CHAPTER 5

Structural Practices for Sustainable Drainage Design

- √ **Overview**
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- √ **Porous Pavement**
- √ **Enhanced Detention**
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- √ **Soil amendment and conservation landscaping**

The purpose of this chapter is to describe the practices that are most appropriate for the Texas coastal region. Guidance on the design of these systems is also available from several other regional sources including Aransas and Harris Counties. The following sections describe the minimum requirements, stormwater practices, selection criteria, design guidelines, and maintenance requirements.

5.1 OVERVIEW

Structural practices for sustainable drainage design are those measures that are used to manage nonpoint source pollution (stormwater runoff quality) and peak flow rates from new development. This Chapter provides technical guidance for the design, construction, and maintenance of such measures. Sustainable practices designed per Chapter 4 and this Chapter will reduce total suspended solids (TSS) by at least 80% after the construction site has been permanently stabilized and maintain post-development peak runoff rates at pre-development levels for the 1.5″ rainfall event. Sustainable drainage practices are required by all new development and redevelopment projects that disturb one acre or more of land, add 10,000 square feet of impervious cover, and projects less than one acre that are part of a larger common plan of development or sale that will result in disturbance of one acre or more. Projects whose final level of impervious cover is less than 20% or use stormwater credits to create an effective impervious cover less than 20% are exempt from the implementation of structural practices.

5.1.1. GENERAL DESIGN GUIDELINES

The following general guidelines apply to all permanent BMPs in this section.

1. SITING REQUIREMENTS:

- All water quality basins must lie outside the buffer zones; and
- All permanent BMPs receiving off-site runoff or serving a single-family subdivision should be shown within a drainage easement or conservation easement. Vegetative filter strips may be shown within the building set back of a lot in lieu of being located in a drainage easement. The easement or building setback must include appropriate restrictions regarding the amount and type of improvements that may be constructed.

2. SAFETY CONSIDERATIONS

- ***Embankment Safety:*** The design should direct grading to avoid drop-offs and other hazards. Side slopes of basins should be 3:1 (H:V) or flatter for grass stabilized slopes. Slopes steeper than 3:1 (H:V) must be stabilized with an appropriate slope stabilization practice;
- ***Dam Safety:*** See Section 299 of the TCEQ rules on Dams and Reservoirs for dam safety requirements. These rules apply to any barriers, including one for flood detention or water quality management, designed to impound liquid volumes and which has a dam height greater than six feet;
- ***Hazardous Materials:*** For developments that store or dispense hazardous materials a valve should be installed so that discharge from the BMP can be stopped in case runoff from a spill of hazardous material enters the basin. The control for the valve must be accessible at all times, including when the basin is full; and
- ***Limit Access:*** Fencing, landscaping and curb stops can be used to impede access to a facility. The primary spillway opening must not permit access by small children. If the facility is fenced, gates must be provided to allow access for inspections and maintenance.

3. STABILIZATION REQUIREMENT

A plan should be provided indicating how disturbed areas will be stabilized and re-vegetated. Revegetation must follow the guidelines in Chapter 3 and begin within 14 days of the end of construction activities. Erosion control must be provided to protect exposed soil on slopes greater than 3:1 and can be provided in the form of sod, matting, straw or other approved means.

4. VEGETATION REQUIREMENTS

The vegetation density for all permanent BMPs must be greater than 80% with no large bare areas. The filter area should be densely vegetated with a mix of erosion-resistant plant species that effectively bind the soil. Native or adapted grasses, shrubs, and trees are appropriate because they generally require less fertilizer and are more drought resistant than exotic plants. Turf grass (vegetated filter strips) should be mowed to maintain a grass height of no more than 4-inches to keep the grass in an active growth phase. Permanent BMP areas should be managed to minimize or avoid the application of fertilizers, pesticides, or herbicides.

5. CONSTRUCTION-PHASE RUNOFF

Structural practices may be used as sediment basins during construction. Embankments and conveyances must be properly compacted with an emergency overflow outlet. Basins must have sediment accumulations removed, final grades restored, and stabilization achieved prior to completion. No portion of a basin using infiltration or filtration shall be used to collect or treat construction-phase runoff. No runoff shall be received by these facilities until site is completely stabilized.

6. MAINTENANCE REQUIREMENTS

Provide adequate maintenance access to all permanent BMP inlet and outlet structures, filtration and sedimentation areas. A fixed vertical sediment depth marker should be installed in the bottom of sedimentation areas to determine when sediment accumulation has exceeded limits set in the maintenance plan.

See Chapter 5 for Maintenance Plan requirements for all permanent BMPs.

5.2 VEGETATED SWALES

5.2.1. INTRODUCTION

Grassy swales are vegetated channels that convey stormwater and remove pollutants by sedimentation and infiltration through soil. They require well-draining shallow slopes and soils. Pollutant removal capability is related to channel dimensions, longitudinal slope, and amount of vegetation. Optimum design of these components will increase contact time of runoff through the swale and improve pollutant removal rates.

A credit is given when impervious cover in a drainage area less than 2 acres is directed to a vegetated swale where it can either infiltrate into the soil or filter over it. The credit is obtained per the criteria in this section where 20% of the impervious area in that 2-acre contributing drainage area can be deducted from the total impervious cover (therefore, potentially gaining compliance with the Low Impact Development impervious cover levels or reducing BMP volume).

Grassy swales are primarily stormwater conveyance systems. They can provide sufficient control under light to moderate runoff conditions, but their ability to control large stormwater flows is limited. Therefore, they are most applicable in low to moderate sloped areas or along highway medians as an alternative to curb and gutter drainage. Grassy swales can be used as a pretreatment measure for other downstream facilities such as bioretention areas. Enhanced grassy swales utilize engineered soils and an underdrain to provide filtration of pollutants. A photograph of a grassy swale is presented in Figure 5-1. They can also be included in the design of commercial parking areas as shown in Figure 5-2.

Grassy swales can be more aesthetically pleasing than concrete or rock-lined drainage systems and are generally less expensive to construct and maintain. Swales can slightly reduce impervious area and reduce the pollutant accumulation and delivery associated with curbs and gutters. Disadvantages of this technique include the possibility of erosion and channelization over time and the need for more right-of-way as compared to a storm drain system.

The suitability of a swale at a site will depend on existing land use, size of the area serviced, soil type, slope, as well as dimensions and slope of the swale system. Irrigation is not required to maintain growth during dry periods but may be necessary for vegetation establishment.

SELECTION CRITERIA

- Preferred method of conveyance in residential developments and islands in commercial parking lots.
- Pretreatment for other sustainable development practices.
- Limited to treating less than 2 acres.
- Sufficient available land area.

LIMITATIONS

- Can be difficult to avoid channelization.
- Number of culverts required may make infeasible in higher density developments.

Figure 5-1: Typical swale in a residential neighborhood in Chambers County, Texas. (Photo courtesy of Google Earth)

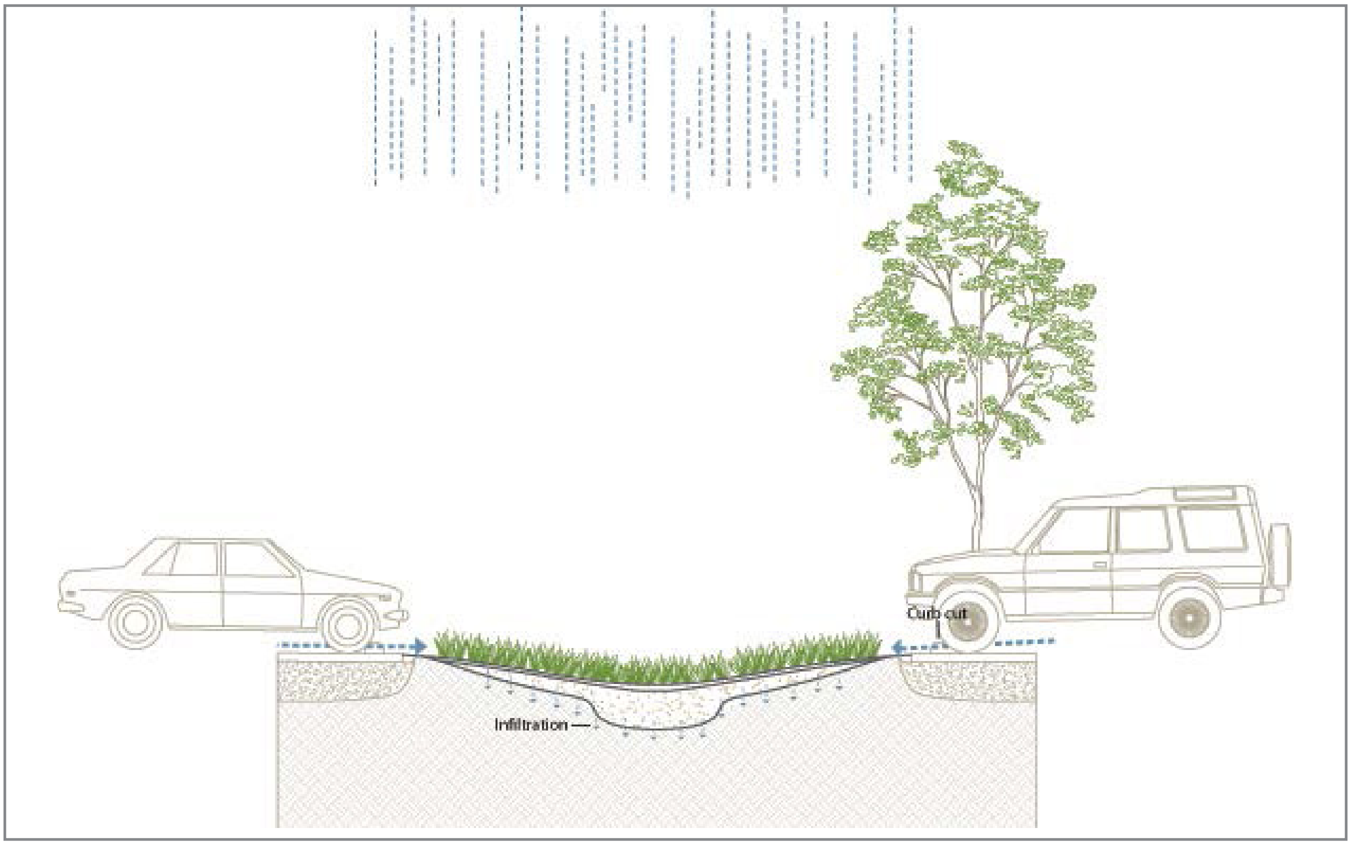

Figure 5-2: Swale in parking lot area. (Showing the use of short grasses, low slopes, curb cuts from parking area and some infiltration.

5.2.2. SWALE DESIGN GUIDELINES

1. The swale should be sized per local requirements for stormwater conveyance and be at least 50 feet long.
2. The geometry of the channel is not critical as long as a broad, relatively flat bottom is provided with a longitudinal slope equal to or less than 0.5%. The side slopes should be no steeper than 6:1 (H:V).
3. Roadside ditches should be regarded as significant potential swale sites and should be utilized for this purpose whenever possible.
4. If flow is to be introduced through curb cuts, place pavement slightly above the elevation of the vegetated areas. Curb cuts should be at least 12 inches wide to prevent clogging. An apron of riprap should be installed at the curb cut to slow the flow of the runoff and induce settling of sediment.
5. Swales must have at least 80% grass cover in order to provide adequate stabilization. For general purposes, select fine, close-growing, water-resistant grasses. Climate-adapted plant species help reduce irrigation needs, vulnerability to pests, and the need for quick release fertilizers.
6. Swales should be evaluated for the need to remove sediment and restore vegetation following construction.
7. During the period of vegetation establishment, cover the graded and seeded areas with suitable erosion control materials.

