes shall not exceed 25 acre-feet.

Design earthen embankments with side slopes not steeper than 3:1 (horizontal to vertical).

Design basins to be placed outside the receiving stream except when a basin is designed as a regional detention basin and LFUCG has approved its use as a regional basin.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least 10 feet wide, with a slope not greater than 5:1

(h:v). Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope not greater than 5:1 (h:v).

Provide a minimum 25-foot wide buffer strip between the basin and the nearest lot. Landscape the buffer strip with low-maintenance native grasses, shrubs, and trees. Provide a landscaping plan for the basin and the buffer. Objectives of landscaping include improving the appearance for adjacent residents and providing wildlife habitat.

Specifications

Embankment, outlet, and emergency spillway specifications are consistent with those for detention basins.

Excavate the basin with light equipment having tracks or over-sized tires to minimize compaction of the underlying soils. After the basin is excavated to the final design depth, deeply till the basin floor with a rotary tiller or disc harrow to restore infiltration rates. After tilling, apply a leveling drag.

Establish vegetation immediately after achieving final grade and preparing the infiltration bed. Stabilize the floor of the basin with a dense cover of water-tolerant herbaceous species consistent with requirements of bioretention systems.

10.4.8 Vegetated Filter Strips

A vegetated filter is a practice that relies upon the use of vegetation to filter out sediment and other pollutants from stormwater runoff. These filters also provide an opportunity for stormwater runoff to infiltrate. Vegetated filters can be used as water quality devices. Vegetated filters can be used for small subareas of a larger development in order to reduce the total volume to be treated by other devices in the development.

A filter strip is a practice that relies upon sheet flow across the entire width of the vegetated area. The vegetation is typically grass; however, other ground cover can be used if it provides for dense vegetation. Filter strips are typically used at the edge of a parking lot or other paved surface.

Design Criteria

Design a filter strip to have a width matching the width of the area draining to the filter.

Design a filter strip to have a smooth transition with the area draining to it so that sheet flow can be developed across the filter.

Design filter strips to have a minimum slope of 2 percent and a maximum slope of 6 percent.

Provide a dense turf or other comparable vegetated ground cover over the whole filter area.

When the contributing area draining to the filter strip is impervious, do not allow the overland flow length of the impervious surface to exceed 75 feet.

When the contributing area draining to the filter strip is pervious, do not allow the overland flow length of the contributing surface to exceed 150 feet.

Infiltration Credit
The infiltration credit for vegetated filters is 0.075 acre-feet per acre of filter.

10.4.9 Riparian Buffers

Riparian buffers are vegetated zones of trees and/or shrubs adjacent to and upgradient from perennial or intermittent streams, lakes, ponds, and wetlands. See Chapter 9 for more information. In the ideal scenario, native riparian buffers would exist adjacent to all receiving waters. However, in many agricultural areas the native riparian buffer has been partially or fully removed to create pasture or cropland right up to the top of streambank. Existing riparian buffers cannot be used for infiltration or water quality credit, but restoration or reforestation of riparian buffers can be used to provide infiltration credit.

Design Criteria
Design a plan for riparian buffer reforestation/revegetation in accordance with requirements of Chapter 9.

In order to obtain infiltration credit for re-establishing a riparian buffer zone, the streambank must also be restored in accordance with Chapter 9.

Infiltration Credit
The infiltration credit for re-establishing a riparian buffer zone is 0.5 acre-feet per acre of buffer restored.

In order to obtain this credit, a buffer zone planting plan must be included with the improvement plans. The plan shall also provide for maintenance of the buffer zone until such time as trees and shrubs are established and the upgradient drainage area is permanently stabilized.

10.5 Sand and Organic Filters

In general usage, stormwater filters are a diverse group of techniques for treating stormwater quality with each using some sort of filtering media such as sand, soil, gravel, peat, compost, or vegetation. Filters will include systems with a designed filter bed composed of sand, gravel, compost, or peat and an outlet to the stormwater drainage system or a receiving stream. Systems described in this section include surface sand filters, underground sand filters, perimeter sand filters, and organic filters.

10.5.1 Applicability

Filters can be used for water quality treatment, but are not appropriate for peak flow (quantity) control.

10.5.2 General Design Criteria

Design criteria in this section apply to all filtration devices in this section.

Provide a pretreatment cell to allow sedimentation prior to the filter bed and reduce clogging.

Locate inlet and outlet structures at extreme ends of the pretreatment cell.

Design the pretreatment or sedimentation cell to have a minimum depth of 3 feet to minimize resuspension and turbulence.

Design the bottom of the pretreatment cell to be nearly level to facilitate sedimentation.

Design the surface area of the pretreatment cell (in square feet) to be at least 0.0081 times the WQV (in cubic feet) for areas with 75 percent or more impervious surface. For areas with less than 75 percent impervious surface, design the surface area of the pretreatment cell (in square feet) to be at least 0.066 times the WQV (in cubic feet). The order of magnitude difference in the two factors derives from the fact that areas with higher percentages of impervious surface (i.e., 75 percent or more) tend to have a greater proportion of coarse-grained sediments, which have a higher settling velocity.

Size the pretreatment cell with a minimum length to width ratio of 2:1.

The length to width ratio of the pretreatment cell can be less than 2:1 if baffles are provided to obtain a flow length equivalent to or greater than would be obtained with a 2:1 ratio.

Design each filtering device for a capture or storage volume equal to or greater than ¾ times the WQV.

Design filtration systems to be off-line by using a flow-splitter or other device to divert flows in excess of the WQV around the filtration systems.

Provide sufficient access to the device for construction and maintenance. Provide an access ramp with a maximum slope of 10 percent for vegetated ramps, 15 percent, if the slope is stabilized with crushed stone, or 25 percent if paved.

Construct exposed piping and accessories out of durable, strong materials to avoid susceptibility to damage by vandalism.

Provide access manholes and/or grates to underground and below grade structures for each subsurface chamber. Provide manhole diameters of at least 30 inches to meet confined space access criteria. Place manhole steps to allow maintenance personnel easy access to structure bottoms. Provide a 5-foot minimum height clearance (from the top of the sand layer to the bottom of slab) for all fixed permanent underground structures. Provide lifting rings or other suitable elements to lift and replace structure top slabs.

Construct the underground sand filter with a dewatering gate valve located just above the top of the sand filter bed. Should the filter bed and/or underdrain system clog completely, the gate valve can be opened to dewater the filter chamber for needed maintenance.

10.5.3 Surface Sand Filter

A surface sand filter is shown in Figure 10-5. This system is constructed of reinforced concrete with a pretreatment (sedimentation) chamber and a filter bed chamber with a sand filter and underdrain system. Figure 10-5 also shows a flow diversion chamber at the inlet end of the structure. The filter bed has an 18-inch to 24-inch sand layer which traps or strains pollutants before runoff is collected in an underdrain system (gravel and perforated pipe) and conveyed to the receiving stream, channel or pipe. The filter bed surface may have a sand or grass cover.

Surface sand filters are open at the top, which provides easy access for maintenance, but renders these unsuitable in areas easily accessible to the general public, especially small children. Control access to surface sand filters by enclosing them in an eight-foot chain link fence. Such a configuration is most suitable to industrial and warehousing facilities rather than commercial/retail establishments where aesthetic impact is significant. Even for industrial sites, consider proximity to residential areas and other locations frequented by children. In some locations, an eight-foot fence may not provide adequate protection.

Design Procedures
Size the pretreatment chamber in accordance with design criteria in 10.5.2.

Size the area of the filter bed using the following equation:

$A_f = WQV*(d_f)/[k*(h_f + d_f)(t_f)]$
where:
A_f = surface area of the sand filter bed (ft^2)
WQV = water quality treatment volume (ft^3)
d_f = sand filter bed depth (ft)

k = coefficient of permeability for sand bed (ft/day)
h_f = average height of water above the sand bed (ft); $h_f = 0.5 * h_{max}$
t_f = time required for the WQV to filter through the sand bed (days).

Note:

- set d_f such that 1.5 feet $\leq d_f \leq$ 2 feet
- h_f can vary depending on the site conditions, but six feet is the maximum value.
- Use 1.7 days (i.e., 40 hours) for the filter bed draw-down time (t_f).
- Use k = 3.5 ft/day.

Design the underdrain system beneath the filter bed to be at least six inches deep, with at least two inches of gravel over drain pipes and pipe slopes of at least 0.5 percent.

Design the underdrain system to ensure that the flow through rate of the filter bed is controlled by the filter media rather than the underdrain system.

Calculate the minimum volume which must be stored within the device as V_{min} = 0.75 (WQV).

Compute the water volume within the filter bed as $V_f = A_f * 0.35 * (d_f + d_u)$, where d_f is the depth of the sand bed and d_u is the depth of the gravel underdrain. The constant 0.35 represents the porosity of the sand and gravel. Figure 10-6 provides an illustration of the parameters used for calculating storage volume.

Compute the temporary storage volume above the filter bed as $V_{f-temp} = 2 * h_f * A_f$.

Compute the remaining volume required for the pretreatment chamber as $V_s = V_{min} - (V_f + V_{f\text{-}temp})$. Check that V_s is approximately 50 percent of V_{min}. If it is not, decrease h_f and recompute. Note that changing h_f will change the computed A_f.

Calculate the height in the pretreatment chamber, h_s, as $h_s = V_s/A_s$.

Check that h_s is greater than $2 * h_f$ and h_s is greater than 3 feet. If not, adjust h_f and repeat computation.

Design a junction box flow splitter with either a pipe or weir overflow to the stormwater system. Set the invert of the overflow to the elevation of the design water level in the pretreatment chamber. Design the overflow to convey the peak discharge anticipated from the 10-year storm.

Design the structural concrete components in accordance with design loads and site soil conditions.

Specifications

Select sand to meet AASHTO M-6 or ASTM C-33 requirements for medium aggregate concrete sand with size range of 0.02 to 0.04 inches.

Select underdrain gravel to meet AASHTO classification M-43 with size range of 0.5 to 2 inches.

Select geotextile fabric to have a minimum puncture strength of 125 pounds (ASTM D-751), minimum mullen burst strength of 400 psi (ASTM D-1117), and minimum tensile strength of 300 pounds (ASTM D-1682). Geotextile fabric shall have an opening size equivalent to U.S. sieve size #80 and shall provide a minimum flow rate of 125 gallons/minute per square foot.

Select underdrain piping to meet AASHTO M-278 requirements for Schedule 40 PVC pipe. Provide 3/8-inch perforations on 6-inch centers with four holes per row.

Construct the base of the sand filter structure on undisturbed soil or rock. If disturbed soil must be used as a base, recompact it to 95 percent of maximum standard dry density in 6-inch compacted lifts.

Do not allow runoff to enter the sand filter bed until the upstream drainage area is completely stabilized and site construction is completed. The sedimentation pond may serve as a temporary sediment control pond during site construction with the provision that overflows will bypass the filtration bed.

Construct the top of the filter bed completely level.

Store materials which might be damaged during construction (such as perforated PVC piping, geotextiles, etc.) in a safe location and handle carefully.

Construct overflow weirs, multiple orifices and flow distribution slots completely level to ensure adequate distribution of design flows.

Construct the main collector pipe for underdrain systems at a minimum slope of 0.5 percent. Provide observation and clean-out pipes for all underdrain piping.

10.5.4 Underground Sand Filter

Underground sand filters are suitable for intensely developed urban areas where space is at a premium. These systems are also suitable in locations that are easily accessible to the public. Figure 10-7 shows an underground sand filter. In this design, the sand filter is placed in a three chamber underground vault accessible by manholes or grate openings. The first chamber is a 3-feet deep sediment chamber used for pretreatment. It is connected to the second chamber (the sand filter bed) by an inverted elbow or submerged slot, which keeps the filter surface free from trash and oil. The filter bed is 18 to 24 inches in depth and has a protective screen of gravel over filter fabric to act as a pre-planned failure plane that can easily be replaced when the filter surface becomes clogged. During a storm, the water quality volume is temporarily stored in both the first and second chambers. Flows in excess of the filter's capacity are diverted through an overflow weir.

Design Procedures

Design procedures are consistent with those described previously for a surface sand filter with the following exceptions. See Figure 10-8 for an illustration of the volume parameters.

After computing the minimum volume which must be stored (V_{min}) and the volume in the filter bed (V_f), compute the minimum wet pool volume in the settling basin as $V_w = 3\ ft * A_s$.

Compute the temporary storage volume required within both chambers as $V_{temp} = V_{min} - (V_f + V_w)$.