5.2.3. MAINTENANCE REQUIREMENTS

Maintenance for grassy swales is minimal and is largely aimed at keeping the grass cover dense and vigorous. Maintenance practices and schedules should be developed and included as part of the original plans to alleviate maintenance problems in the future. Recommended practices include:

- ***Seasonal Mowing and Lawn Care.*** Lawn mowing should be performed routinely, as needed, throughout the growing season. Regular mowing should also include weed control practices; however, as noted previously, herbicide use should be kept to a minimum. An Integrated Pest Management approach can help reduce chemical use. Healthy grass can be maintained without using fertilizers and is typically assisted by nutrient inflow from runoff.
- ***Sediment Removal.*** Sediment accumulating near culverts and in channels needs to be removed when it results in a significant amount of standing water.
- ***Grass Reseeding.*** A healthy dense grass should be maintained in the channel and side slopes. Grass damaged during the sediment removal process should be promptly replaced using the same seed mix used during swale establishment.
- ***Public Education.*** Private homeowners are often responsible for roadside swale maintenance. Unfortunately, overzealous lawn care by homeowners can present numerous problems. For example, excessive application of fertilizer and pesticides is detrimental to water quality. Pet waste can also be a problem in swales and should be removed to avoid contamination. The delegation of maintenance responsibilities to individual landowners is a cost benefit to the locality. However, localities should provide an active educational program to encourage these recommended practices.

5.3 VEGETATED FILTER STRIPS

5.3.1. INTRODUCTION

Filter strips, also known as vegetated buffer strips, are vegetated sections of land superficially similar to grassy swales. One important characteristic of filter strips is that they are essentially flat with low slopes and designed only to accept runoff as overland sheet flow. A diagrammatic photograph of a vegetated buffer strip is shown in Figure 5-3. The dense vegetative cover facilitates conventional pollutant removal through sedimentation and infiltration.

There are two primary applications for vegetative filter strips. First, roadways and small parking lots are ideal locations where runoff can pass through a filter strip, rather than discharge directly to a piped conveyance system. Properly designed roadway medians and shoulders can make effective vegetated filter strips. Another application for vegetative filter strips is simply leaving land located adjacent to perimeter lots in subdivisions that will not drain via gravity to other stormwater conveyance systems in its natural condition.

Successful performance of filter strips relies heavily on maintaining shallow dispersed flow. To avoid flow channelization and maintain performance, a filter strip should contain dense vegetation with a mix of erosion resistant, soil binding species. Filter strips can be used up-gradient from watercourses, wetlands, or other water bodies, along toes and tops of slopes, and at outlets of other stormwater management structures. The most important criteria for selection and use of this practice are space and slope.

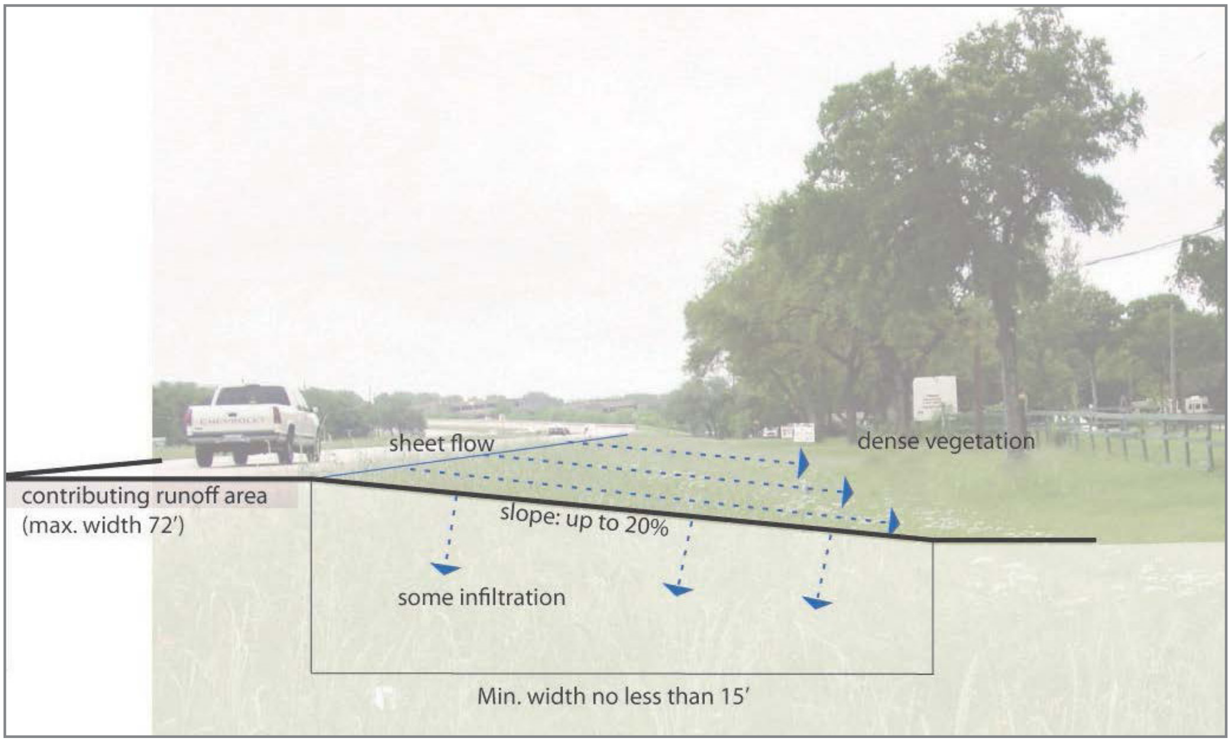

Figure 5-3: Filter strip along side of highway.

SELECTION CRITERIA

- Soils and moisture are adequate to grow relatively dense vegetative stands.
- Sufficient space is available.
- Slope is less than 20% for engineered strips.

LIMITATIONS

- Can be difficult to maintain sheet flow.
- Area required may make infeasible on some sites.

5.3.2. FILTER STRIP DESIGN GUIDANCE

Filter strips may be natural or engineered. Natural filter strips can be applied to impervious areas as noted in Figure 5-3 and to perimeter lots and other areas that will not drain by gravity to other drainage facilities on the site.

A credit is given when parking lots and roads are disconnected from the drainage system and then directed to a vegetated filter strip where it can either infiltrate into the soil or filter over it. The credit is obtained in parking lot areas and roads with a maximum flow length of 72 feet. When meeting the criteria in this section, 50% of the impervious area contributing runoff to the vegetated filter strip can be deducted from the total impervious cover (therefore, potentially gaining compliance with the Low Impact Development impervious cover levels or reducing BMP volume).

NATURAL FILTER STRIPS

1. The filter strip should extend along the entire length of the contributing area.
2. The slope should not exceed 10% for natural filter strips.
3. The minimum dimension (in the direction of flow) should be 25 feet.
4. All of the filter strip should lie above the elevation of the 2-yr, 24-hr storm of any adjacent drainage.
5. There is no requirement for vegetation density or type but diverse native vegetation of varying physical types is preferred.

ENGINEERED FILTER STRIPS

Many of the general criteria applied to swale design apply equally well to engineered vegetated filter strips. Vegetated roadside shoulders provide one of the best opportunities for incorporating filter strips into roadway and highway design, as shown in Figure 5-3. The general design goal is to produce uniform, shallow overland flow across the entire filter strip.The slope should not exceed 10% for natural filter strips.

1. The filter strip should extend along the entire length of the contributing area and the slope should not exceed 20%. The minimum dimension of the filter strip (in the direction of flow) should be no less than 15 feet. The maximum width (in the direction of flow) of the contributing impervious area should not exceed 72 feet. For roadways with a vegetated strip along both sides the total width of the roadway should not exceed 144 feet (i.e., 72 feet draining to each side).
2. The minimum vegetated cover for engineered strips is 80%.
3. The area contributing runoff to a filter strip should be relatively level so that the runoff is distributed evenly to the vegetated area without the use of a level spreader.
4. The area to be used for the strip should be free of gullies or rills that can concentrate overland flow.
5. The top edge of the filter strip along the pavement will be designed to avoid the situation where runoff would travel along the top of the filter strip, rather than through it.
6. The top edge of the filter strip should be level, otherwise runoff will tend to form a channel in the low spot.
7. Filter strips should be landscaped after other portions of the project are completed.

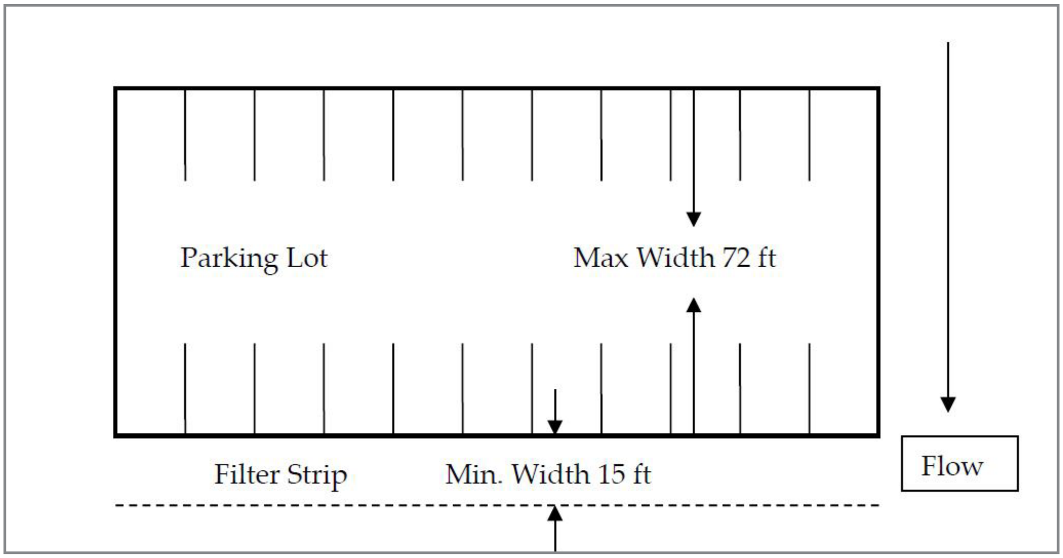

Figure 5-4: Example configuration of filter strip adjacent to a parking lot.

5.3.3. MAINTENANCE REQUIREMENTS

Once a vegetated area is well established, little additional maintenance is generally necessary. The care and maintenance a vegetated feature receives in the first few months after it is planted is key to establishing long-term viability. Once established, all vegetated facilities require some basic maintenance to ensure the health of the plants including:

- ***Seasonal Mowing and Lawn Care.*** Grass height should be limited to 18 inches and mowed regularly. If native grasses are used, the filter may require less frequent mowing. While weeds should be removed, herbicide use should be kept to a minimum. Irrigation can help assure a dense and healthy vegetative cover.
- ***Sediment Removal.*** Sediment removal is not normally required in filter strips, since vegetation grows through sediment and binds it to the soil. However, sediment may accumulate along the upstream boundary of the strip and prevent uniform overland flow. Excess sediment should be removed by hand or with flat-bottomed shovels.
- ***Grass Reseeding and Mulching.*** A healthy dense grass should be maintained. Dense vegetation may require irrigation immediately after planting and during particularly dry periods.

5.4 POROUS PAVEMENT

5.4.1. INTRODUCTION

Porous pavements allow rain to pass through and can be used on both permeable and impermeable soils. In the latter case, these porous pavements are designed with an underdrain system. Where soils are sufficiently permeable, runoff can infiltrate into the soil and the discharge of stormwater or associated pollutants can be avoided. Systems designed with an underdrain provide substantial pollutant removal and increase the time of concentration, which are substantial benefits even when the volume of runoff is not substantially reduced.

There are several types of porous pavement, including porous asphalt, pervious concrete, pavers, and grid-type systems. Porous asphalt consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Pervious concrete differs from regular concrete in the proportion of coarse aggregate, the absence of fine material, and the reduced quantity of water in the mix. Pervious concrete has enough void space to allow rapid percolation of rainfall through the pavement. Pavers themselves are typically impermeable; however, infiltration occurs either in the gaps between the pavers or within openings cast as part of the geometry of the paver. The use of pavers in a portion of a parking lot in South Texas are presented in Figure 5-5.

Figure 5-5: Permeable pavers in parking stall of Cascade Park parking lot in Cameron County.

Porous pavement is typically placed over a highly permeable layer of open-graded gravel and crushed stone as shown in Figure 5-6. The void spaces in the aggregate layers act as a storage reservoir for runoff. The liner and underdrain are optional features that might be required because of structural considerations and/or low soil permeability.