Compute the total surface area of both chambers as $(A_f + A_s)$.

Calculate the height of temporary storage needed as $h_{temp} = V_{temp}/(A_f + A_s)$.

Check that h_{temp} is greater than or equal to $2h_f$. If not, decrease h_f and recalculate volume requirements.

Specifications

Specifications are consistent with those provided for surface sand filters with the following addition.

To help extend the design life of the sand filter bed for the underground sand filter, place a wide mesh geotextile screen on the surface of the filter bed to trap the large quantities of trash, litter, and organic detritus associated with highly urban areas. During maintenance operations the screen is rolled up, removed and cleaned, and reinstalled.

10.5.5 Perimeter Sand Filters

The perimeter sand filter consists of two parallel trench-like chambers that are typically installed along the perimeter of a parking lot. Figure 10-9 shows a perimeter sand filter. Parking lot runoff enters the first chamber that has a shallow permanent pool of water. The first trench provides pretreatment before the runoff spills into the second trench, which consists of an 18-inch deep sand layer over a gravel/perforated pipe underdrain system. During a storm event, runoff is temporarily ponded above the normal pool and sand layer, respectively. When both chambers fill up to capacity, excess parking lot runoff is routed to a bypass drop inlet.

Design Procedures

Design procedures are consistent with those described previously for a surface sand filter with the following exceptions. See Figure 10-10 for an illustration of the volume parameters.

After computing the minimum volume which must be stored (V_{min}) and the volume in the filter bed (V_f), calculate the minimum wet pool volume in the pretreatment basin as $V_w = A_s * 2\ ft$.

Calculate the temporary storage volume required as $V_{temp} = V_{min} - (V_f + V_w)$.

Compute the total surface area of both chambers as ($A_f + A_s$).

Check that h_{temp} is greater than or equal to $2h_f$. If not, decrease h_f and recompute areas and volumes. Note that changing h_f will change the required A_f.

Specifications
Specifications are consistent with those given for a surface sand filter.

10.5.6 Organic Filters

Organic filters are designed consistent with surface or underground filters except that the sand filter bed is replaced or modified with organic media. There are two basic options for organic filters: a peat-sand system and a compost system.

In the peat-sand system, the filter bed is a minimum of 24 inches deep over the underdrain system. This 24-inch bed consists of a 6-inch sand layer overlain by an 18-inch layer of peat-sand mix.

The compost filter system consists of a fabricated leaf compost filtration bed overlying the underdrain system. The compost must be mature and humic so that the organic material is no longer rapidly decaying, and it must be locally available at a reasonable cost.

Design Procedures
Design procedures are consistent with those given previously for surface sand filters or underground sand filters except that the coefficient of permeability, k, for the organic filter is modified. For a peat-sand system, use k = 2.75 ft/day. For a compost system, use k = 8 ft/day.

Specifications
For peat-sand filter beds, select a fibric peat that is shredded, uniform, and clean.

For peat-sand filter beds, combine equal volumes of peat and sand and mix to obtain uniform distribution of peat and sand. Sand specifications are given in Section 10.5.3.

For peat-sand filter beds, place a 6-inch layer of sand over the gravel underdrain. Separate the sand layer from the gravel layer with geotextile fabric. Select sand and geotextile consistent with specifications in Section 10.5.3. Above the 6-inch sand layer, place 18 inches of the 50/50 peat-sand mixture. Construct the filter bed so that the surface of each layer is level. Provide nominal compaction of the gravel and sand layers using a mechanical tamper. Do not compact the sand-peat layer.

For a compost filter bed, select a compost that is mature and humic, composed of leaf medium rather than general yard waste compost.

For a compost filter bed, place a minimum of 18 inches above the geotextile overlying the underdrain system. Do not compact the compost filter bed.

10.6 Prefabricated Treatment Devices

Several manufacturers produce devices that are effective in removing suspended solids and floating oils from stormwater runoff. These devices are typically well-suited to sites that are relatively small and have a high percentage of impervious cover. These devices are not as effective in applications where a majority of the ground cover is pervious and a high percentage of the suspended solids are eroded fine soil particles. Contact the LFUCG Division of Engineering for a list of approved products.

10.6.1 Design Criteria

The treatment devices shall be capable of demonstrating 80% capture of particles in a size range of 2 mm (very coarse sand) to 0.125 mm (very fine sand). The design storm shall have an intensity of 2.1 inches/hour (3-month frequency storm with a time of concentration of 10 minutes).

10.7 Detention Ponds

A detention pond is a traditional stormwater quantity control device that is designed for peak discharge control. Detention ponds are designed to completely drain after the design storm passes. Figure 10-11 illustrates a detention pond.

10.7.1 Applicability

Detention ponds are not effective as water quality treatment devices and can only be used for water quantity control (i.e., detention).

10.7.2 Design Criteria

Design detention ponds so that discharge rates do not exceed calculated pre-development peak runoff rates for the storms given in Chapter 5.

Design outlet structures so that detention volume is released within 24 hours.

Provide an emergency spillway sized to discharge the peak runoff from the 100-year storm assuming the principal spillway is clogged, without overtopping the crest.

Provide a minimum of 1 foot of freeboard above the calculated high water elevation for the 100-year storm.

Embankment heights shall not exceed 20 feet (measured from the downstream toe) and storage volumes shall not exceed 25 acre-feet and shall not be less than 0.3-acre feet. Regional facilities may exceed these limits, but they must comply with the applicable requirements of the Kentucky Division of Water.

Design earthen embankments with side slopes not steeper than 3:1 (horizontal to vertical).

Provide anti-seep collars where the spillway barrel passes through the embankment. Stabilize earthen embankments immediately with temporary or permanent vegetation in accordance with requirements of Chapter 11.

Design ponds to be placed outside the receiving stream except when a pond is designed as a regional detention pond and LFUCG has approved its use as a regional pond.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least 10 feet wide and not steeper than 5:1 (h:v). Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope not steeper than 5:1 (h:v).

Provide a minimum 25-foot wide buffer strip between the pond and the nearest property line. Landscape the buffer strip with low-maintenance native grasses, shrubs, and trees. Provide a landscaping plan for the pond and the buffer. Objectives of landscaping include improving the appearance for adjacent residents and providing wildlife habitat.

Outlet works may be a combination of pipes, weirs, orifices and drop inlets, but design any outlet pipes to be at least 15 inches in diameter to facilitate maintenance.

Design ponds to have a minimum bottom slope of two percent with a pilot channel for low flow.

10.7.3 Design Procedures

Compute the inflow hydrographs for both pre- and post-developed conditions for the 10-year and 100-year storms given in Chapter 5.

Size the outlet structure for the maximum allowable peak discharge at the estimated peak stage.

Develop a stage-storage curve for the proposed pond.

Develop a stage-discharge curve for all outlet control structures.

Perform flood routing calculations using the post-development hydrographs determined for the design storms.

If the routed post-development peak discharge(s) from the design storm(s) exceeds the pre-development discharge, or the peak stage varies significantly from the estimated peak stage, revise the pond volume and/or outlet structure design. Develop a revised stage-storage curve and a revised stage-discharge curve and rerun the flood routing.

Design the emergency spillway to handle the 100-year peak discharge from the post-development hydrograph with no conveyance through the primary outlet structure.

Evaluate the downstream effects of detention outflow to ensure that the routed hydrograph does not cause downstream flooding problems.

Evaluate the control structure outlet velocity and provide channel and bank stabilization if the velocities are greater than the natural stream velocities.

10.7.4 Material Specifications

Construct embankments of ML, CL, MH, or CH soils as determined in accordance with the Unified Soil Classification System (USCS).

Determine the maximum standard dry density (ASTM D698) of at least two distinct samples of the soils to be used for embankment construction.

All conduits used for principal spillways shall be reinforced concrete pipe (RCP). The conduits shall be sealed with rubber gaskets to form a flexible watertight seal under all conditions of service. All pipes shall meet the requirements set forth in the Kentucky Transportation Cabinet's Standard Specifications for Road and Bridge Construction, latest edition. The Design Engineer shall be responsible for determining the size and grade of pipe to be used.

Anti-seep collars shall be provided on all conduits through earthen embankments, foundations, and abutments. The number and size of anti-seep collars shall be determined based on guidance set forth in the Kentucky Department for Environmental Protection, Division of Water's Engineering Memorandum No. 5, Design Criteria for Dams and Associated Structures.

All stone shall meet the requirements set forth in the Kentucky Transportation Cabinet's Standard Specifications for Road and Bridge Construction, latest edition.

Gradation of stone material will be performed in accordance with ASTM C-33. Tests shall be performed on every 5 tons of stone installed or at least once per installation location in locations where less than 5 tons are placed.

All geotextiles shall meet the requirements for performance and strength as set forth by the design engineer. Any alternative material used on the project shall be approved by the design engineer.

The following tests shall be performed and included in the manufacturer's certifications for each shipment of geotextile or every 500 square yards (or once per lot if manufacturer's records show multiple rolls came from same lot), whichever is less:

- Mass per unit area per ASTM D-5261
- Grab tensile strength per ASTM D-4632
- Trapezoidal tear strength per ASTM D-4533
- Burst Strength per ASTM D-3786
- Puncture strength per ASTM D-4833
- Thickness per ASTM D-5199
- Apparent opening size per ASTM D-4751
- Permittivity per ASTM D-4491
- Ultraviolet light resistance per ASTM D-4355

In the case that a more recent testing standard has been released, then that standard shall be used in lieu of the listed testing standards.

10.7.5 Construction Specifications

Verify areas to be backfilled are free of debris, snow, ice, or water, and ground surfaces are not frozen.

When necessary, compact subgrade surfaces to density requirements for the backfill material and prepare subgrade or previous layer of compacted fill prior to placement of additional fill by scarifying or disking.

Cut out soft areas of subgrade not readily capable of in situ compaction. Backfill with subsoil and compact to density equal to requirements for subsequent backfill material.

Backfill areas to contours and elevations. Use materials that are not frozen. The Contractor shall keep the foundation and subgrade free from water or unacceptable materials after the fill operations have started.

Backfill systematically, as early as possible, to allow minimum time for natural settlement. Do not backfill over porous, wet, or spongy subgrade surfaces.

Place and compact soil fill materials in continuous layers not exceeding eight (8) inches loose depth. Compact soil fill materials to 95 percent of maximum dry density. Field density tests shall be performed on each lift. Areas that fail to meet the requirements will be reworked as necessary to meet the requirements and then tested again. This process shall be repeated until the compaction requirements are met.

Tests shall be performed on each 400 square feet of surface area and on each lift of the surface area.

Maintain optimum moisture content of backfill material to attain required compaction density as specified. Material deposited on the fill that is too wet shall be removed or spread and permitted to dry, assisted by disking or blading, if necessary, until the moisture content is reduced to the specified limits.

All crushed stone fill and crushed stone backfill under structures and pavements adjacent to structures shall be DGA crushed stone per Kentucky Highway Department Standard Specifications for Road and Bridge Construction, unless indicated otherwise. Stone fill and backfill materials shall be placed in layers not exceeding six (6) inches in thickness and compacted to 95 percent of maximum dry density.

Backfill shall not be placed against or on structures until they have attained sufficient strength to support all loads to which subjected without distortion, cracking, or damage. Deposit soil evenly around the structure.

Slope grade away from structures minimum two (2) inches in ten (10) feet, unless noted otherwise.

Make changes in grade gradual. Blend slopes into level areas.

Remove surplus excavation materials to designated areas.

Pipe bedding shall meet the requirements set forth in the Kentucky Highway Department Standard Specifications for Road and Bridge Construction, latest edition, and the LFUCG Standard Drawings, latest edition.

The pipe trench shall be overexcavated six (6) inches and properly backfilled prior to laying pipe. In no case shall pipe be laid on solid or blasted rock.

Pipe bedding material shall be placed in six (6) inch loose lifts and compacted to 95 percent maximum dry density at ± 2 percent of the optimum moisture content.

When the subgrade is found to be unstable or to include ashes, cinders, refuse, organic material, or other unsuitable material, such material shall be removed to the depth ordered by the Design Engineer and replaced under the directions of the Design Engineer with clean, stable backfill material. When the bottom of the trench or the subgrade is found to consist of material that is unstable to such a degree that, in the judgment of the Design Engineer it cannot be removed, a foundation for the pipe and/or other appurtenance shall be constructed using piling, timber, concrete, or other materials as the direction of the Design Engineer.

All pipe shall be laid with ends abutting and true to the lines and grades indicated on the Drawings. The pipe shall be laid straight between changes in alignment and at uniform grade between changes in grade. Pipe shall be fitted and matched so that when laid to grade, it will provide a smooth and uniform invert.

The pipe shall be thoroughly cleaned prior to placement. Any piece of pipe or fitting which is known to be defective shall not be laid. If any defective pipe or fitting shall be discovered after the pipe is laid, it shall be removed and replaced with a satisfactory pipe or fitting.

The interior of the pipe, as the work progresses, shall be cleaned of dirt, jointing materials, and superfluous materials of every description. When laying of pipe is stopped for any reason, the exposed end of such pipe shall be closed with a plug fitted into the pipe bell so as to exclude earth or other material. Other precautions shall be taken to prevent flotation of pipe by runoff into trench.

All pipe shall be laid starting at the lowest point and installed so that the spigot ends point in the direction of flow.

All joint surfaces shall be cleaned immediately before jointing the pipe. The bell or groove shall be lubricated in accordance with the manufacturer’s recommendation. Each pipe unit shall then be carefully pushed into place without damage to pipe or gasket. All pipes shall be provided with home marks to insure proper gasket seating. Details of gasket installation and joint assembly shall follow the direction of the manufacturer’s of the joint material and of the pipe. The resulting joints shall be watertight and flexible. No solvent cement joints shall be allowed.

After the embankment has been built to final grade, scarify or till the top and side slopes to a depth of 6 inches to prepare a seed bed. Immediately seed and mulch with temporary or permanent seed according to the season (see Chapter 11).

10.8 Extended Detention Ponds

In this manual, an extended detention pond is a dry detention pond equipped with an outlet structure that provides extended detention time (typically 24 hours) for a specific water quality treatment volume. Figure 10-12 illustrates an extended detention pond.

10.8.1 Applicability

Extended detention ponds can be used for both water quality treatment and water quantity management. For water quality treatment, the extended detention volume is at least equal to the WQV derived from Table 10-1 less any credits for infiltration or bioretention.

In locations with continuous dry weather flow, an extended detention pond will tend to be continuously wet. In this instance, quantify the base flow so that the peak flow and water quality control structures can be designed accordingly.

Design ponds to be located outside the receiving stream except when a pond is designed as a regional detention pond.

10.8.2 Design Criteria

The minimum drainage area for extended detention ponds shall be 10 acres.

Design the extended detention outlet so that the "design" WQV requires at least 24 hours to discharge.

To calculate the design WQV, take the full WQV for the site, minus any credits allowed for bioretention and infiltration practices.

Design extended detention ponds with two stages. The lower stage would be the extended detention pool sized for the design WQV. The upper stage would be larger in area and sized for storm peak control.

Design the bottom slopes with a two percent minimum slope to promote drainage.

When a base flow into the pond exists, design the lower stage as a wetland marsh. In this case, provide a permanent pool of 6 to 12 inches below the design WQV. See section 10.10 for a list of wetland plants.

Provide an emergency spillway sized to discharge the peak runoff from the 100-year storm assuming the principal spillway is clogged, without overtopping the crest.

Provide a minimum of 1 foot of freeboard above the calculated high water elevation for the 100-year storm.

Embankment heights shall not exceed 20 feet (measured from the downstream toe) and storage volumes shall not exceed 25 acre-feet. The minimum storage volume shall be 0.3 acre-feet. Regional facilities may exceed these limits, but they must comply with the applicable requirements of the Kentucky Division of Water.

Design earthen embankments with side slopes not steeper than 3:1 (horizontal to vertical).

Provide anti-seep collars where the spillway barrel passes through the embankment. Stabilize earthen embankments immediately with temporary or permanent vegetation in accordance with requirements of Chapter 11.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least 10 feet wide and not steeper than 5:1 (h:v) or less. Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope not greater than 5:1 (h:v).

Provide a minimum 25-foot wide buffer strip between the pond and the nearest property line. Landscape the buffer strip with low-maintenance native grasses, shrubs, and trees. Provide a landscaping plan for the pond and the buffer. Objectives of landscaping include improving the appearance for adjacent residents and providing wildlife habitat.

10.8.3 Design Procedures

Design procedures for stormwater quantity and peak discharge control are the same for extended detention ponds and traditional dry detention ponds, except that the design WQV will be retained longer in the extended detention pond. To design the storm detention volume and peak control structure for an extended detention pond, follow the procedures given in section 10.7.3 and assume for design purposes that the elevation of the dry pond bottom corresponds to the elevation of the surface of the design WQV (i.e., the top of the extended detention pool).

Sand Filter Outlet

Figure 10-13 illustrates an outlet configuration that may be used to regulate discharge of the extended detention pool. A perforated riser may also be used.

To size this device pick a preliminary configuration and check it using the falling head permeability equation. Set t equal to 24 hours and calculate k. If the calculated k varies significantly from 3.54 ft/hr, adjust the filter dimensions and recalculate.

The falling head equation is:

$$k = 2.303 * (aL/At) * \log (H/h)$$

where:
k = coefficient of permeability (ft/hr),
a = average surface area of extended detention pool (ft^2),
L = depth of sand (ft),

A = surface area of filter = width of sand layer * length of sand layer (ft^2),
t = time (hr),
H = height of water over the perforated pipe with full extended detention pool (ft), and
h = height of filter from the top of the perforated pipe to the top of the sand (ft).

Size the sand filter trenches relative to the underdrain pipe such that the sand filter controls the discharge rate rather than the drain pipe. Provide calculations demonstrating that the underdrain pipe will convey the design flow rate under gravity flow conditions.

10.8.4 Specifications

Specifications are consistent with those provided in section 10.7.

10.9 Wet Ponds

In this manual, wet pond refers to a basin designed for both water quality and water quantity management and which has a permanent pool. Figure 10-14 illustrates a wet pond.

10.9.1 Applicability

Wet ponds can be used for water quantity management and water quality treatment. For water quality treatment, the WQV is at least equal to the WQV derived from Table 10-1, less any credits earned from bioretention and infiltration.

Design ponds to be placed outside the receiving stream except when a pond is designed as a regional detention pond.

10.9.2 Design Criteria

Design retention ponds to have a contributing drainage area of at least 10 acres and a surface area of at least one-fourth of an acre.

When using a wet pond with a permanent pool for water quality control, size the permanent pool to at least equal the design WQV.

To calculate the design WQV, take the full WQV for the site, minus any credits allowed for infiltration and bioretention.

Design the permanent pool to have an average depth between 3 feet and 6 feet and a maximum depth of no more than 8 feet.

Design wet ponds to be wedge-shaped with the narrow end at the inlet and the wide end at the embankment.

Provide a minimum length to width ratio of 3:1 or provide gabion baffles to extend the flow path to a length that meets or exceeds the path that would be achieved using a 3:1 length to width ratio.

Provide irregular shorelines so that the permanent pool has a natural appearance.

Provide a 10-foot wide, 12-inch deep, underwater bench around the perimeter except at the embankment.

Provide safety benches at least 10 feet wide around the perimeter above the permanent pool. Design these benches to have a slope not greater than 10:1 (h:v).

Design a liner for the permanent pool using on-site soils or other materials. Document that the proposed soils are suitable for use as a liner by providing soil classification data (Unified

Soil Classification System) and standard moisture-density data (proctor density test). Design soil liners to be at least 6 inches thick.

Provide an emergency spillway sized to discharge the peak runoff from the 100-year storm, assuming the principal spillway is clogged.

Provide a minimum of 1 foot of freeboard above the calculated high water elevation for the 100-year storm.

Embankment heights shall not exceed 20 feet (measured from the downstream toe) and storage volumes shall not exceed 25 acre-feet. Regional facilities may exceed these limits, but they must comply with the applicable requirements of the Kentucky Division of Water.

Design earthen embankments with side slopes not steeper than 3:1 (horizontal to vertical).

Provide anti-seep collars where the spillway barrel passes through the embankment. Stabilize earthen embankments immediately with temporary or permanent vegetation in accordance with requirements of Chapter 11.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least 10 feet wide and no steeper than 5:1 (h:v). Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope no steeper than 5:1 (h:v).

Provide a minimum 25-foot wide buffer strip between the pond and the nearest lot. Landscape the buffer strip with low-maintenance native grasses, shrubs, and trees. Provide a landscaping plan for the pond and the buffer. Objectives of landscaping include improving the appearance for adjacent residents and providing wildlife habitat.

10.9.3 Design Procedures

Design of the stormwater detention volume and peak control structure for a wet pond is similar to procedures given for a traditional dry detention pond. The permanent pool is sized to match the design WQV, which allows for effective water quality treatment. For quantity control, the pond must have capacity to hold the stormwater detention volume above the permanent pool. That portion of the stormwater detention volume equal to the design WQV is called the extended detention volume. That volume must be discharged slowly to protect the receiving stream from increased flood frequency. See Figure 10-15.

Reverse Slope Pipe

This section describes the design procedure for sizing a reverse slope pipe to discharge that portion of the stormwater detention volume equal to the design WQV. Figure 10-15 illustrates a reverse slope pipe.

Select a pipe diameter, length, and material and use the energy equation to calculate the discharge. The energy equation can be written as:

$Q = A (2gH)^{0.5}/(1 + K_e + K_b + K_cL)^{0.5}$
where:
Q = discharge (ft^3/s)
A = cross-sectional area of pipe (ft^2)
$g = 32.2\ ft/s^2$
H = head above discharge end of pipe (ft^2)
K_e = entrance loss coefficient
K_b = bend loss coefficient (0 for no bends)
K_c = head loss coefficient for pipe
L = pipe length (ft)

Assume that the design WQV is placed above the permanent pool and calculate the corresponding height above the permanent pool. This is the head value, H, corresponding to the WQV.

Calculate the discharge (Q) at 0.25-foot intervals from the top of the design WQV (extended detention pool) to the bottom of the extended detention pool (i.e., top of permanent pool).

Calculate the average discharge for each 0.25-foot increment by averaging the Q calculated at the top and bottom of each increment.

Use the stage-storage curve for the ponds to determine the storage volume in cubic feet corresponding to each 0.25-foot increment of depth.

Divide each incremental storage volume by its corresponding average discharge to calculate the time required for each incremental volume to be discharged through the selected pipe.

Sum the incremental discharge durations to determine if the total design WQV required 24 hours to discharge. If not, adjust the pipe size and recalculate.

10.9.4 Specifications

Specifications are consistent with those provided in section 10.7.

10.10 Constructed Wetlands

Constructed wetlands can provide a very effective management measure for mitigation of pollution from runoff, because they have the ability to assimilate large quantities of suspended and dissolved materials from inflow. The term "constructed wetland" can apply to a wetland which is constructed to mitigate impacts to a natural wetland (per a Corps of Engineers permit), or a wetland which is constructed as part of a wastewater treatment system. In this manual, a constructed wetland is a device constructed in accordance with the following criteria and procedures to treat and control stormwater.

10.10.1 Applicability

Constructed wetlands can be used for both water quality and water quantity management or for water quality only. For management of water quantity, a wetland would be constructed much like a wet pond with a 6 to 12 inch deep permanent pool. The most important criterion in determining whether a constructed wetland is applicable is the existence of a base flow that can be used to supply the permanent pool.

10.10.2 Design Criteria

For water quality control, size the extended detention pool above the permanent pool equal to the design WQV.

Design the extended detention outlet so that at least 24 hours would be required to release the design WQV.

To calculate the design WQV, take the full WQV for the site, minus any credits allowed for infiltration and bioretention.

For stormwater quantity control, determine the necessary detention volume, and design the peak control outlet consistent with the design criteria and design procedures for detention ponds in Section 10.7. The extended detention volume is a portion of the total detention volume rather than being an addition to it.

Size the surface area of the wetland according to procedures described in the following section.

Provide a sediment forebay. Design the forebay to be 4 to 6 feet deep and have a volume of at least 10 percent of the design WQV at the inlet to the constructed wetland.

Use a reverse slope pipe as the extended detention outlet and protect it from blockage using aggregate as shown in Figure 10-15.

Provide a micropool at the extended detention outlet so that the reverse slope outlet pipe can be placed 1 foot below the permanent pool surface. Design the micropool to be 4 to 6 feet deep with a volume of at least 10 percent of the WQV.

Provide a drain with a valve at the base of the micropool.

Design the permanent pool, with the exception of the sediment forebay and the outlet micropool, to be 3 to 12 inches deep with an average depth of 6 to 9 inches.