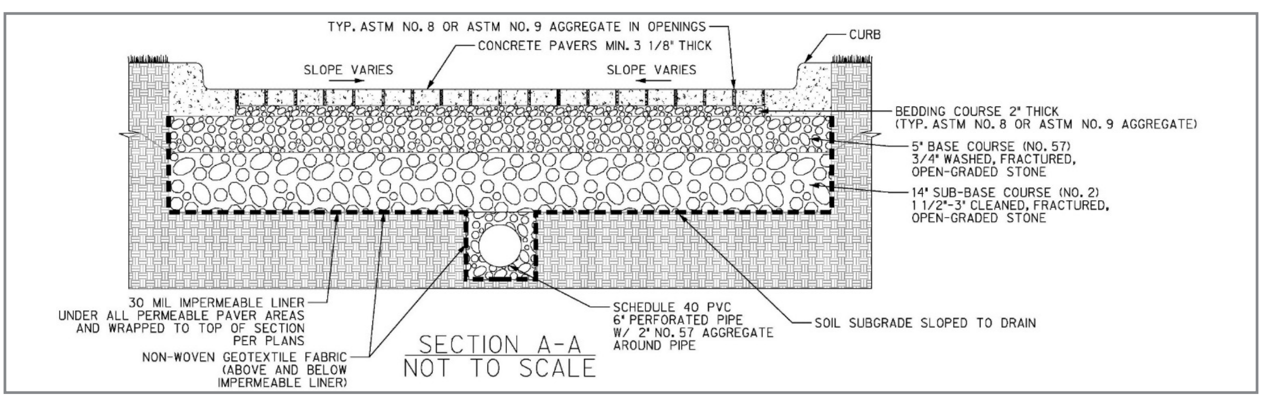

Figure 5-6: Representative cross-section of porous pavement.

SELECTION CRITERIA

Porous pavement may substitute for conventional pavement on parking areas, streets, sidewalks, and patios. Slopes should be flat or very gentle. Soils should have field-verified permeability rates of greater than 0.5 in/hour, and there should be a 4-foot minimum clearance from the bottom of the system to bedrock or the water table for systems installed without underdrains.

The advantages of using porous pavement include:

- Substantial pollutant reduction, even in systems with underdrains and surface discharge.
- Less need for curbing and storm sewers.
- Potential for groundwater recharge

LIMITATIONS

The use of porous pavement is constrained, requiring deep permeable soils (in systems without underdrains), and consideration of impacts to adjacent buildings. Some specific disadvantages of porous pavement include the following:

- Porous pavement has a tendency to become clogged if improperly installed.
- Pervious concrete and porous asphalt have a tendency to ravel in areas with a short turning radius.

5.4.2. POROUS PAVEMENT DESIGN GUIDLINES

Most porous pavement installations are designed to infiltrate water into the soil, resulting in the requirements described below for minimum infiltration rate and separation from groundwater. If these requirements are not met, porous pavement can be installed with an underdrain in order to increase concentration time and reduce pollutants in runoff. Information on the structural requirements for various pavement types can be found at industry websites such as:

- Permeable pavers: http://www.icpi.org/
- Pervious concrete: http://www.perviouspavement.org/
- Porous asphalt: http://www.asphaltpavement.org/index.php?option=com_content&view=article&id=359&Itemid=863

Recommended design guidelines for porous pavement that does not incorporate an underdrain include the following elements:

1. A minimum of 6 inches of reservoir rock must be provided below the pavement to store the 1.5-inch rainfall event.
2. As part of the site evaluation, obtain a soil boring to a depth of at least 4 feet below bottom of stone reservoir to check for soil permeability, porosity, depth of water table, and depth to bedrock.
3. Minimum infiltration rate 3 feet below bottom of stone reservoir is 0.5 inch per hour or an underdrain is required.
4. Provide an under-drain system with perforated pipe in areas where infiltration rates do not meet the design requirements.
5. Minimum depth to the seasonally high-water table is 4 feet.
6. Minimum setback from water supply wells is 100 feet.
7. Minimum setback from building foundations is 10 feet down-gradient.

8. Porous pavement should be used for sidewalks, patios, parking areas and lightly used access roads.
9. Excavate and grade with light equipment with tracks or oversized tires to prevent soil compaction.
10. Divert stormwater runoff away from planned pavement area before and during construction.

5.4.3. MAINTENANCE REQUIREMENTS

Like all BMPs, porous pavements need to be maintained. Maintenance requirements will depend on the environmental context, intensity of use, etc. and may include periodic street sweeping, vacuum sweeping, and/or high pressure washing. Potholes and cracks can be filled with patching mixes unless more than 10% of the surface area needs repair. Spot-clogging may be fixed by drilling half-inch holes through the porous pavement layer every few feet. The pavement should be inspected several times during the first few months following installation and annually thereafter. Annual inspections should take place after large storms, when puddles will make any clogging obvious.

5.5 ENHANCED DETENTION

Many regulatory agencies in the Coastal Zone require detention facilities for new development to manage the increased runoff volume associated with the increase in impervious cover. These facilities, sometimes with little or no modification to standard designs, can help create a sustainable stormwater drainage system. Excavation of detention ponds often brings the basin invert in contact with the water table. When this occurs, the basins with only a little additional excavation can take on the characteristics of either wetlands or wet ponds. The difference between the two is that wet ponds include substantially more open water. These two designs are described in detail below.

5.5.1. ENHANCED DETENTION WETLAND

Constructed wetlands are shallow pools with or without open water elements that create growing conditions suitable for marsh plants. Conventional stormwater wetlands are shallow manmade facilities supporting abundant vegetation and a robust microbial population. As constructed water quality facilities, stormwater wetlands should never be located within delineated natural wetlands areas. Significant potential exists for creative design and participation of an experienced wetland designer is highly recommended.

Constructed wetlands provide physical, chemical, and biological water quality treatment of stormwater runoff. Physical treatment occurs as a result of decreasing flow velocities in the wetland, and is present in the form of evaporation, sedimentation, adsorption, and/or filtration. Constructed wetlands offer natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal. Natural wetlands should not be used for stormwater treatment. A picture of a wetland detention system is presented in Figure 5-7.

Figure 5-7: Constructed wetland in Aransas County, Texas. (Photo courtesy of Danica Adams)

It is necessary to recognize that a fully functional wetland cannot be established spontaneously. Time is required for vegetation to establish and for nutrient retention and wildlife enhancement to function efficiently. Additionally, constructed wetlands should approximate natural situations as much as possible. Unnatural attributes, such as a rectangular shape or rigid channels, should be avoided. Because wetlands must have a source of flow, it is desirable that the water table is at or near the surface.

SELECTION CRITERIA

- Ideal when water table is relatively close to the ground surface
- Multiple benefits of passive recreation (e.g., bird watching, wildlife habitat)
- Never use natural wetlands, or wetlands provided as mitigation for impacts to natural wetlands, as a treatment device

LIMITATIONS

- When located in an area of high visibility, constructed wetlands may not appear especially attractive to residents
- May be infeasible to site or retrofit in dense urban areas

DETENTION WETLAND DESIGN GUIDANCE

1. ***Construction:*** The wet pond enhancement is created by over-excavating a portion of the detention basin. The material excavated, when suitable, can be used onsite to increase the finished floor elevations of any buildings constructed as part of development. The surface water elevation should be equal to the invert of the detention basin outlet.
2. ***Basin Inlets:*** Discharge to the facility should occur from as many inlets as possible to reduce concentrated flow. Energy dissipation should be provided at the inlet if the velocity of the flow is greater than 1 ft/s. Incorporation of low flow channels within the facility should be avoided as they concentrate runoff and reduce performance.
3. ***Facility Sizing:*** The excavated volume of the wetland area should be no smaller than the volume of runoff produced by a 1.5-inch rainfall event.
4. ***Pond Configuration:*** Stormwater constructed wetlands offer significant flexibility regarding pond configuration with the exception that short-circuiting of the facility must be avoided. Provision of irregular, multiple flow paths is desired. At least 25% of the basin should be an open water area at least 2-ft deep if the facility is exclusively designed as a shallow marsh. Added open-water area makes marsh space more aesthetically pleasing, and the combined water/wetland area creates a good habitat for waterfowl. The wetland zone should be 50 to 70% of the area and should be 6- to 12-inch deep.
5. ***Vegetation:*** A diverse, locally appropriate selection of wetland plant species is vital for all constructed wetlands. Wetland vegetation elements should be placed along the aquatic bench or in the shallow portions of the permanent pool. The optimal elevation for planting wetland vegetation is within 6 inches vertically of the normal pool elevation. Participation of a wetland designer or landscape architect familiar with local plants is highly recommended.
6. ***Outflow Structure:*** The outflow structure should be designed as required by local regulations to achieve necessary detention requirements.

5.5.2. ENHANCED DETENTION WET PONDS

The wet pond is a detention basin with a permanent volume of water incorporated into the design (Figure 5-8). Wet ponds are stormwater quality control facilities that maintain a permanent wet pool and a standing crop of emergent littoral vegetation. Wet ponds are often perceived as a positive aesthetic element in a community and offer significant opportunity for creative pond configuration and landscape design.

Biological processes occurring in the permanent pool aid in reducing the amount of soluble nutrients present in the water. Because they are designed with permanent pools, wet basins can also have recreational and aesthetic benefits. During storm events, runoff inflows displace part or all of the existing basin volume and are retained in the facility until the next storm event. Wet basins also help provide erosion protection for the receiving channel by limiting peak flows during larger storm events. Wet ponds may be feasible for watershed areas greater than 10 acres with a water table close to the land surface.

Figure 5-8: Picture of an enhanced detention wet pond. (Photo courtesy of Houston-Galveston Area Council)

SELECTION CRITERIA

- Multiple benefits of passive recreation (e.g., bird watching, wildlife habitat)
- Ideal for large, regional tributary areas
- Site area greater than 10 acres

LIMITATIONS

- There is concern about mosquitoes; however, aeration and/or stocking the pond with gambusia may eliminate this problem
- May be infeasible to site or retrofit in dense urban areas
- Potential hazard (drowning when side slopes are too steep or are bulk-headed)

DETENTION/WET POND DESIGN GUIDANCE

1. ***Construction:*** Wet pond enhancement is created by over-excavating a portion of the detention basin. The material excavated, when suitable, can be used onsite to increase the finished floor elevations of any buildings constructed as part of the development. The surface water elevation should be equal to the invert of the detention basin outlet.

2. ***Basin Inlets:*** Discharge to the facility should occur from as many inlets as possible to reduce concentrated flow. Incorporation of low flow channels within the facility should be avoided as they concentrate runoff and reduce performance.

3. ***Facility Sizing:*** The volume of the wet pond should be no smaller than the volume of runoff produced by a 1.5-inch rainfall event.

4. ***Pond Configuration:*** The wet basin can be configured as a two-stage facility with a sediment forebay and a main pool. Basins should be wedge-shaped, narrowest at the inlet and widest at the outlet when possible. The minimum length to width ratio should be 1.0. Higher ratios are recommended. A schematic of this design is presented in Figure 5-9.

5. ***Pond Side Slopes:*** Side slopes of the basin should be 3:1 (H:V) or flatter for grass stabilized slopes. Slopes steeper than 3:1 should be stabilized with an appropriate slope stabilization practice.

6. ***Safety Considerations:*** Safety is provided either by fencing off the facility or by managing the contours of the pond to eliminate drop-offs and other hazards. Earthen side slopes should not exceed 3:1 (H:V). Landscaping can be used to impede access to the facility if desired. The primary spillway opening should not permit access by small children. Outfall pipes more than 48 inches in diameter should be fenced.

7. ***Depth of the Permanent Pool:*** The permanent pool should be no deeper than 8 feet and should average 4-6 feet deep.

8. ***Aeration:*** The performance and appearance of a wet pond may be improved by providing aeration of the permanent pool; however, this is not a requirement.

9. ***Vegetation:*** Aquatic plants should be allowed to grow along banks s to enhance water quality treatment and habitat functions and to discourage inappropriate recreational activities (e.g. swimming).

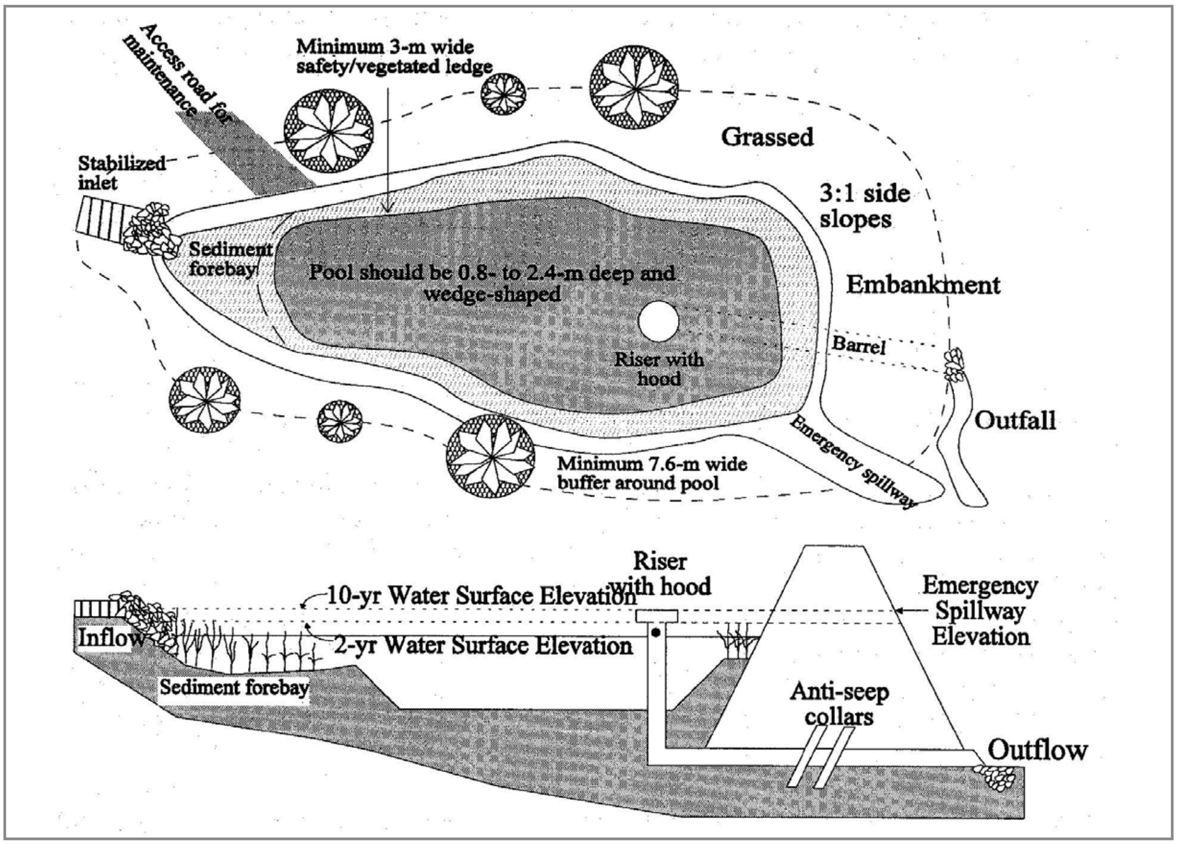

Figure 5-9: Schematic of a wet basin.

5.4.2. ENHANCED EXTENDED DETENTION

Extended detention basins capture and temporarily detain the water quality volume. They are intended to serve primarily as settling basins for the solids fraction, nutrients attached to solids, and as a means of limiting downstream erosion by managing stormwater.

- Extended detention basins may be constructed either online or offline.
- Extended detention basins are typically depressed basins that temporarily store stormwater runoff following a storm event and do not have a permanent water pool between storm events.

Water is controlled by means of a hydraulic control structure to restrict outlet discharge. Provided water quality benefits are the removal of sediment and buoyant materials. Furthermore, nutrients, heavy metals, toxic materials, and oxygen-demanding materials associated with these particles are also removed. Control of the maximum runoff rates serves to protect drainage channels below the device from erosion and to reduce downstream flooding. Refer to Figure 5-10 for a schematic of an extended detention basin.

One of the main advantages of extended detention basins is their adaptability; they can be used on areas with thin soils, high evaporation rates, low-soil infiltration rates, in limited space areas, and where groundwater is to be protected. Due to the simplicity of design, extended detention basins are relatively easy and inexpensive to construct and operate.

Extended detention basins are generally best suited to drainage areas greater than three acres, since the outlet orifice becomes prone to clogging for small water quality volumes. Extended detention basins can also be combined with flood control detention facilities by providing additional storage above the water quality volume.

DESIGN GUIDELINES

1. ***Contributing Drainage Area:*** These areas should be less than 128 acres with no minimum drainage area.
2. ***Pre-treatment:*** A sediment forebay is designed to retain the bulk of the sediment entering the facility. This will simplify sediment removal and reduce overall basin maintenance. Refer to the design guidelines for sediment forebays in General Guidelines Item No. 7, where the forebay volume is equal to 25% of the water quality volume to retain the first flush runoff volume. To promote advanced treatment of the first flush volume, the forebay design relies on a berm and/or gabion within the basin to promote pollutant settling. Non-woven filter fabric with a 0.15 mm (U.S. Sieve Size 100) opening shall be placed on the gabion to enhance detention and facilitate maintenance. Rock riprap shall be placed on the downstream side to prevent scouring in the event flow passes over the gabion. Use guidance found in 3.2.4 and 3.2.
3. ***Basin Sizing:*** The BMP Volume is calculated by applying a factor of 1.05 to the Water Quality Volume (WQV) calculated per Chapter 2.3. The WQV is increased by a factor of 5% to accommodate for reduction in the available storage volume due to deposition of solids in the time between full-scale maintenance activities.

   BMP Volume = WQV * 1.05

   WQV = Required Water Quality Volume as calculated in Chapter 2.3 (cubic feet)

4. ***Basin Configuration:*** The extended detention basin is optimally designed to have a gradual expansion from the inlet toward the middle of the facility and a gradual contraction toward the basin outfall. The ratio of flow-path length to width from the inlet to the outlet should be at least 2:1 (L:W). Flow-path length is defined as the distance from the inlet to the outlet as measured at the surface. Width is defined as the mean width of the basin. Higher length-to-width ratios are recommended. Outlets should be placed to maximize the flow-path through the facility. The basin should maintain a longitudinal slope between 1.0 – 5.0% with a lateral slope between 1.0 – 1.5%.
5. ***Basin Depth:*** The water depth in the basin when full should be no greater than 8 feet.
6. ***Basin Outlet:*** The facility's drawdown time should be regulated by an orifice plate located downstream of the primary outflow opening. The outflow structure should be sized to allow for complete drawdown of water quality volume within 48 to 72 hours. In addition, the outlet shall be configured to provide at least 12- hour detention for 0.5 inches of runoff from the total effective impervious cover. The minimum orifice diameter is 1-inch. Non woven filter fabric with a minimum opening of 0.15 mm (U.S. Sieve Size 100) shall be wrapped around the riser to enhance detention. Risers should be double-wrapped with filter fabric until the contributing drainage area is vegetated and stabilized. Outflow structures must have a trash rack or other acceptable means of preventing clogging at the entrance to the outflow pipes. The following equation can be used to determine the required orifice size:

$$A_O = \frac{0.001 BMP\_Vol.}{C\sqrt{2gH_{avg}}}$$

A_O = maximum orifice area (square inches)
BMP Vol. = required basin volume as calculated above (cubic feet)
C = orifice coefficient (Typical. 0.62)
g = acceleration of gravity (32.2 ft/s^2)
H_{avg} = H_T/2, average hydraulic head (ft)
H_T = total hydraulic head determined from difference between the WQ elev. and the center of orifice

7. ***Basin Soils:*** To enhance infiltration and water storage within the basin, topsoil must be placed on the basin floor after excavated bottom is scarified to a depth of 2 to 3 inches to improve drainage. Topsoil must be 6 to 8 inches deep with a soil mixture of 30-40% sand or granite sand, 60-70% topsoil, and 5-10% compost or peat to aid in water retention and promote vegetation growth. Soil blend must have clay content less than 20% and be free of stones, stumps, roots or other similar objects larger than one (1) inch. If on-site soils do not meet these specifications, topsoil per the above specs must be added. Sandy loam is not an approved soil and caliche is not considered a soil.

8. ***Vegetation:*** To enhance appearance and function, trees, shrubs, and additional forb vegetation are recommended along with Bermuda grass coverage (strongly recommend sod). Refer to bioretention basin vegetation requirements (4.2.2 (10)) for guidance. Muhly grass can be used to aid in spreading flow and concealing the riser pipe and mid-basin gabion. Trees and shrubs can effectively screen other structural aspects while also aiding in evapotranspiration and basin floor drying.

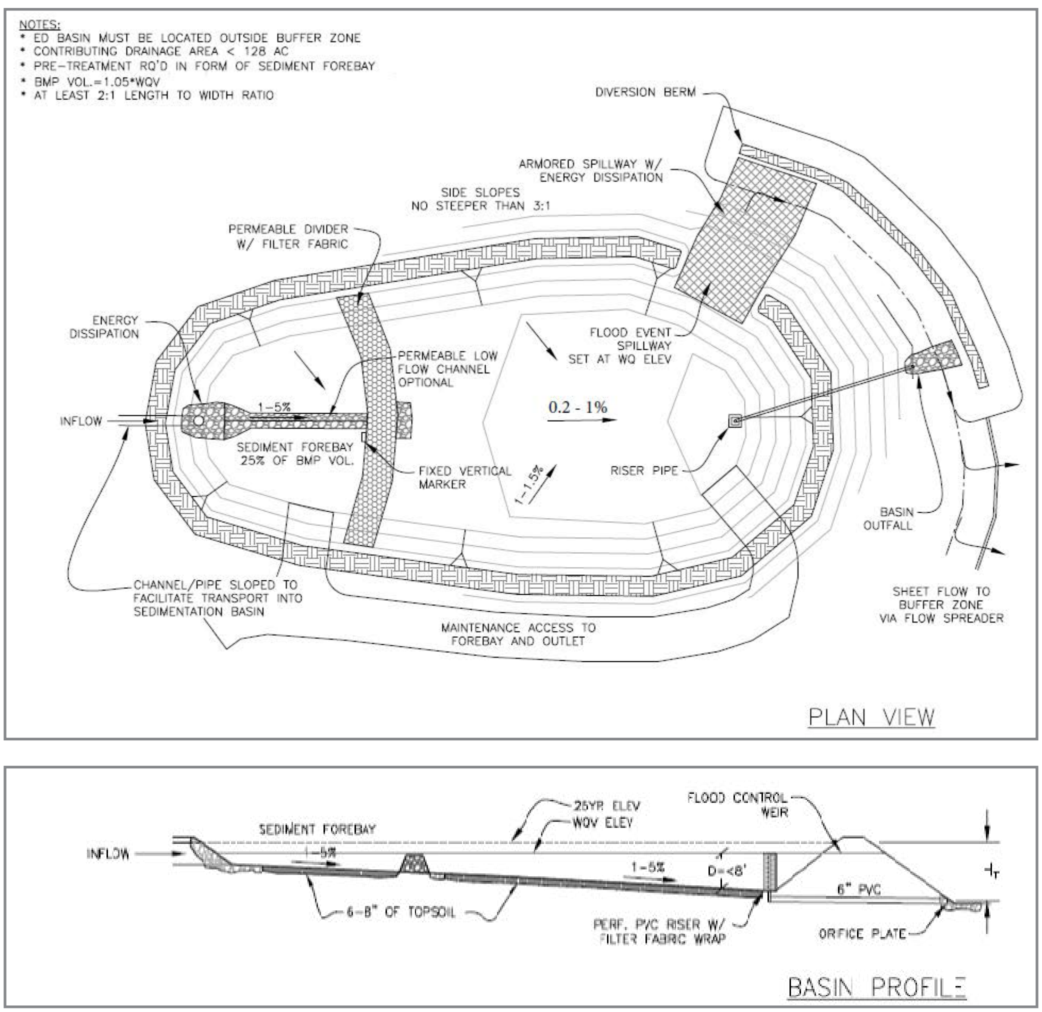

Figure 5-10: Schematic of an Enhanced Extended Detention Basin

5.5.4. RECOMMENDED MAINTENANCE

Extended detention basins capture and temporarily detain the water quality volume. They are intended to serve primarily as settling basins for the solids fraction, nutrients attached to solids, and as a means of limiting downstream erosion by managing stormwater.

ROUTINE MAINTENANCE

- ***Mowing.*** The side-slopes, embankment, and emergency spillway of the basin should be mowed at least twice a year to prevent woody growth and control weeds.
- ***Inspections.*** Wet basins should be inspected at least twice a year to evaluate facility operation. When possible, inspections should be conducted during wet weather to determine if the basin is functioning properly. The embankment should be checked for subsidence, erosion, leakage, cracking, and tree growth. The condition of the emergency spillway should also be evaluated. The inlet, barrel, and outlet should be inspected for clogging. The adequacy of upstream and downstream channel erosion protection measures should be checked. Stability of the side slopes should be tested. Any modifications to the basin structure and contributing watershed should also be evaluated.