Design the grades in the constructed wetland so that the wetland will drain to the micropool at the outlet if the micropool is drained. Providing the ability to drain the wetland will facilitate maintenance and revegetation if necessary.

Design the wetland to have low marsh and high marsh in the permanent pool. Low marsh refers to a zone with 6 to 12 inches of permanent pool, while high marsh refers to a zone with zero to 6 inches of permanent pool. Design the wetland so that low marsh and high marsh each represent 35 to 45 percent of the total surface area. Design so that the total deep pool (i.e., the micropool plus the sediment forebay) represent 10 to 20 percent of the surface area.

Design the wetland to have a length-to-width ratio of at least 2:1.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least 10 feet wide and no steeper than 5:1 (h:v). Design the easement to provide access to the sediment forebay and the outlet micropool.

Check the velocity of design storm flows at the inlet to the wetland and provide a stable entrance to prevent erosion.

Design a planting plan that shows 40 to 50 percent of the shallow (12 inches or less) wetland planted with wetland vegetation. A list of suitable species is available from the KY Division of Water. Plan to include a minimum of three emergent wetlands species as the majority planting with at least three additional emergent species comprising the remaining planting.

10.10.3 Design Procedures

Use Table 10-2 to determine the minimum surface area required based upon the size of the watershed draining to the wetland. Values in Table 10-7 are based upon expected nitrogen and phosphorus loading rates in urban areas and the maximum loading per acre that a constructed wetland can effectively treat.

Procedures for sizing the reverse slope pipe outlet at the micropool are consistent with procedures for wet retention ponds given in Section 10.9.

TABLE 10- 2
WETLAND SURFACE AREA

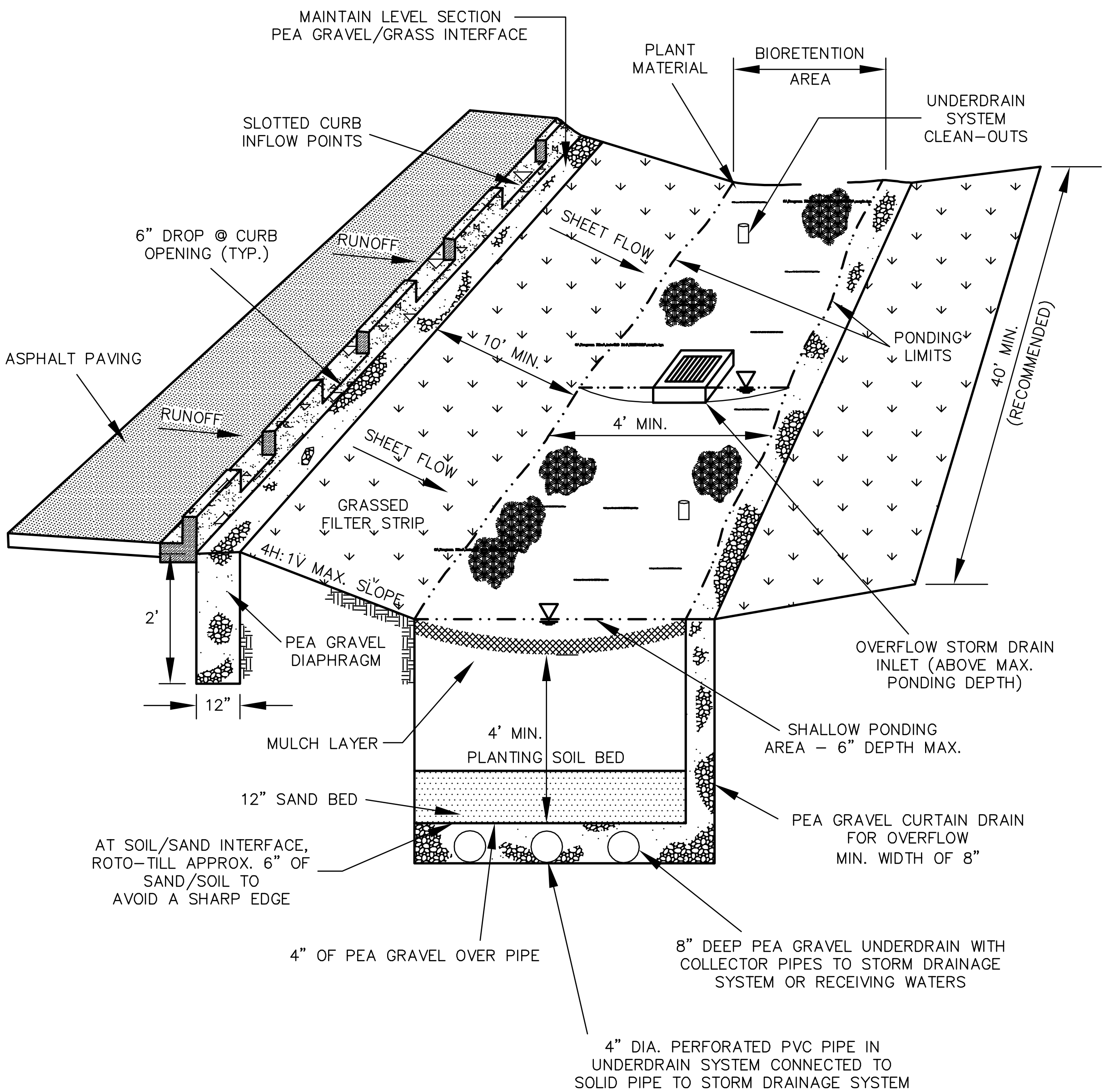
% Impervious Surface	Surface Area in Acres per Acre of Watershed
10	0.025
20	0.031
30	0.037
40	0.042
50	0.049
60	0.055
70	0.060
80	0.066
90	0.072
100	0.078

Note: Use linear interpolation for percent impervious values between those given in the table.

FIGURE 10-1

BIORETENTION SYSTEM

(EFFECTIVE DATE 1/01/09)

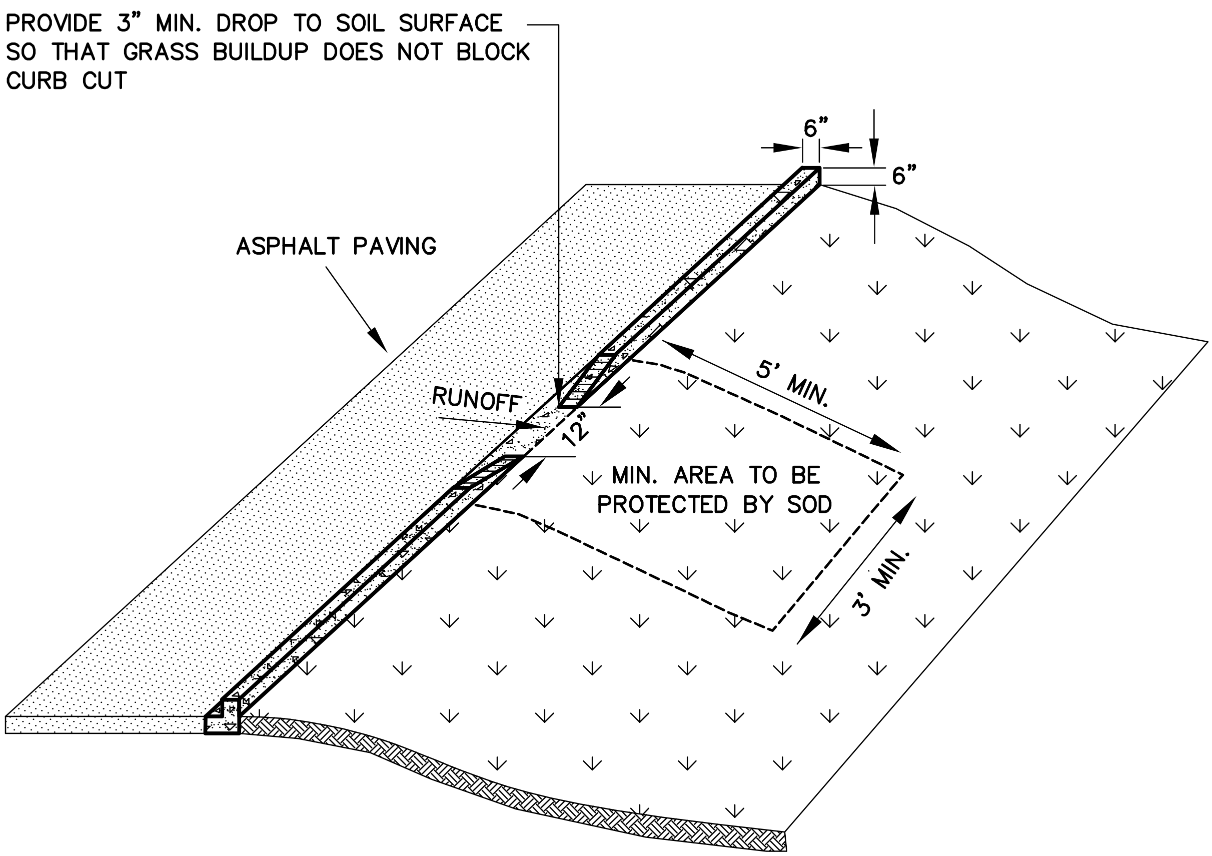


STORMWATER MANUAL

FIGURE 10-2

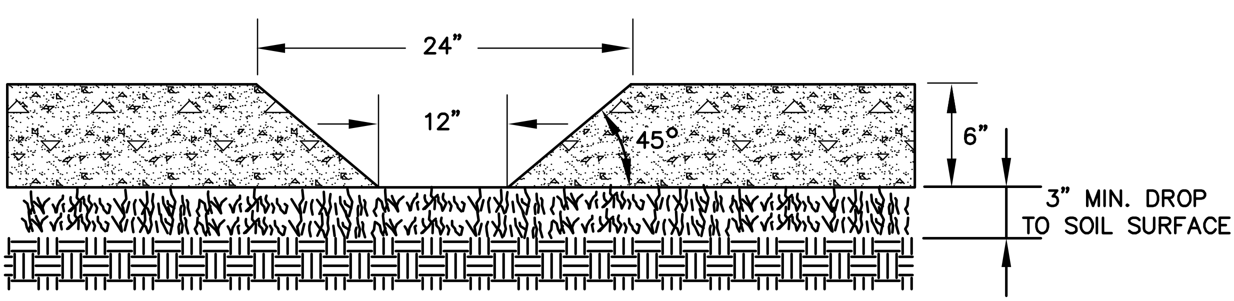
CURB CUT TO SWALE

(EFFECTIVE DATE 1/01/09)



ISOMETRIC VIEW

N.T.S.



ELEVATION VIEW

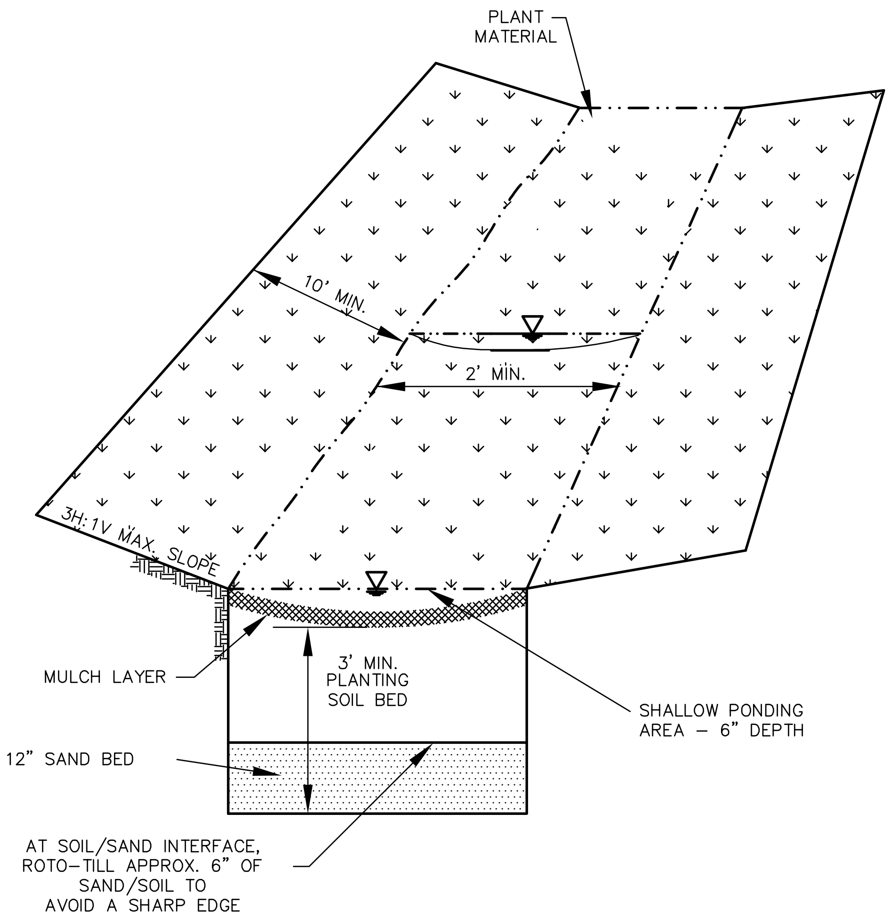
N.T.S.