  During semi-annual inspections, prepare and update maintenance checklists and replace any dead or displaced vegetation. Replanting various species of wetland vegetation may be required until a viable mix of species is established. Cracks, voids, and undermining should be patched/filled to prevent additional structural damage. Trees and root systems should be removed to prevent growth in cracks and joints that can cause structural damage. Inspections should be carried out with as-built pond plans in hand.
- ***Debris and Litter Removal.*** Debris and litter should be removed from the surface of the basin. Particular attention should be paid to floatable debris around the riser, and the outlet should be checked for possible clogging.
- ***Erosion Control.*** The basin side slopes, emergency spillway, and embankment all may periodically suffer from slumping and erosion. Corrective measures such as regrading and revegetation may be necessary. Similarly, riprap protecting the channel near the outlet may need to be repaired or replaced.
- ***Nuisance Control.*** Most public agencies surveyed indicate that control of insects, weeds, odors, and algae is needed in some ponds. If the ponds are properly sized and vegetated, these problems should be rare in wet ponds with the exception of extremely dry weather conditions. Twice a year, the facility should be evaluated in terms of nuisance control (insects, weeds, odors, algae, etc.). Biological control of algae and mosquitoes using fish such as fathead minnows is preferable to chemical applications.

NON-ROUTINE MAINTENANCE

- ***Structural Repairs and Replacement.*** Eventually, the various inlet/outlet and riser works in the wet basin will deteriorate and must be replaced. Some public works experts have estimated that corrugated metal pipe (CMP) has a useful life of about 25 years, while concrete barrels and risers may last 50 to 75 years. The actual life depends on the type of soil, pH of runoff, and other factors. Polyvinyl chloride (PVC) pipe is a corrosion resistant alternative to metal and concrete pipes. Local experience typically determines which materials are best suited to the site conditions. Leakage or seepage of water through the embankment can be avoided if the embankment has been constructed of impermeable material, has been compacted, and if anti-seep collars are used around the barrel. Correction of these design flaws is difficult.
- ***Sediment Removal.*** Wet ponds will eventually accumulate enough sediment to significantly reduce storage capacity of the permanent pool. As might be expected, the accumulated sediment can reduce both the appearance and pollutant removal performance of the pond. Sediment accumulated in the sediment forebay area should be removed from the facility every two years to prevent accumulation in the permanent pool. Dredging of the permanent pool should occur at least every 20 years, or when accumulation of sediment impairs functioning of the outlet structure.

- ***Harvesting.*** If vegetation is present on the fringes or in the pond, it can be periodically harvested and the clippings removed to provide export of nutrients and to prevent the basin from filling with decaying organic matter. Clippings may be composted onsite, away from the wet pond, or at an off-site composting facility.

5.6 BIORETENTION

5.6.1. INTRODUCTION

Rain garden and bioretention best management practices function as a soil and plant-based filtration device that remove pollutants through a variety of physical, biological, and chemical treatment processes. These facilities normally consist of a filtration bed, ponding area, organic or mulch layer, and plants. Exfiltration of the stored water in the bioretention area planting soil into the underlying soils occurs over a period of days when installed as an unlined system.

Figure 5-11 illustrates the basic components of the system and a picture of a bioretention system located in a parking lot island is presented in Figure 5-12. TSS removal efficiency = 89%.

Rain gardens and bioretention systems are very similar in their design and function. Both systems can be used in any land use type or for any site. For the purposes of this guidance manual, the main difference between the two systems is that a bioretention system uses engineered soils while rain gardens do not. However, rain gardens can incorporate slightly modified soils. Both systems can be designed with or without underdrains.

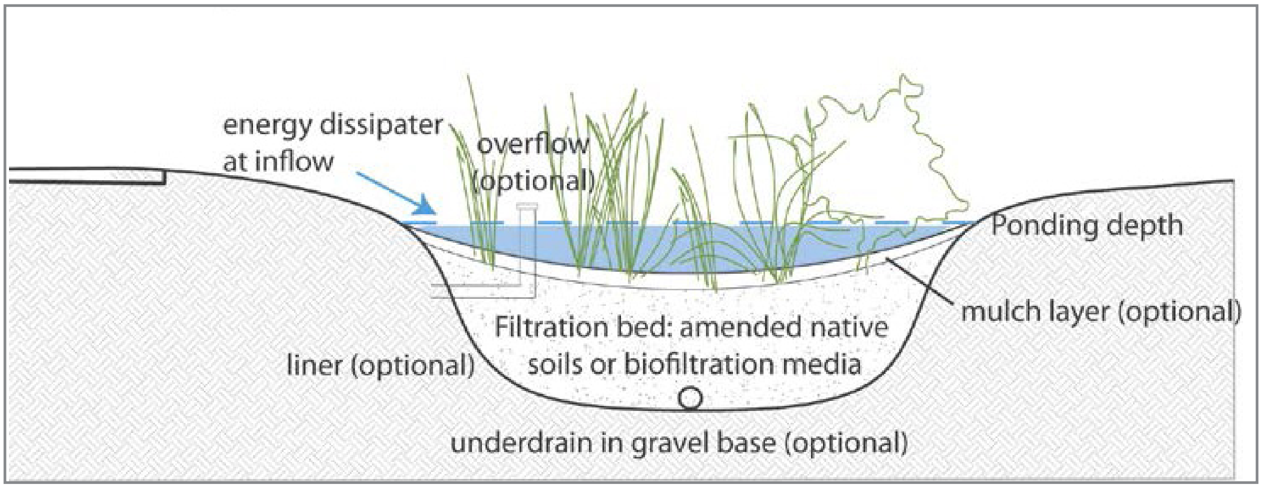

Figure 5-11: A diagram of the basic rain garden / bioretention system components including optional components.

Figure 5-12: Picture of a bioretention facility. (Photo courtesy of David Dods)

SELECTION CRITERIA

- Onsite systems serving a relatively small drainage areas are ideal since they can be incorporated into the site landscaping.
- Bioretention provides stormwater treatment that enhances the quality of downstream water bodies by temporarily storing runoff and releasing it over a period of days to the receiving water.
- Vegetation provides shade and wind breaks, absorbs noise, and improves an area's landscape.

LIMITATIONS

- Bioretention is not recommended for areas with slopes greater than 20% or where mature tree removal would be required since clogging may result, particularly if the facility receives runoff with high sediment loads.
- Unlined bioretention systems are not suitable at locations where the water table is within 4 feet of the ground surface and where the surrounding soil stratum is unstable.
- Inclusion of substantial amounts of compost in the filter media can substantially increase nutrients in the discharge.

5.6.2. BIORETENTION DESIGN GUIDANCE

Bioretention facilities include inorganic and soil material in the filtration media to support vegetation. This allows these facilities to be integrated into site landscaping where they can provide unobtrusive treatment of stormwater runoff. The following design guidelines are appropriate for conventional systems in the public domain. The reader should be aware that there are proprietary versions of bioretention systems commonly called "tree box filters", which will provide the same level of pollutant removal. Design of these systems should follow manufacturer's recommendations.

A schematic of a bioretention system is provided in Figure 5-13, which illustrates recommended design components. The figure includes a grass filter strip for pretreatment of runoff to reduce sediment loading to the bioretention cell. While this is a useful component, it is not required and may not always be feasible depending on space constraints at the site. The "gravel curtain drain" and "optional sand filter layer" are not common or required.

Underdrains are required if the system is installed in soils with infiltration rates of less than 0.5 in/hr. A bridging layer of pea gravel should be placed between the planting media and gravel layer to prevent the planting media from migrating into the gravel layer below.

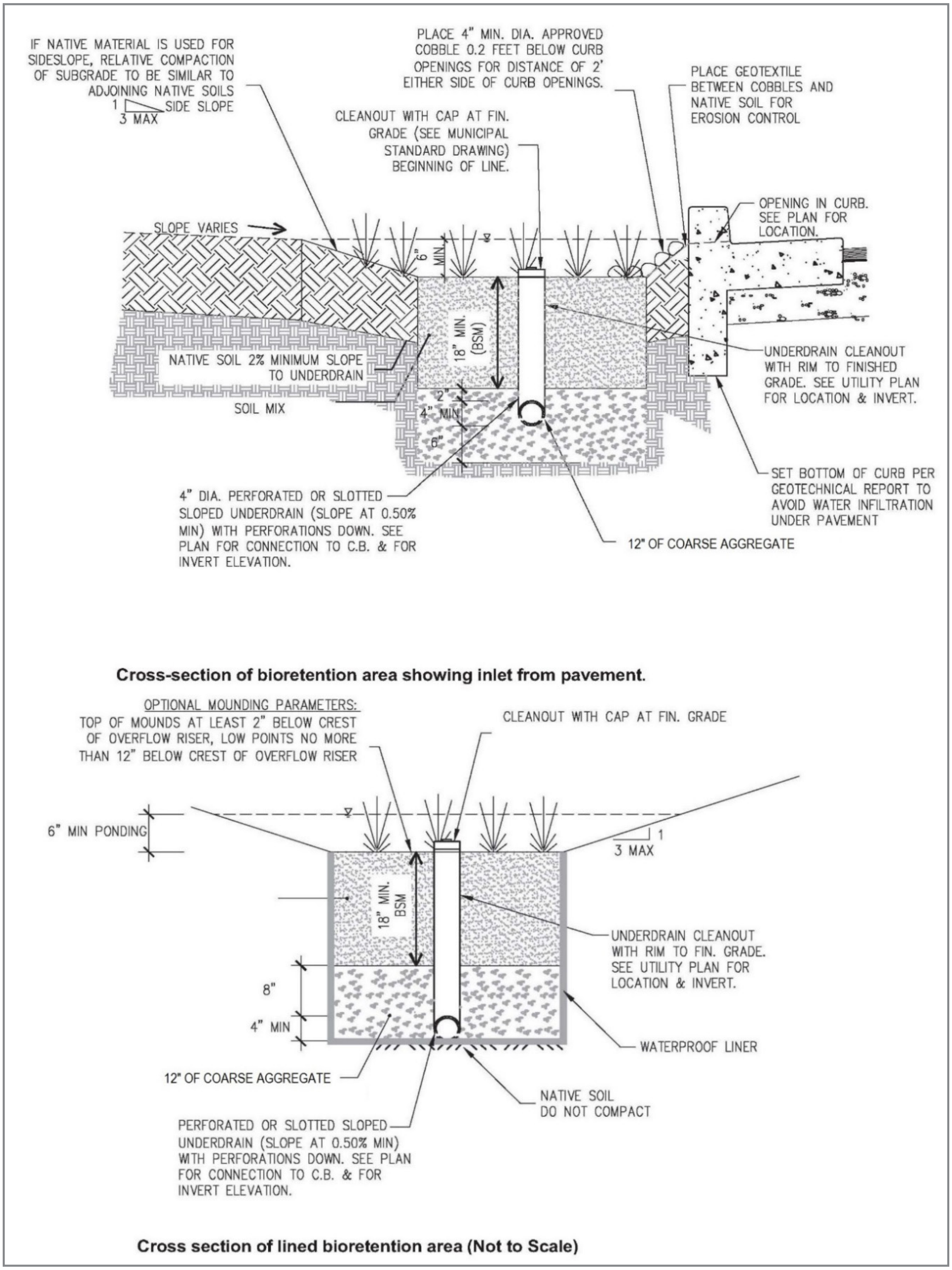

Figure 5-13: Schematic diagram of a bioretention system.

1. ***Bioretention Sizing:*** The storage volume above the surface of the planting media should be sufficient to retain the volume of runoff from a 1.5-inch rainfall. Water depth over the media for the design storm should not exceed 18 inches.

2. ***Inlet Design:*** When siting bioretention facilities to intercept drainage, the designer should attempt to use a preferred "off-line" facility design. Off-line facilities are defined by the flow path through the facility. Any facility that utilizes the same entrance and exit flow path upon reaching pooling capacity is considered an off-line facility.

3. ***Media Properties:*** The filtration media should have a minimum thickness of 18 inches and should have a maximum clay content of less than 5%. Soil mixtures should be 75-90% sand; 0-4% organic matter; and 10-25% screened bulk topsoil. Soil should be a uniform mix, free of stones, stumps, roots, or other similar objects larger than two inches. No other materials or substances should be mixed or dumped within the bioretention facility that may be harmful to plant growth or prove a hindrance to planting or maintenance operations. Provide clean sand, free of deleterious materials. Sand may be composed of either ASTM C-33 (concrete sand) or ASTM C-144 (masonry sand). A good source of media is the material commonly used to construct golf course greens.

   The organic matter listed above should be carefully selected. Traditional options for organic matter include peat moss or shredded bark mulch.

   A high-flow geotextile fabric or bridging stone is required to separate the soil media from the washed river gravel underdrain. A layer of pea gravel, a minimum of three inches thick will typically provide this bridge. This is an alternative to high-flow geotextile fabric.

   Installation of filter media must be done in a manner that will ensure adequate filtration. After scarifying the invert area of the proposed facility, place soil. Avoid over compaction by allowing time for natural compaction and settlement. No additional manual compaction of soil is necessary. Rake soil material as needed to level out. For facilities designed with a liner, no scarification of the invert area is required.

4. ***Underdrains:*** Underdrains should be incorporated in all designs unless installed where infiltration rates exceed 0.5 in/hr. Underdrain piping should consist of a main collector pipe and two or more lateral branch pipes, each with a minimum diameter of 4 inches. Underdrains should be perforated with ¼ - ½ inch openings, 6 inches center to center. The pipes should have a minimum slope of 1% (1/8 inch per foot) and the laterals should be spaced at intervals of no more than 10 feet. Each individual underdrain pipe should have a cleanout access location. Ideally the cleanout access will be located in the facility embankment to reduce the possibility of bypass if the cleanout is damaged (see Figure 5-14 for example). All piping is to be Schedule 40 PVC.

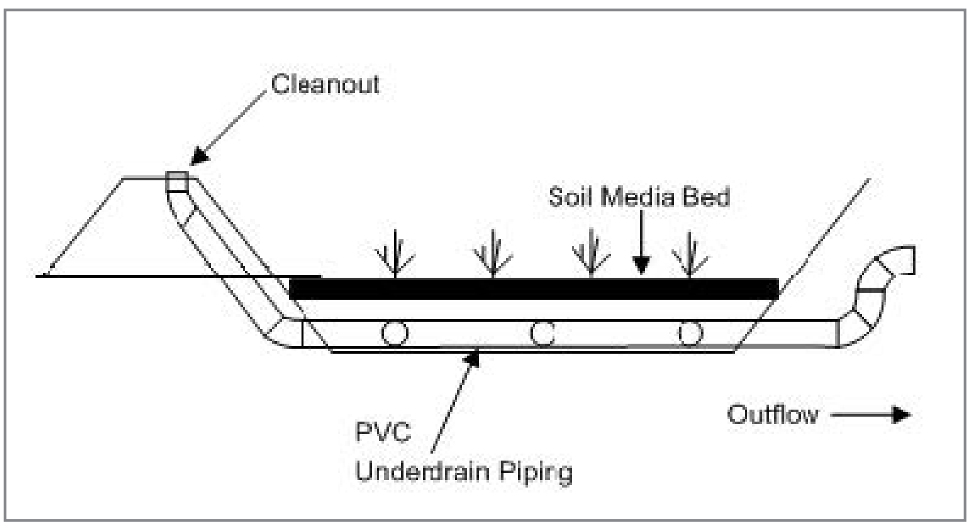

Figure 5-14: Detail of cleanout location.

5. ***Outlet:*** A raised outlet as illustrated in Figure 5-15 is optional. It has the potential advantage of reducing head-loss across the facility and providing a permanent pool that will supply additional water for plants during long dry periods.

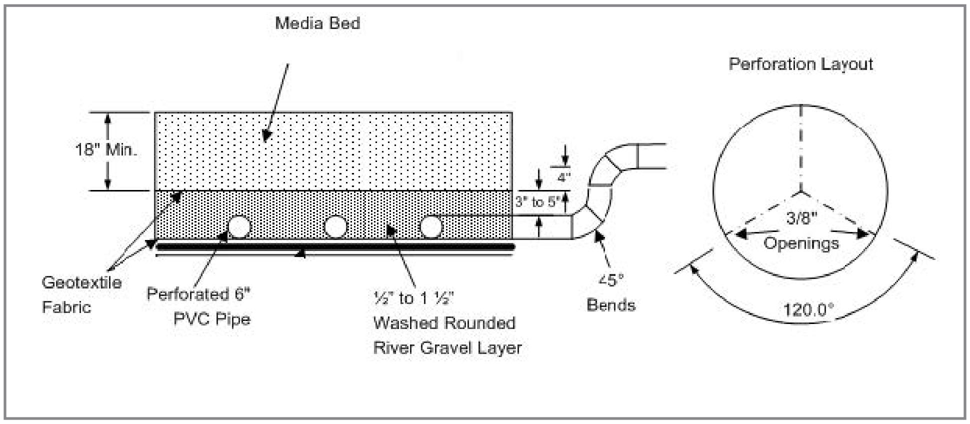

Figure 5-15: Illustration of optional outlet design.

6. ***Setbacks:*** When siting bioretention facilities, a 50-foot setback from septic fields should be provided. Setback from a foundation or slab should be 5 feet or greater.

7. ***Vegetation:*** Vegetation selected for the bioretention system should be climate-adapted and tolerant of frequent inundation during extended periods of wet weather. If a low maintenance landscape is desired, Bermuda grass throughout the basin will function as an appropriate vegetative cover. No additional plants are necessary.

8. ***Curb Cut Inlet:*** There are several design options for curb cuts, where curbs are used or modified, to allow runoff to enter the bioretention or rain garden system. Several of these (non-exclusive) options are diagrammed below. The last option in the figure below demonstrates inlet where a sediment/debris catchment area is included. These types of modifications can provide places to catch larger items such as aluminum cans or other floatables and can be designed with grates to allow water through the 'box' and into the rain garden. These curb inlets can also be designed to run level with the base of the bioretention system. In either method, they should be designed to be shovel-size for easy maintenance.

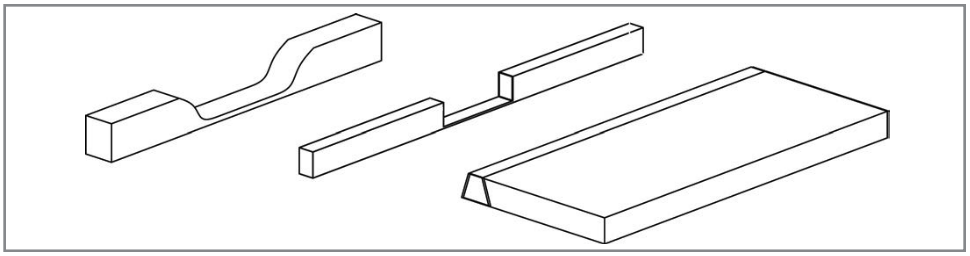

Figure 5-16: Curb cut options: smooth cut, hard cut and flush curb.

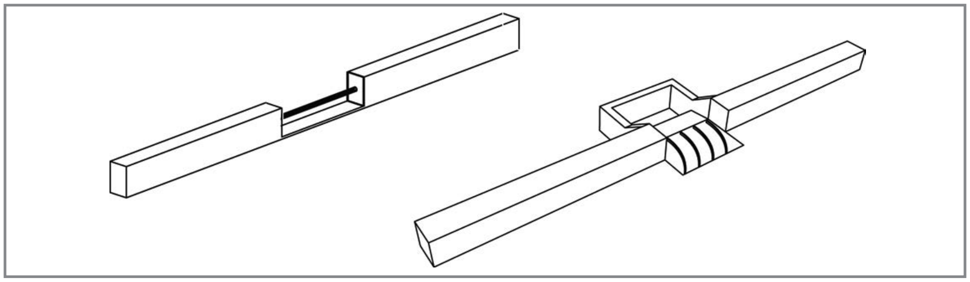

Figure 5-17: Curb cuts with optional sediment/trash screens.

9. ***Inlet Design:*** Where flows enter the treatment measure, allow change in elevation of 4 to 6 inches between the paved surface and the soil media elevation, so that vegetation growth or mulch build-up does not obstruct flow. Install cobbles, rocks or a small cement slab to dissipate flow energy where runoff enters the treatment measure.

10. ***Construction:*** During construction, minimize compaction of existing soils. Protect the area from construction traffic and site runoff. Additionally, runoff from un-stabilized areas should be diverted away from the facility.

11. ***Mulch:*** Provide a 3-inch layer of mulch to cover exposed soil between plantings.

TREE BOX FILTERS – ROADSIDE BIORETENTION

Tree box filters are bioretention systems enclosed in concrete boxes or other sub-surface structures that drain runoff from paved areas via a standard storm drain inlet structure. They consist of a precast concrete (or other) container, a mulch layer, bioretention media mix, observation and cleanout pipes, under-drain pipes, a street tree or large shrub, and a grate cover.

DESIGN REQUIREMENTS

The ponding area in Tree Box Filters shall be designed with a maximum ponding depth of 24" and the capacity to drain ponded water within 24 hours. Other criteria include:

- Plants can also be selected from those that would be used in traditional bioretention systems (See Appendix A).
- An underdrain pipe is required to drain the feature.
- A maximum of 75% of the void space volume may be counted for detention.
- Pre-manufactured systems must be installed in accordance with the manufacturer's instructions.

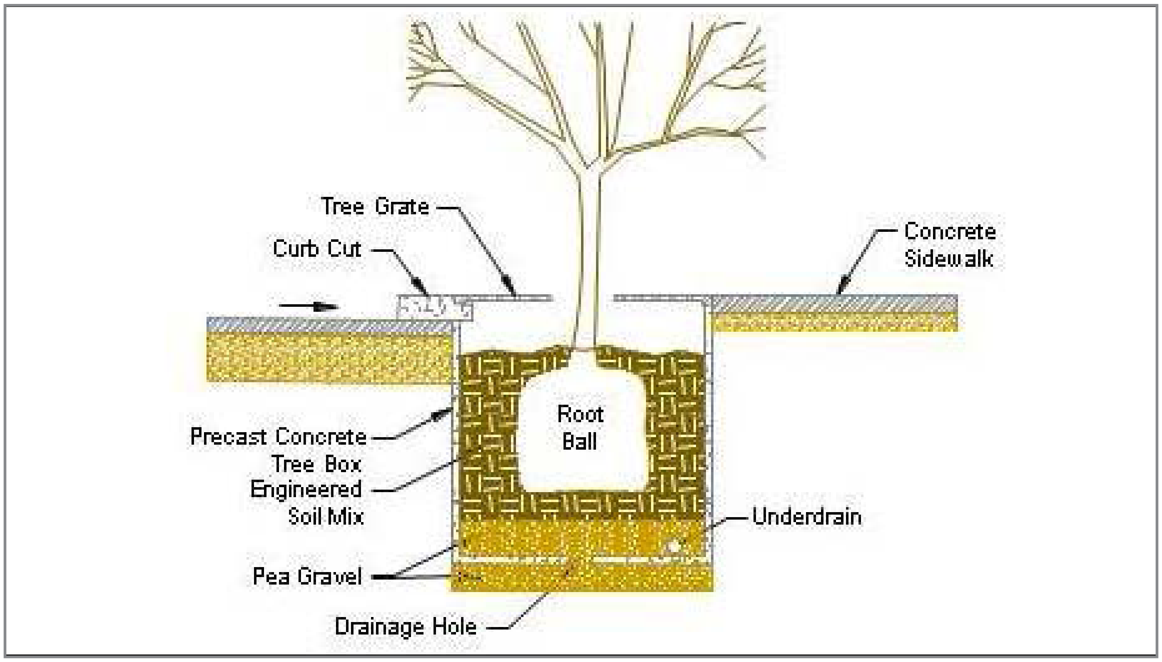

Figure 5-18: Tree Box Filters (Harris County LID Manual)

STORMWATER PLANTER BOXES – ROADSIDE AND BUILDING BIORETENTION

Storm Water Planters, also known as flow through planters, are bioretention systems enclosed in concrete structures. They can be designed to drain runoff from paved areas via curb inlet structures or pipes, or can be located under roof drain downspouts for treatment of roof runoff.