STORMWATER MANUAL

FIGURE 10-3

BIOFILTRATION SWALE

(EFFECTIVE DATE 1/01/09)



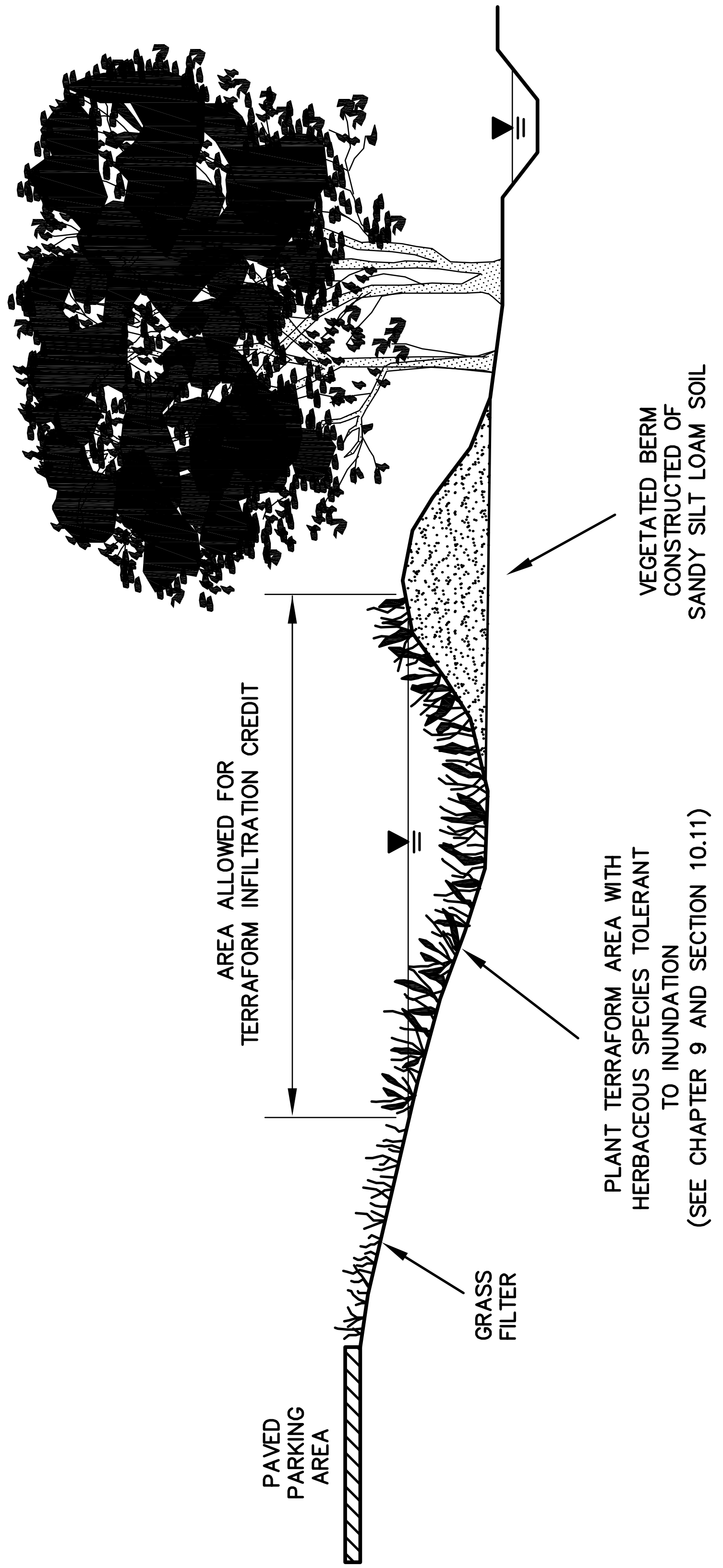
NOTE:
IF LONGITUDINAL SLOPE EXCEEDS 2 PERCENT, CONSTRUCT A BERM AT THE DOWNSTREAM END OF BIOFILTRATION SWALE. CONSTRUCT BERM SO THAT IT IS 12 TO 18 INCHES HIGH IN CENTER WITH A LEVEL TOP ACROSS THE PLANTING BED. CONSTRUCT THE BERM TO HAVE SIDE SLOPES NO GREATER THAN 2 HORIZONTAL TO 1 VERTICAL.

STORMWATER MANUAL

FIGURE 10-4

TERRAFORM BERM

(EFFECTIVE DATE 1/01/09)

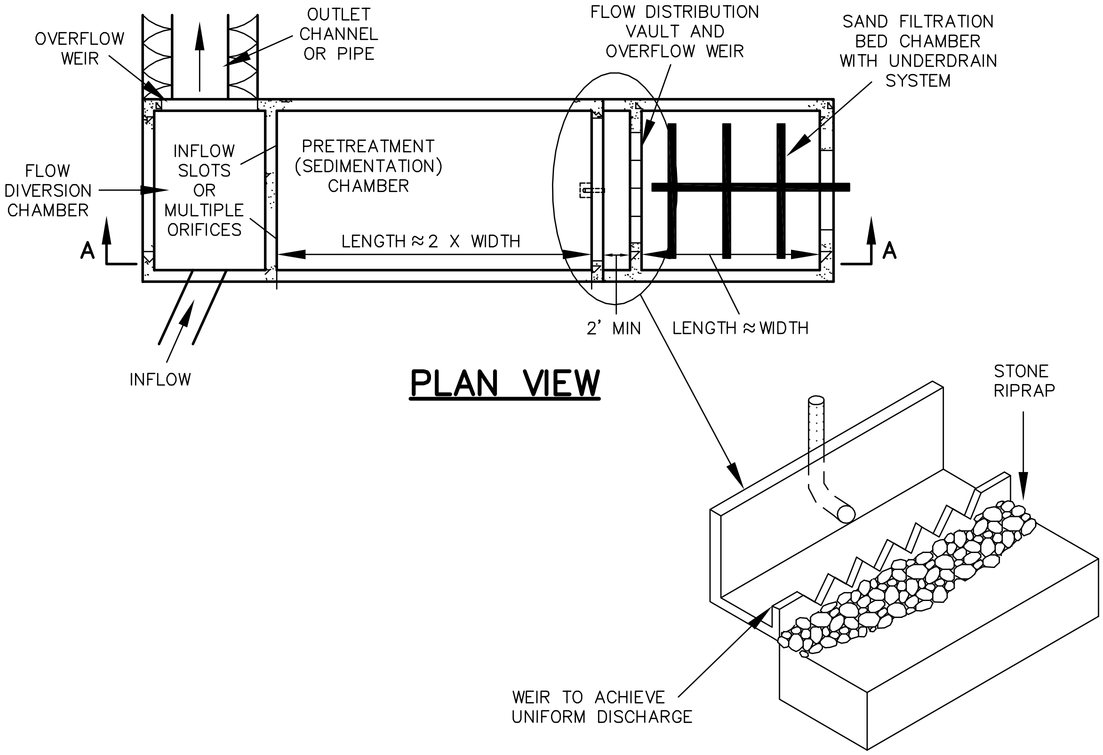


STORMWATER MANUAL

FIGURE 10-5

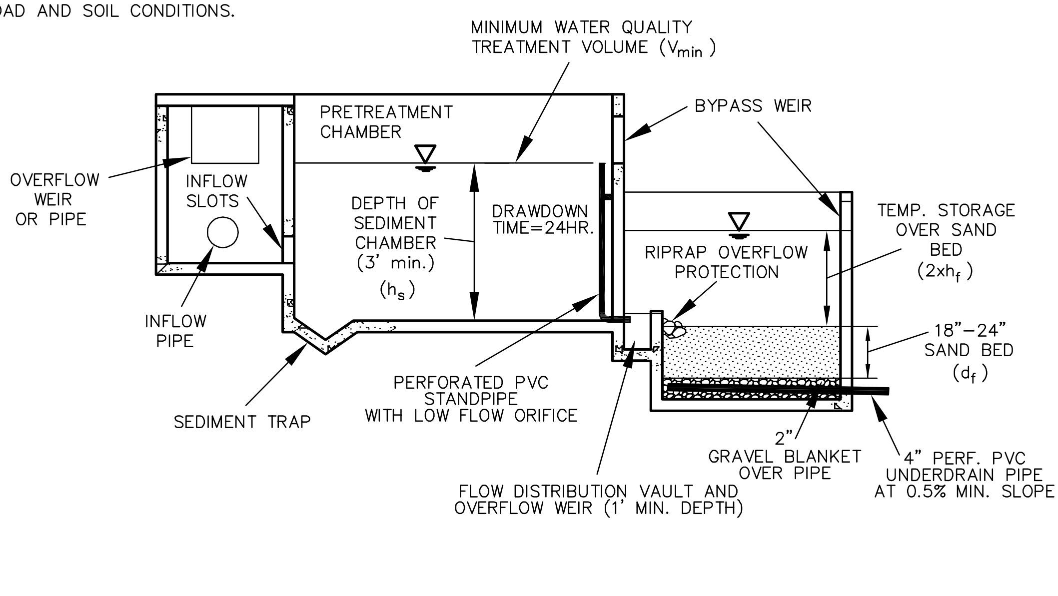
SURFACE SAND FILTER

(EFFECTIVE DATE 1/01/09)



PLAN VIEW

NOTE: STRUCTURAL CONCRETE DESIGNED FOR LOAD AND SOIL CONDITIONS.



SECTION A-A

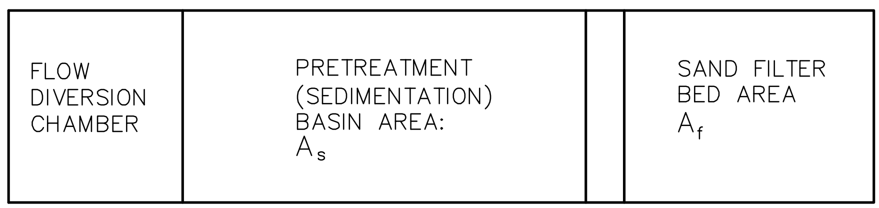
SOURCE: CLAYTOR AND SCHUELER, 1996

STORMWATER MANUAL

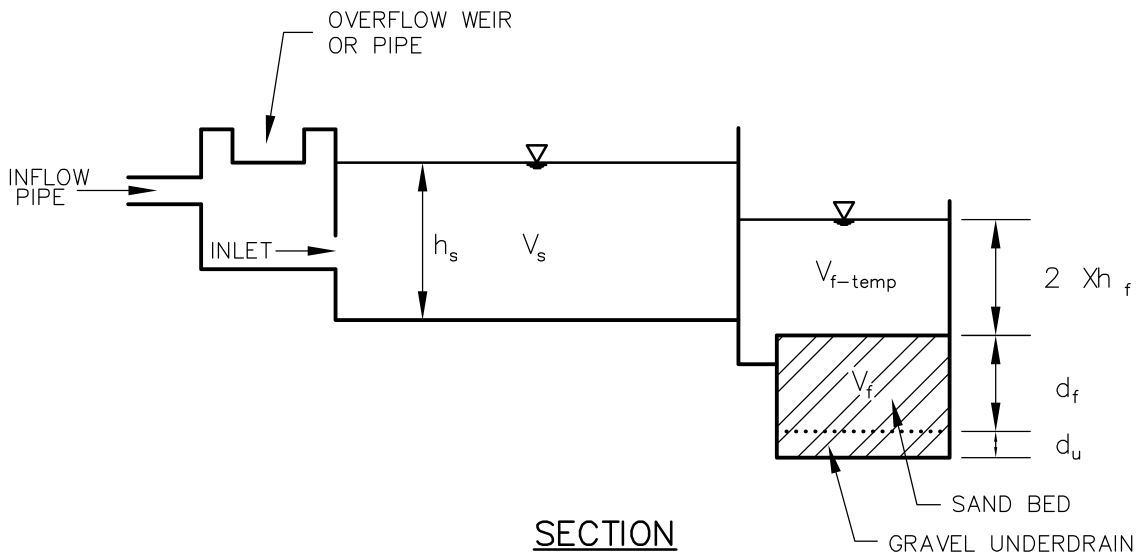
FIGURE 10-6

SURFACE SAND FILTER SCHEMATIC

(EFFECTIVE DATE 1/01/09)