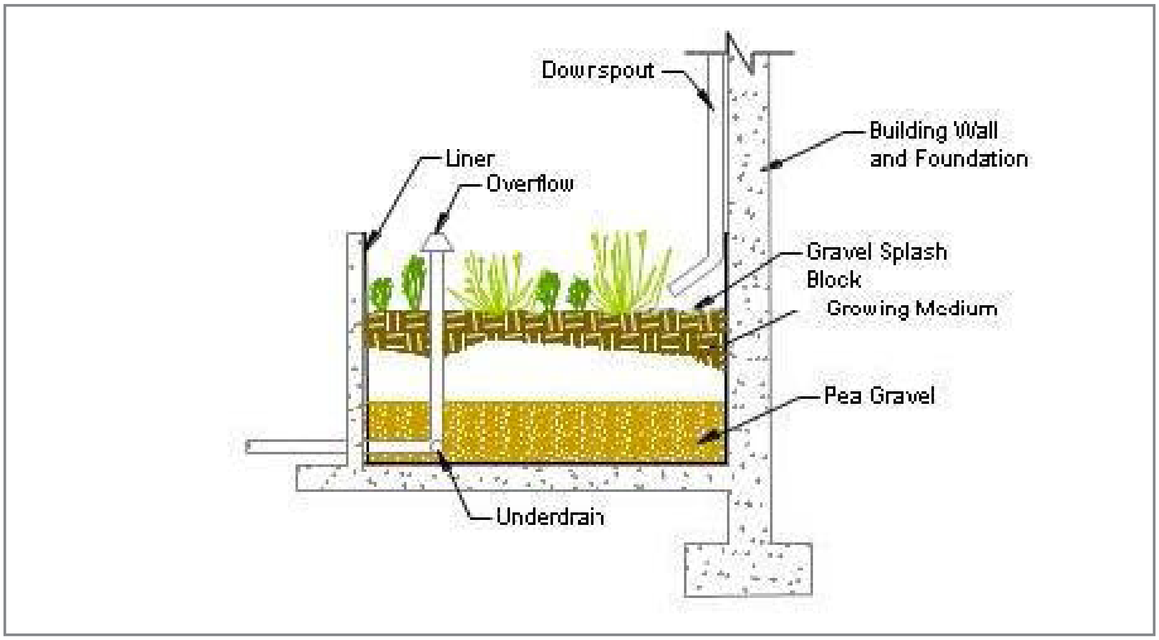

Figure 5-19: Stormwater Planter Box (Harris County LID Manual)

DESIGN REQUIREMENTS

- Waterproofing shall be incorporated into the designs of Storm Water Planters sited near buildings and other structures. An underdrain pipe is required.
- The ponding area in Storm Water Planters shall be designed with a maximum ponding depth of 24" and the capacity to drain ponded water within 24 hours.
- Plants can also be selected from those that would be used in traditional bioretention systems.
- Pre-manufactured systems must be installed in accordance with the manufacturer's instructions.

5.6.3. RECOMMENDED MAINTENANCE

The primary maintenance requirement for bioretention areas is routine inspection and repair or replacement of the treatment area's components. Generally, this involves nothing more than periodic maintenance that is required for landscaped area. Appropriate plants for the site, climate, and watering conditions should be selected for use in the bioretention cell. Properly selected or native plants will aide in reducing fertilizer, pesticide, water, and overall maintenance requirements. Bioretention system components should blend over time through plant and root growth, organic decomposition, and the development of a natural soil horizon. These biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance.

Routine maintenance should include a semi-annual health evaluation of trees and shrubs growing within the area and the subsequent removal of excessive dead or diseased vegetation. Diseased vegetation should be treated as needed using preventative and low-toxic measures to the highest extent possible. Bioretention systems have the potential to create very attractive habitats for mosquitoes because of highly organic, often heavily vegetated areas mixed with shallow water. Routine inspections for areas of standing water within the facility and corrective measures to restore proper infiltration rates are necessary to prevent mosquito breeding.

In order to maintain the treatment area's appearance, it may be necessary to prune and weed. Furthermore, mulch replacement is suggested when erosion is evident or when the site begins to look unattractive. In some cases, the entire area may require mulch replacement every year, while in others spot mulching may be sufficient.

Other potential tasks include replacement of dead vegetation, erosion repair at inflow points, unclogging the underdrain, and repairing overflow structures.

Other recommended maintenance guidelines include:

1. ***Inspections.*** Bioretention facilities should be inspected at least twice a year (once during or immediately following wet weather) to evaluate facility operation. During each inspection, erosion areas inside and downstream of the facility must be identified and repaired or revegetated immediately.
2. ***Sediment Removal.*** Remove sediment when accumulated sediment hinders the flow of water into the facility.
3. ***Drain Time.*** When the drain time exceeds 48 hours, the top few inches of filter media should be removed and replaced with material that meets the specifications of the original media.
4. ***Vegetation.*** All dead and diseased vegetation considered beyond treatment should be removed and replaced. Re-mulch any bare areas by hand whenever needed. Replace mulch annually in the spring, or more frequently if needed, in landscaped areas of the basin where grass or groundcover is not planted. Grass areas in and around bioretention facilities should be mowed at least twice annually. More frequent mowing to maintain aesthetic appeal may be necessary in landscaped areas. Use Integrated Pest Management techniques to avoid or minimize the use of synthetic pesticides and fertilizers.
5. ***Debris and Litter Removal.*** Debris and litter will accumulate in the facility and should be removed during regular mowing operations.
6. ***Filter Underdrain.*** Clean underdrain piping network to remove any sediment buildup as needed to maintain design drawdown time.

5.7 INFILTRATION FACILITIES

5.7.1. INTORDUCTION

Infiltration basins are vegetated stormwater retention facilities designed to capture runoff and allow it to infiltrate directly to the soil profile rather than discharging to receiving waters. This practice is intended to mimic the natural rainfall retention and infiltration characteristics of undeveloped watersheds. Basins are typically excavated in native soils, constructed above grade using structural walls, or created with berms. Typical designs allow for complete infiltration of the capture volume within 2 to 3 days and provide a splitter structure to route surplus inflows around the facility when full. Infiltration basins are generally suitable for treatment of drainage areas from 5 to 15 acres. A schematic of an infiltration basin is presented in Figure 5-20.

Vegetation resistant to temporary inundation should be used in the facility. Root penetration and thatch formation maintains and often enhances infiltration capacity of the basin floor. In addition, vegetation can trap stormwater constituents by growing through accumulated sediments and preventing re-suspension. Vegetation also provides nutrient uptake in the shallow root zone and a substructure for microbial residence.

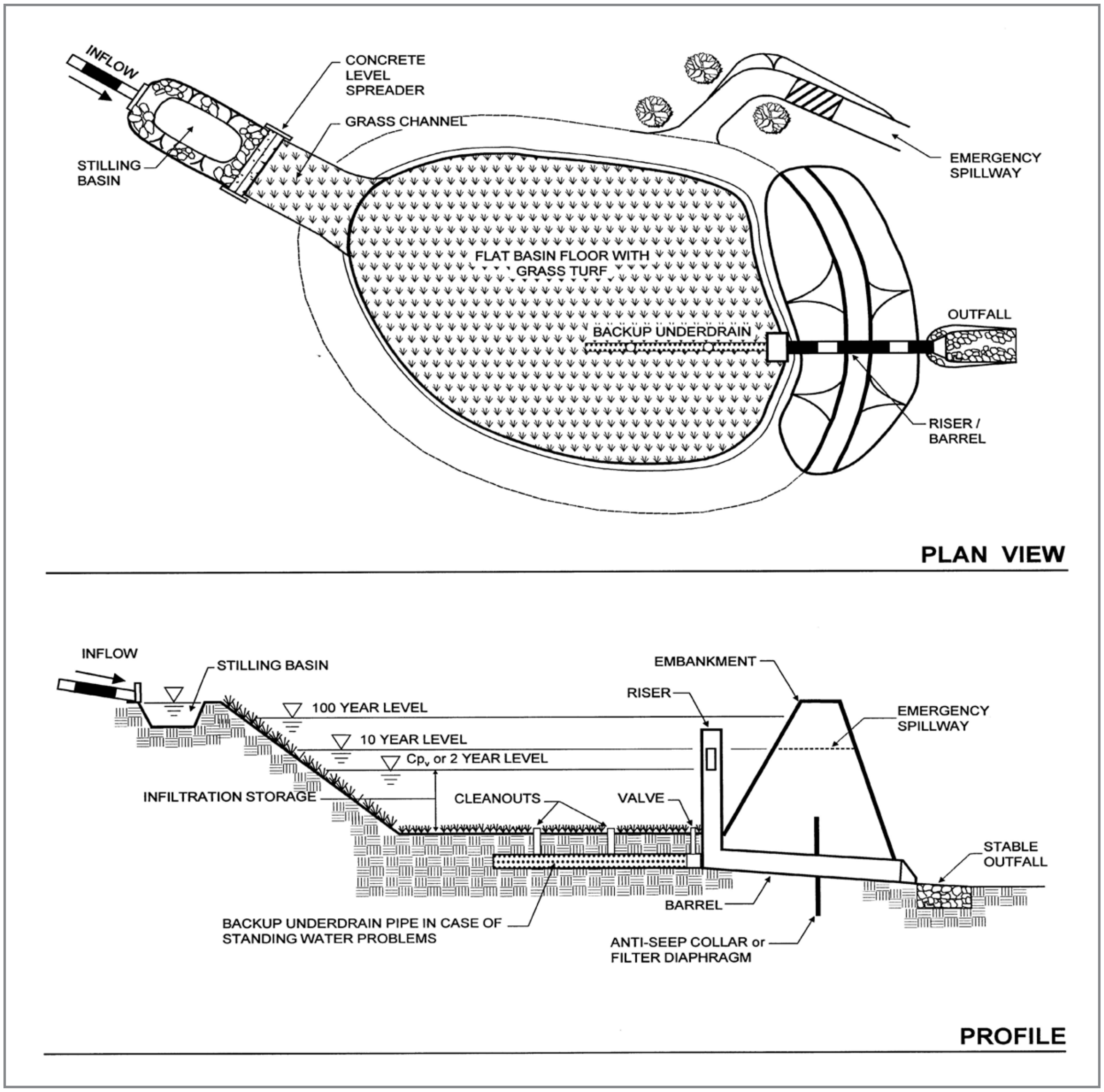

Figure 5-20: Infiltration Basin Schematic. (Photo courtesy of MDE, 2000)

ADVANTAGES

- This approach provides a 100% reduction in the volume discharged to surface waters, for frequent small storms.
- The principal benefit of infiltration basins is the approximation of pre-development hydrology during which a significant portion of the average annual rainfall runoff is infiltrated and evaporated rather than flushed directly to creeks.
- If the volume is adequately sized, infiltration basins can be useful for providing control of channel forming (erosion) and high frequency (generally less than the 2-year) flood events.

LIMITATIONS

- Infiltration basins may not be appropriate for industrial sites or locations where spills may occur.
- Infiltration basins require a minimum soil infiltration rate of 0.5 inches/hour which is not appropriate at sites with Hydrologic Soil Types C and D.
- Infiltration basins are not suitable on fill sites or steep slopes.
- Upstream drainage area must be completely stabilized before construction.
- Once clogged, it can be difficult to restore functioning of infiltration basins.
- Basin depth to groundwater should exceed 4 feet.

5.7.2. DESIGN AND SIZING GUIDELINES

1. ***Basin Sizing:*** The volume of the basin should be sized to retain at least the volume of runoff from a 1.5-inch rainfall event. Maximum water depth in the basin should not exceed 2.0 feet.
2. Provide pretreatment if sediment loading is a maintenance concern for the basin.
3. Include energy dissipation in the inlet design for the basins.
4. The bottom elevation shall be at least 4 feet above the seasonally high groundwater table.
5. Obtain soil borings to determine the soil infiltration rate.

SITING

The key element in siting infiltration basins is identifying sites with appropriate soil properties, which is critical for long term performance.

- Determine soil type (consider RCS soil type A or B only) from mapping and consult USDA soil survey tables to review other parameters such as the amount of silt and clay, presence of a restrictive layer or seasonal high-water table, and estimated permeability.
- Groundwater separation should be at least 4 feet from the basin invert to the measured ground water elevation. There is concern at the State and regional levels of the impact on groundwater quality from infiltrated runoff, especially when the separation between groundwater and the surface is small.
- Infiltration basins should be located away from buildings, slopes and highway pavement (by a distance greater than 20 feet) and away from wells and bridge structures (by a distance greater than 100 feet).
- Ensure that adequate head is available to operate flow splitter structures (to allow the basin to be offline) without ponding in the splitter structure or creating backwater upstream of the splitter.
- Dry weather flow should not be present in the tributary watershed.