PLAN



SECTION

$V_{TOTAL} = V_s + V_{f-temp} + V_f$

CHECK THAT $V_{TOTAL} \geq V_{MIN} = 0.75 \times WQV$

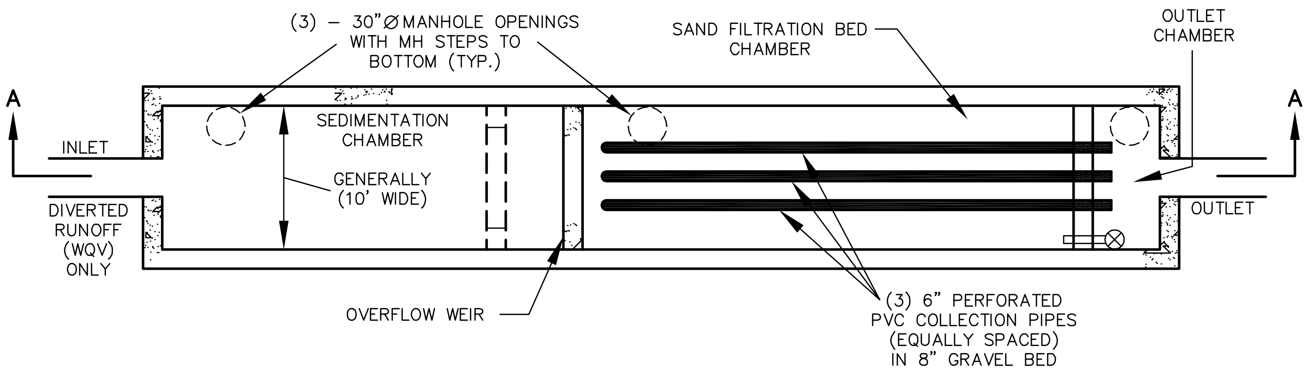
SOURCE: CLAYTOR AND SCHUELER, 1996

STORMWATER MANUAL

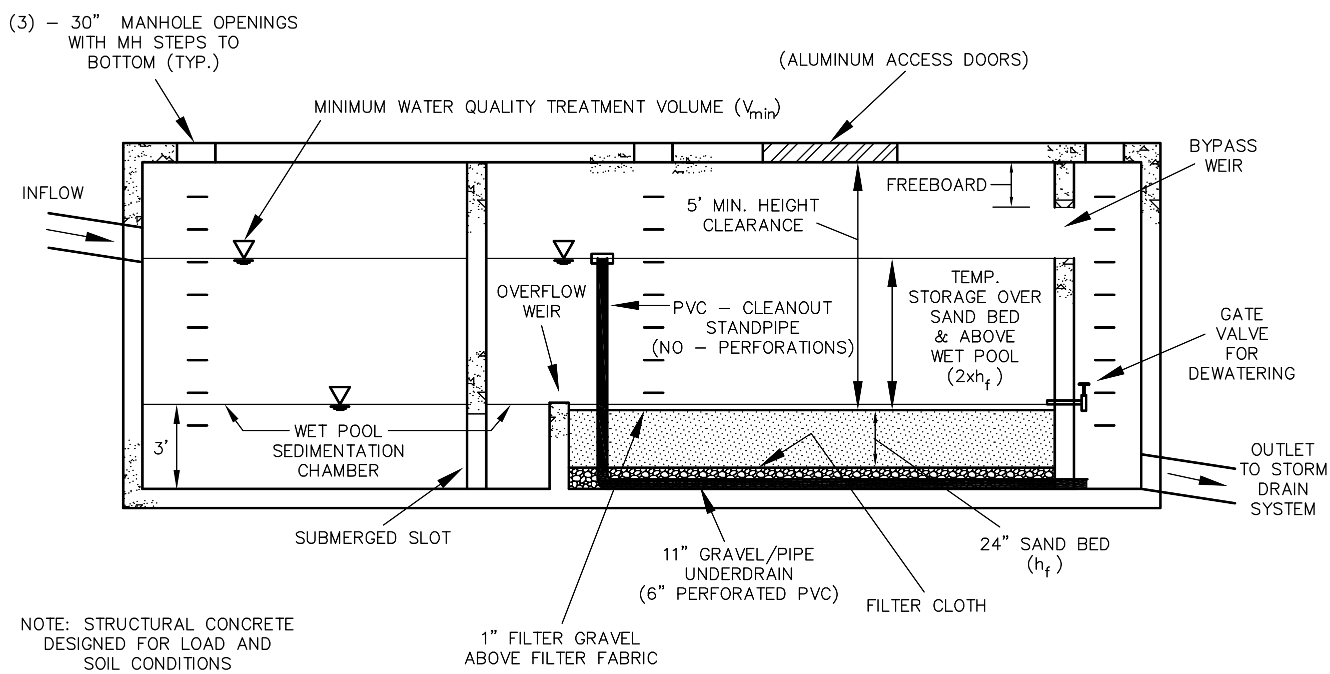
FIGURE 10-7

UNDERGROUND SAND FILTER

(EFFECTIVE DATE 1/01/09)



PLAN



NOTE: STRUCTURAL CONCRETE DESIGNED FOR LOAD AND SOIL CONDITIONS

SECTION A–A

SOURCE: CLAYTOR AND SCHUELER, 1996

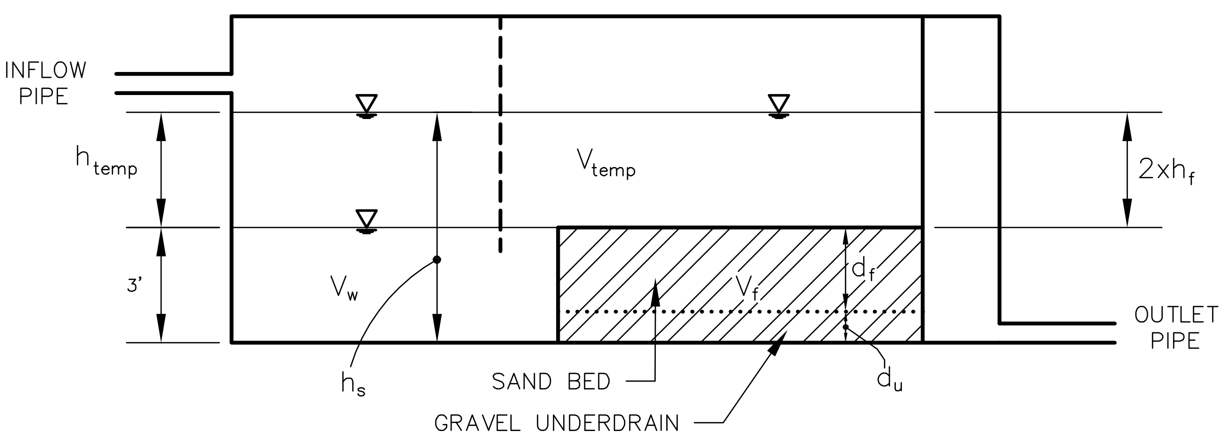
STORMWATER MANUAL

FIGURE 10-8

UNDERGROUND SAND FILTER SCHEMATIC

(EFFECTIVE DATE 1/01/09)

PLAN



SECTION

$$V_{TOTAL} = V_w + V_{temp} + V_f$$

CHECK THAT $V_{TOTAL} \geq V_{MIN} = 0.75 \times WQV$

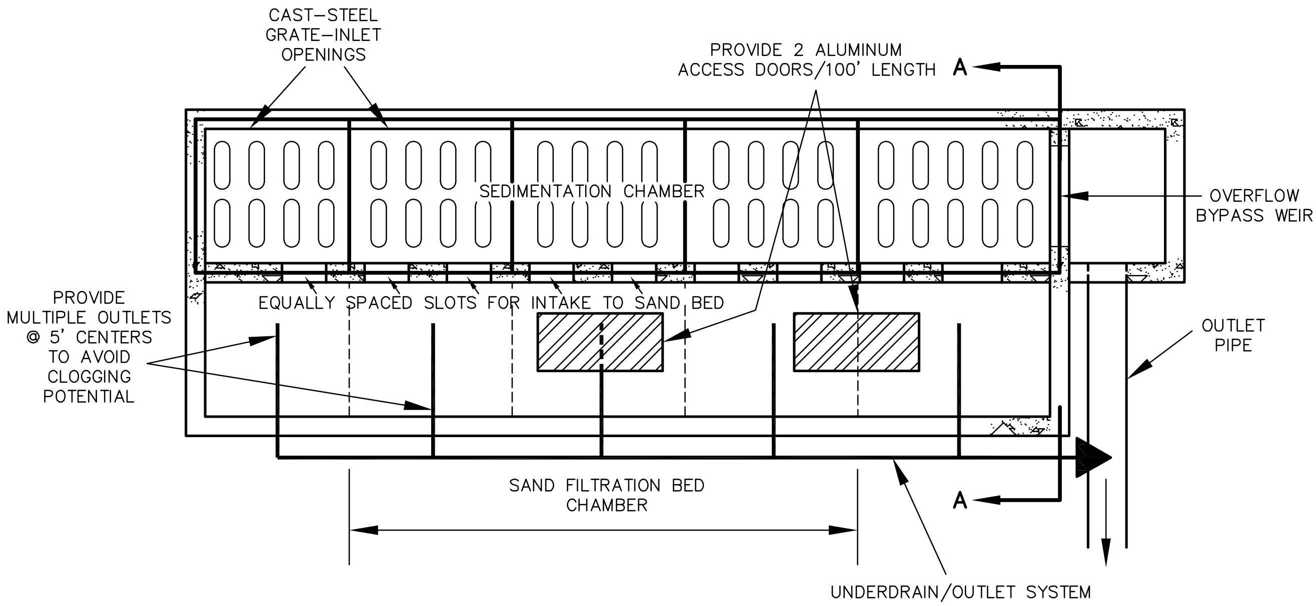
SOURCE: CLAYTOR AND SCHUELER, 1996

STORMWATER MANUAL

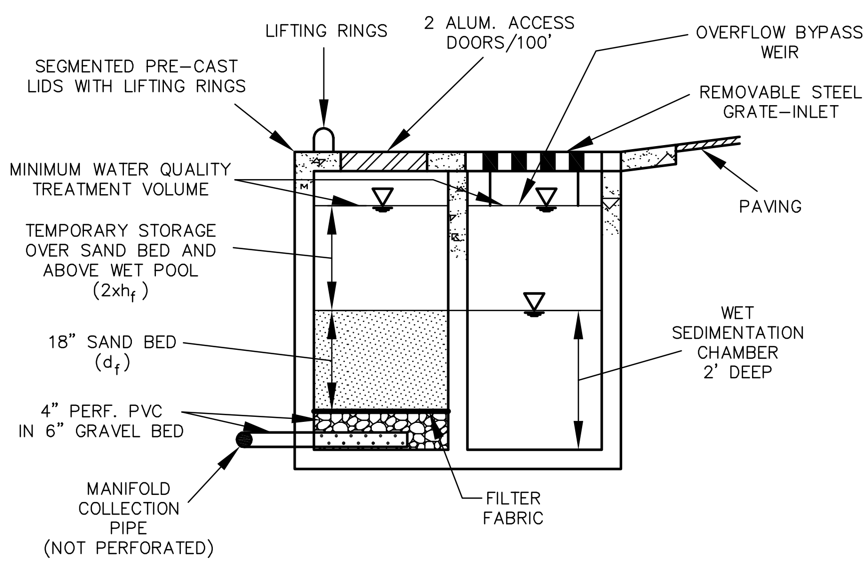
FIGURE 10-9

PERIMETER SAND FILTER

(EFFECTIVE DATE 1/01/09)



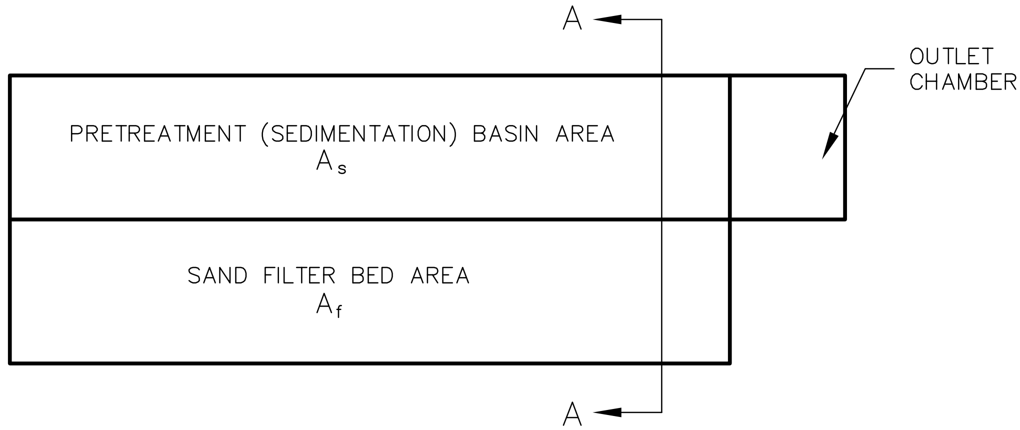
PLAN



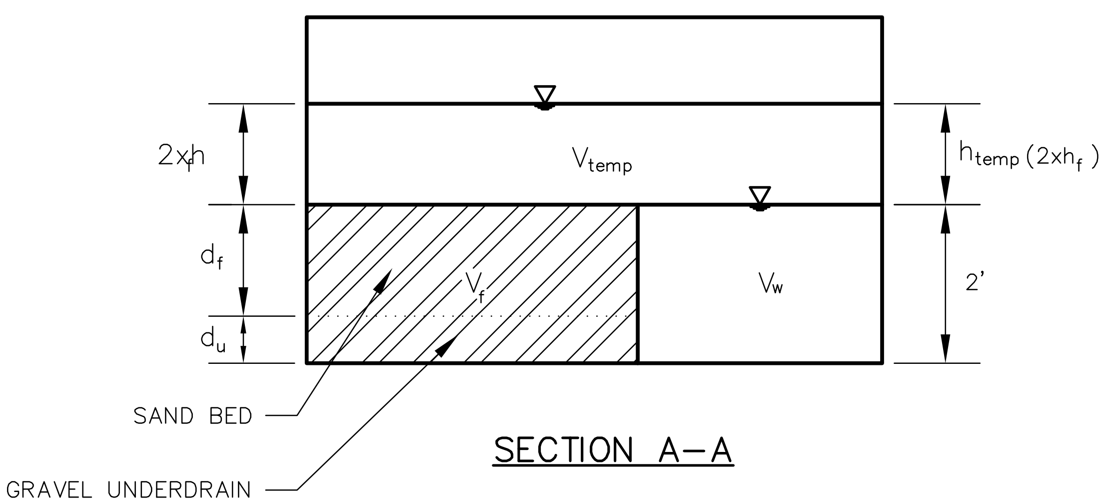
SECTION A-A

SOURCE: CLAYTOR AND SCHUELER, 1996

STORMWATER MANUAL	**FIGURE 10–10** PERIMETER SAND FILTER SCHEMATIC (EFFECTIVE DATE 1/01/09)



PLAN



SECTION A–A

$$V_{TOTAL} = V_w + V_{temp} + V_f$$

CHECK THAT $V_{TOTAL} \geq V_{MIN} = 0.75 \times WQV$

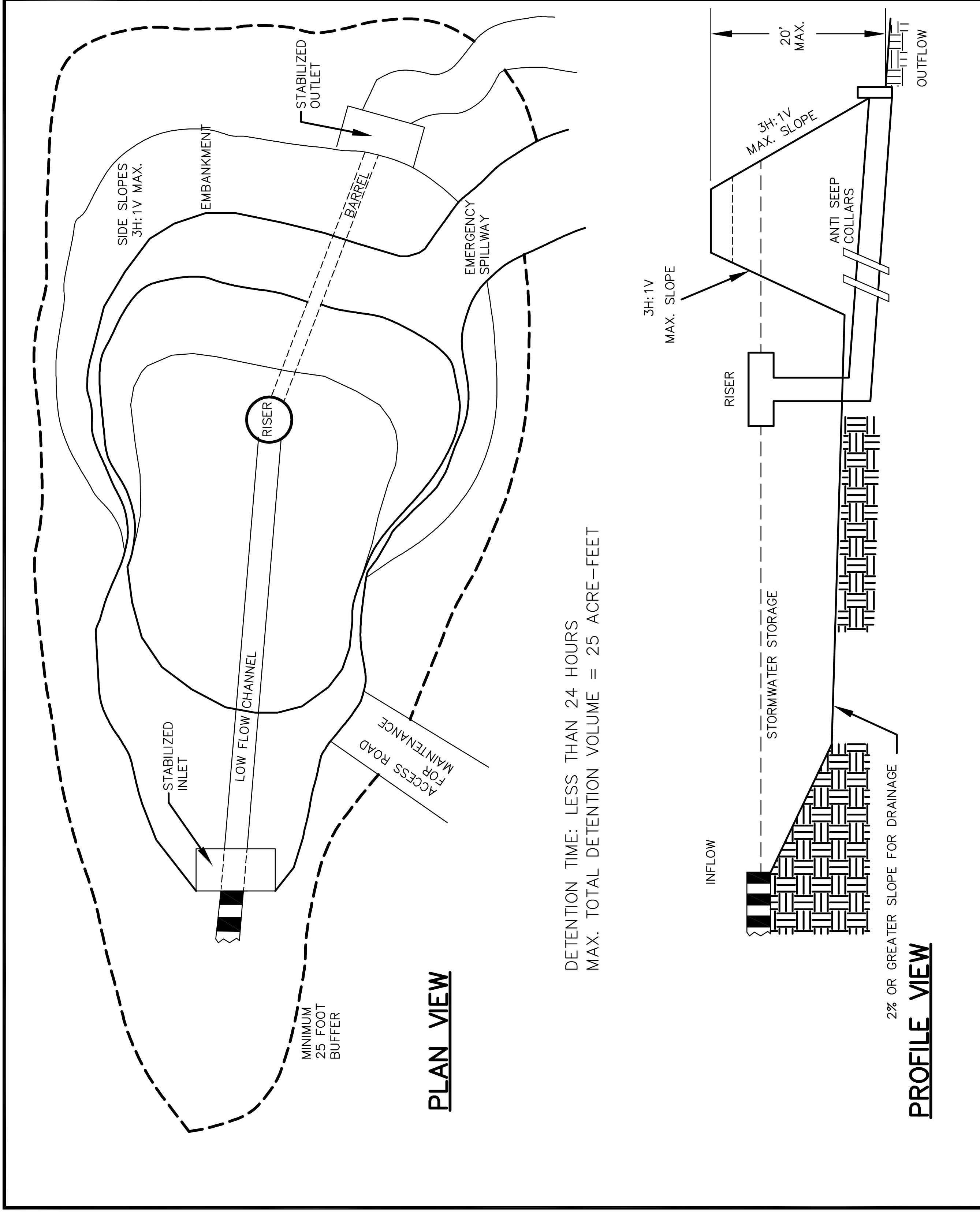
SOURCE: CLAYTOR AND SCHUELER, 1996

STORMWATER MANUAL

FIGURE 10-11

DETENTION POND

(EFFECTIVE DATE 1/01/09)

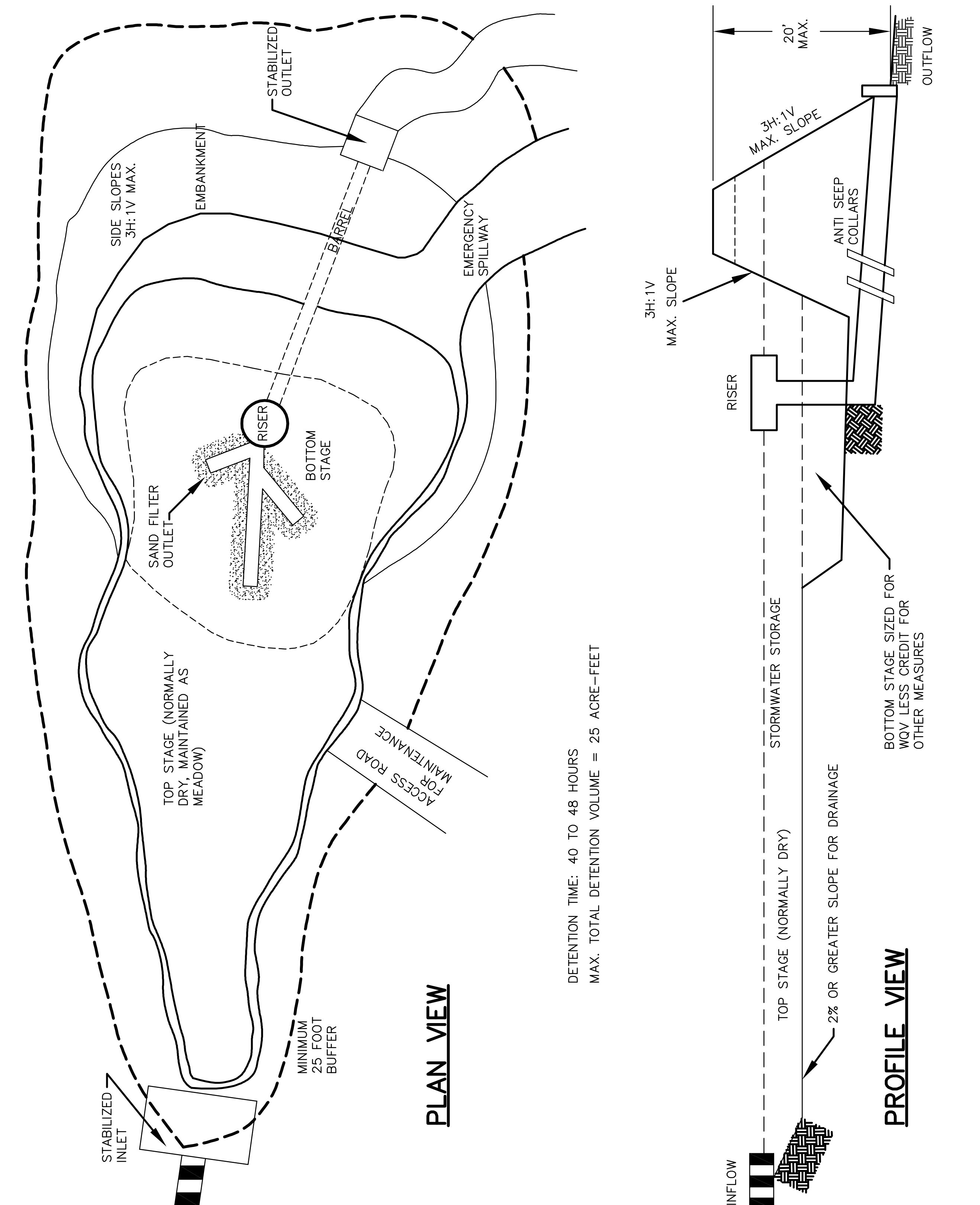


STORMWATER MANUAL

FIGURE 10-12

EXTENDED DETENTION POND

(EFFECTIVE DATE 1/01/09)

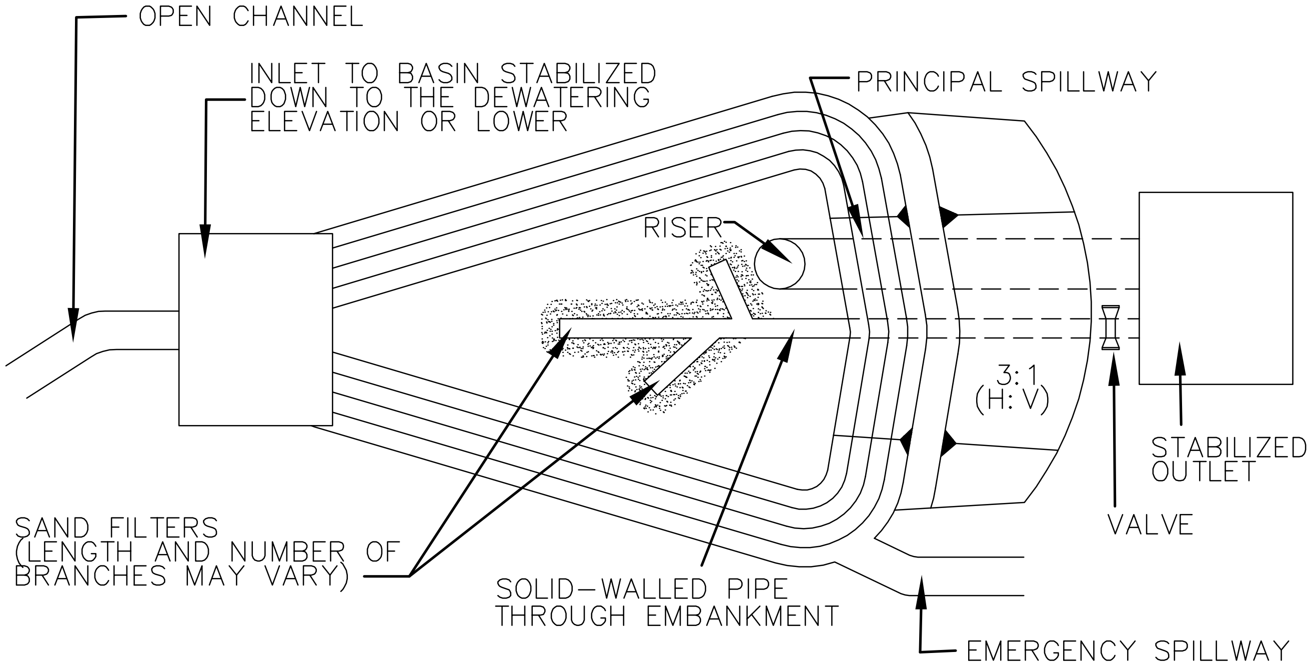


STORMWATER MANUAL

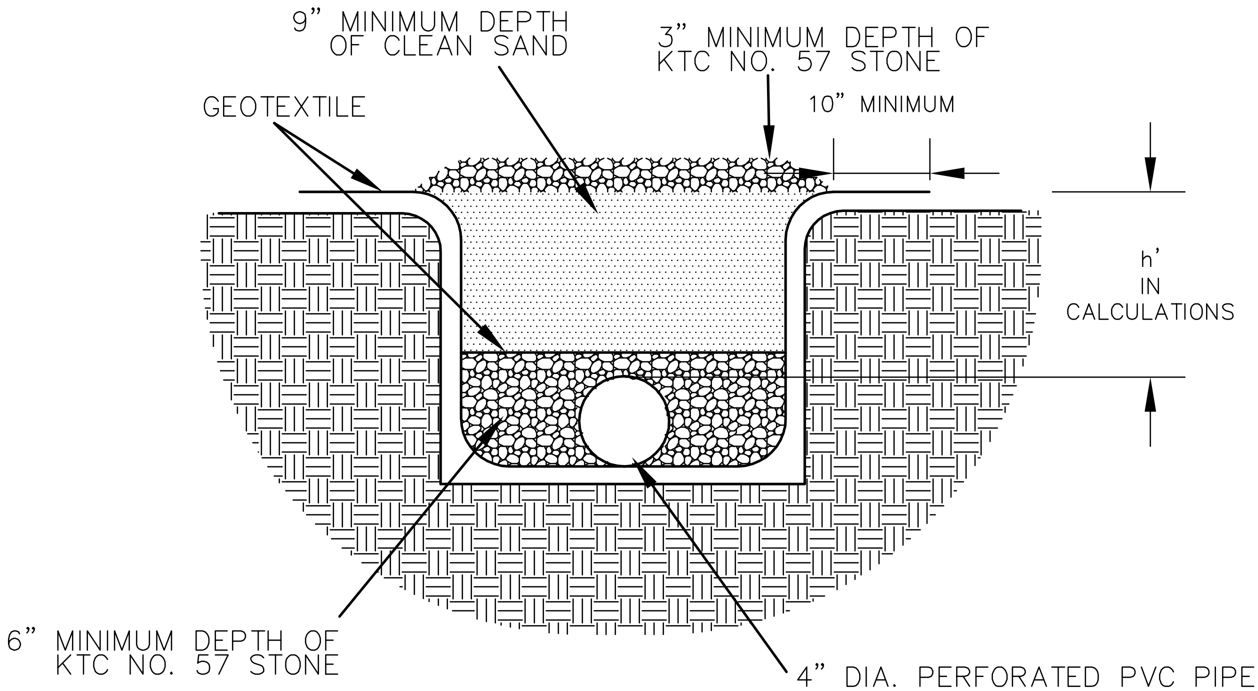
FIGURE 10–13

EXTENDED DETENTION OUTLET USING SAND FILTER

(EFFECTIVE DATE 1/01/09)



PLAN VIEW
N.T.S.



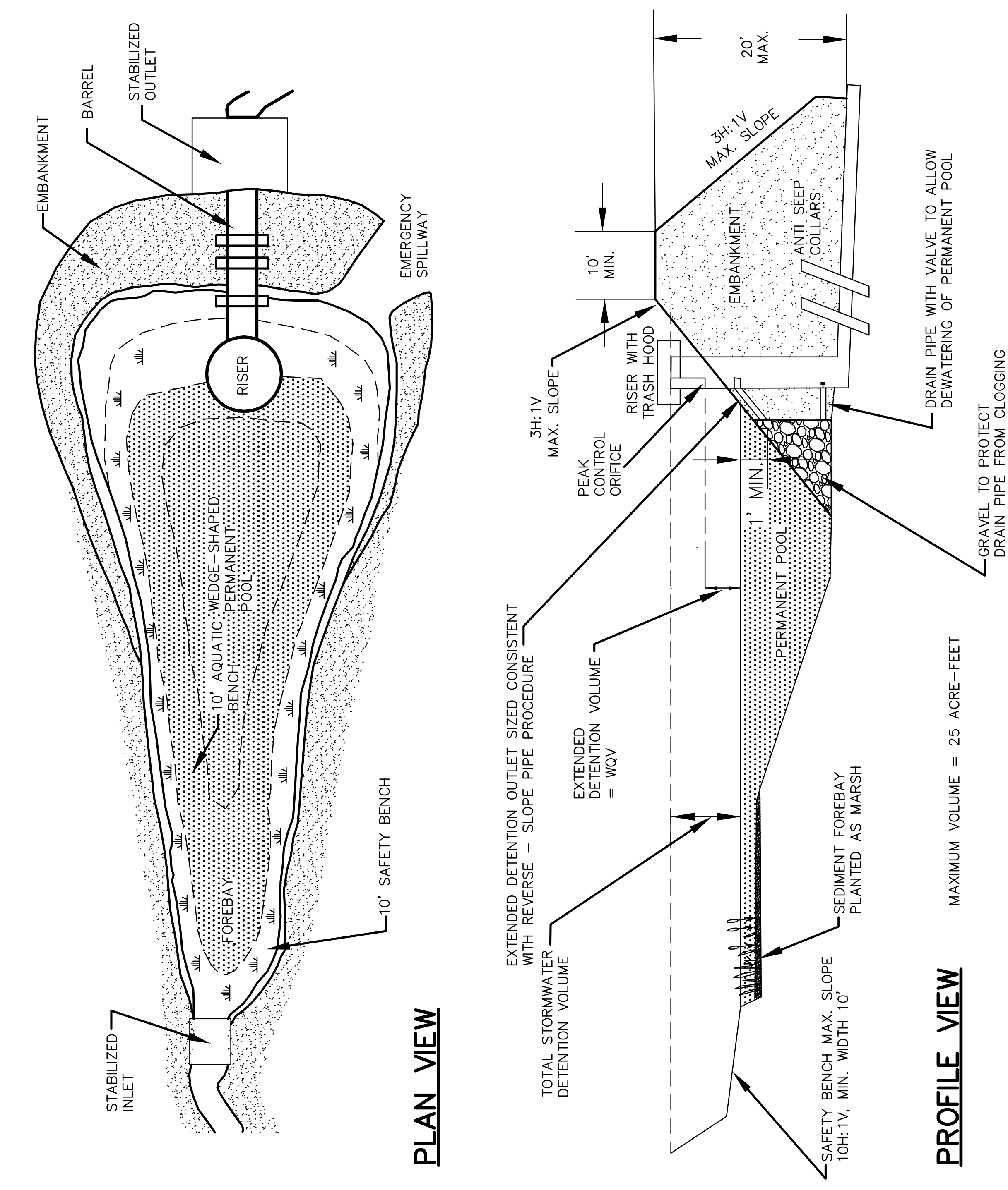
TYPICAL SECTION
N.T.S.

STORMWATER MANUAL

FIGURE 10–14

WET POND

(EFFECTIVE DATE 1/01/09)

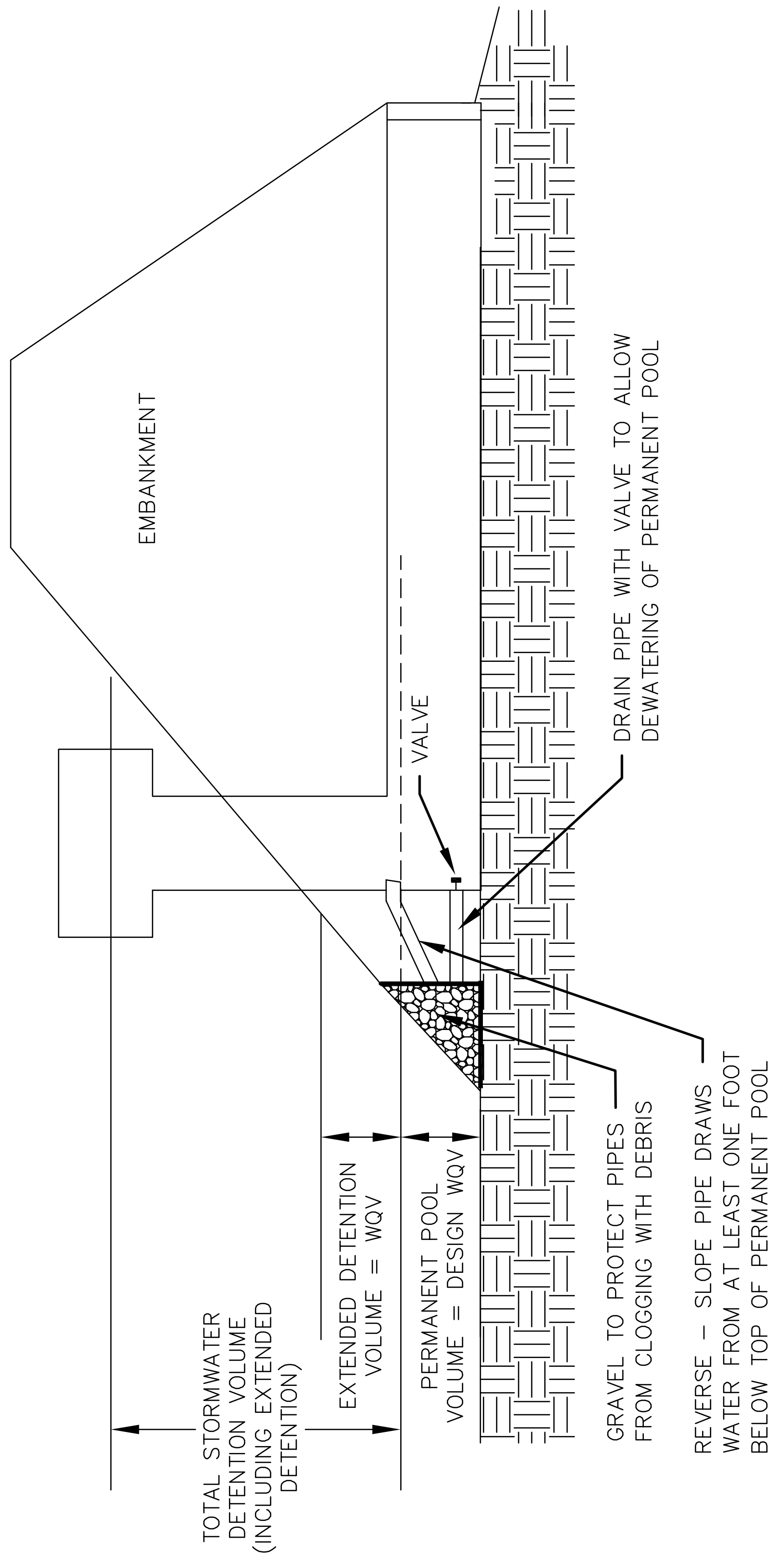


STORMWATER MANUAL

FIGURE 10–15

EXTENDED DETENTION OUTLET FOR WET POND

(EFFECTIVE DATE 1/01/09)



PROFILE VIEW
N.T.S