Before construction begins, stabilize the entire area draining to the facility. If impossible, place a diversion berm around the perimeter of the infiltration site to prevent sediment entrance during construction or remove the top 2 inches of soil after the site is stabilized. Stabilize the entire contributing drainage area, including the side slopes, before allowing any runoff to enter once construction is complete. Place excavated material such that it cannot be washed back into the basin if a storm occurs during construction of the facility.

Build the basin without driving heavy equipment over the infiltration surface. Any equipment driven on the surface should have extra-wide ("low pressure") treads or tires. Prior to any construction, rope off the infiltration area to stop entrance by unwanted equipment. After final grading, till the infiltration surface deeply.

5.7.3. RECOMMENDED MAINTENANCE

Regular maintenance is critical to the successful operation of infiltration basins. Recommended operation and maintenance guidelines include:

- Observe drain time for the basin after completion or modification of the facility to confirm that the basin drains within 48 hours.
- Schedule annual inspections to identify potential problems such as erosion of the basin side slopes and invert, the existence of standing water, and the accumulation trash debris, and sediment.
- Remove accumulated trash and debris annually.
- Avoid reversing soil development; scarification or other disturbance should only be performed when there are actual signs of clogging, rather than on a routine basis. Always remove deposited sediments before scarification through the use of a hand-guided rotary tiller or a disc harrow pulled by a very light tractor.

5.8 RAINWATER HARVESTING

DEFINITION OF RAINWATER HARVESTING/CISTERN CREDIT

A credit is given when rainwater collection systems are used to retain roof runoff resulting in the reduction of the development impervious cover. Rainwater collection systems will generate an impervious cover reduction for the area that drains to the rainwater collection barrel(s) based on the ratio of the barrel volume to the roof (catchment) area. Rainwater collection can occur at single family residences, multi-family complexes, and commercial developments. This credit can be used to gain compliance with the Alternate Standards or reduce the water quality volume. The maximum impervious cover reduction is 75% to account for rainwater system maintenance and operation challenges that may occur over the system life.

Rainwater collection can also be used to satisfy the rooftop disconnection credit, but can not be counted as a credit for both rainwater harvesting and rooftop disconnection.

Reduced impervious cover credit is computed per the following equation and figure:

Ar = ART * %IC REDUCTION FACTOR (per Figure 5.21 below)

Where: Ar = Allowable reduction in impervious cover

ART = Area of roof-top directed to rain barrel(s) (catchment area) (sq ft)

% IC REDUCTION FACTOR = % Impervious area reduction

RBV = Rain barrel volume (cubic feet)

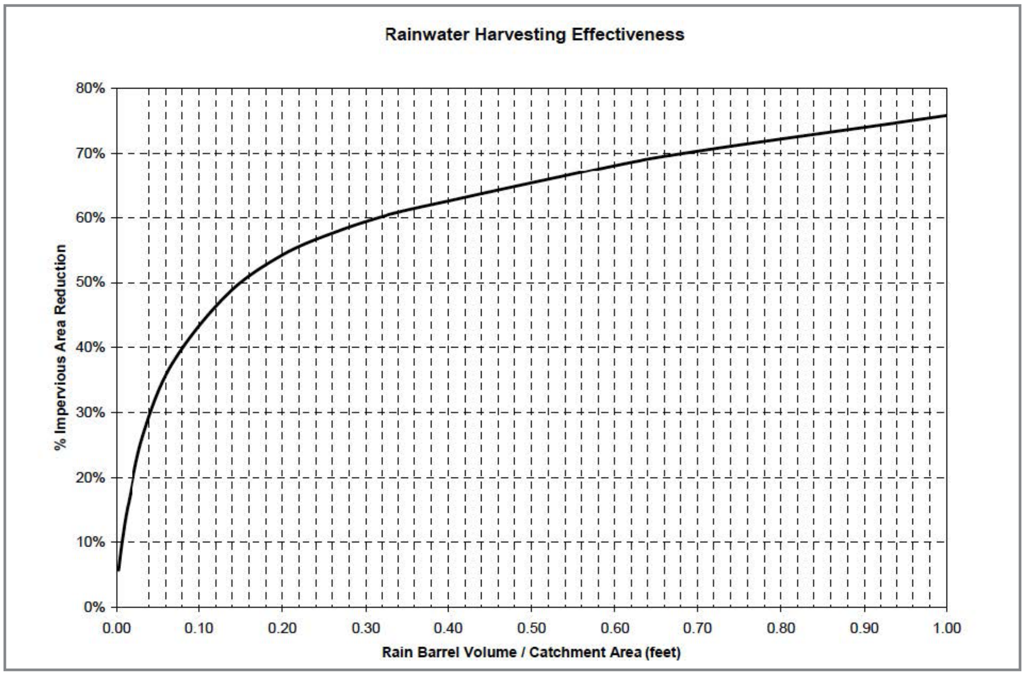

Figure 5-21: Rainwater Harvesting Effectiveness

RAINWATER COLLECTION CREDIT

Restrictions on the Credit: The rainwater harvesting credit is subject to the following restrictions:

- Rainwater collection and distribution systems must be designed and installed per the requirements in this Section.
- A rainwater collection system maintenance plan must be approved before issuance of a development permit. The maintenance plan will need to identify the responsible maintenance party and allow for periodic inspection.

- The development permit will include a condition that the contractor must contact the jurisdictional stormwater authority 48 hours prior to the final completion of the rainwater collection system.
- Storage shall be provided in cisterns, rain barrels, tanks, or other approved methods.
- Overflows from rainwater tanks should be diverted to grassy swales and/or lawns to promote infiltration of excess runoff volume.

Example calculation: The required water quality volume before the credit for a ten (10) acre site with 30 single family lots would be:

Impervious cover = 3 acres = 30%
1.5-inch storm runoff volume = 0.48 inches based on Equation 4.9
Water quality volume = (0.48 inches) * (10 acres) * (43,560/12) = 17,424 cubic- feet.

Applying the credit, each single-family lot will utilize a rainwater collection system per the criteria. Each house has a roof area of 2,000 square feet, however, individual roof design is not known at this phase, thus a factor of 0.75 is applied to the roof area, resulting in the assumption that 1,500 square feet can be drained to rainwater collection tanks. The home storage barrel(s) will provide 1,500 gallons of storage.

Roof area draining to collection barrels = 2,000 square feet * 0.75 = 1,500 square feet
Barrel volume = 1,500 gallons per plat note and deed restriction = 200 cubic feet
Barrel volume to catchment area = 200 / 1,500 = 0.13
Using the Rainwater Harvesting Effectiveness Figure, % IC Reduction = 43%
Ar = Allowable impervious cover reduction per house = (1,500) X (0.43) = 645 square feet
Impervious cover with credit = (3 acres) – ((30 lots) * (645 sq. ft)) = 2.56 acres
Effective impervious cover = 26%
1.5-inch storm runoff volume = 0.43 inches based on Equation 4.9
Water quality volume = (0.43 inches) * (10 acres) * (43,560/12) = 15,464 cubic-feet.

The BMP water quality volume is reduced by 11% in this example.

DESCRIPTION

Rainwater harvesting is a method of diverting and collecting rainfall that falls onto impervious surfaces, such as roofs. Harvested rainfall is typically used for indoor residential use, landscape irrigation, or both. By capturing and slowly releasing rooftop runoff over vegetated areas, rainwater harvesting can reduce stormwater volume and flow rates and the resultant erosion and pollutant discharges to surface waters. Schematics of a complex rainwater harvesting system are presented in Figures 5.22 and 5.23 below.

APPLICATION

In a rooftop rainwater harvesting system, runoff flows via gravity through gutters and downspouts into a storage tank where it is slowly released to landscaped areas or stored for later use. Rainwater harvesting systems are primarily designed for conservation— long-term storage and use—rather than to mitigate the impacts of impervious cover and increased runoff. If a tank is full or near-full (beneficial for conservation and long-term use) it will not provide stormwater benefits.

Rainwater harvesting systems can provide pretreatment for other BMPs and qualify for stormwater credit to reduce water quality basin size or gain compliance with the Alternate Standards. Collection systems are equally appropriate in large-scale landscapes, such as parks, schools, commercial sites, parking lots and apartment complexes and in small residential landscapes. Rainwater harvesting is a feasible alternative for intensively developed areas and is suitable for steep terrain and flat landscapes where collected water can be diverted to depressed landscaped areas or grassy swales.

Rooftop rainwater harvesting provides a lower-cost method of treating surface water runoff than other permanent water quality treatment structures. Costs include the storage tank, filtering system, and pressure pump. Routine maintenance is a minor expense but is essential for the system to properly function. In an effort to encourage water conservation, the State or local governments may provide financial incentives and tax exemptions to offset the equipment costs. Municipal incentives are also available in some areas.

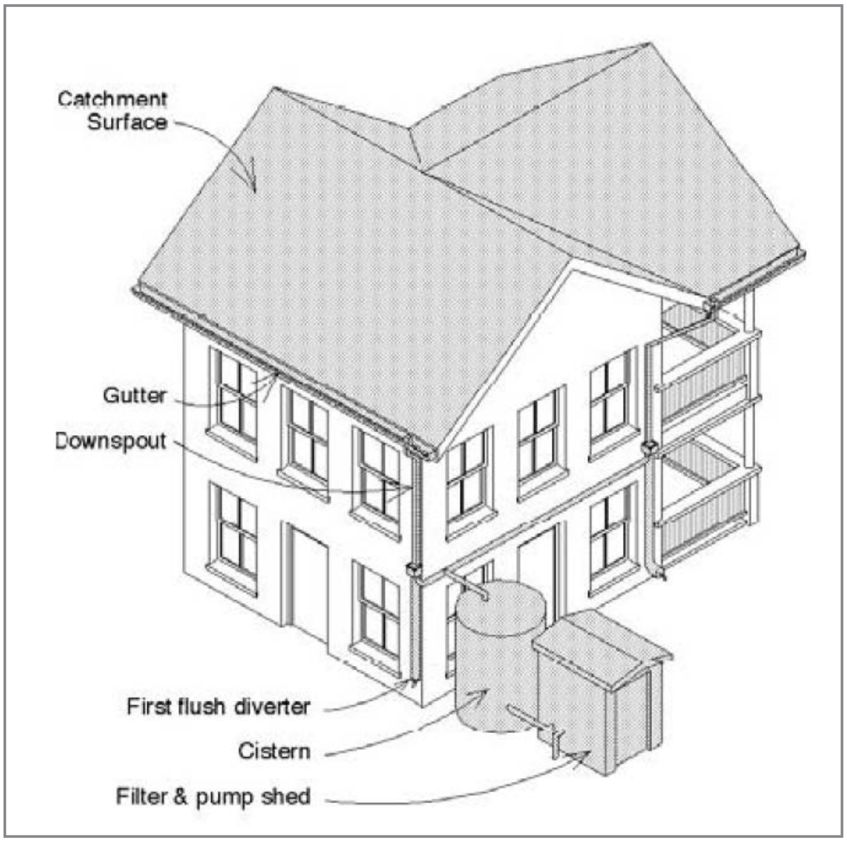

Figure 5-22: Complex water harvesting system (With roof catchment, gutter, downspout and storage tank City of Austin Energy's Green Building Fact Sheet, 1995).

Additional information can be found in the Texas Rainwater Harvesting Manual.

DESIGN GUIDELINES

Rainwater Harvesting is a system of collecting, conveying, and storing rainfall from impervious surfaces and directing water to where it is needed.

1. ***Catchment surface:*** The collection surface is the "footprint" of the roof. The effective collection surface is the length times the width of the roof from eave to eave and front to rear.

2. ***Conveyance systems:*** Gutters should be properly sized and located to maximize catchment efficiency and prevent overrunning. Overrunning can result from an inadequate number of downspouts, excessively long roof distances from ridge to eave, steep roof slopes, and inadequate gutter maintenance. Preventative strategies may include modifications to the size and configuration of gutters and addition of gutter boxes with downspouts and roof diverters near the eave edge. Gutters should slope towards the downspout with the outside face of the gutter lower than the inside face to encourage drainage away from the building wall. Downspouts should provide 1 square inch of downspout opening for every 100 square feet of roof area. The first flush runoff should outfall onto an adequately sized rock splash pad that will prevent erosion, channeling, or puddling.

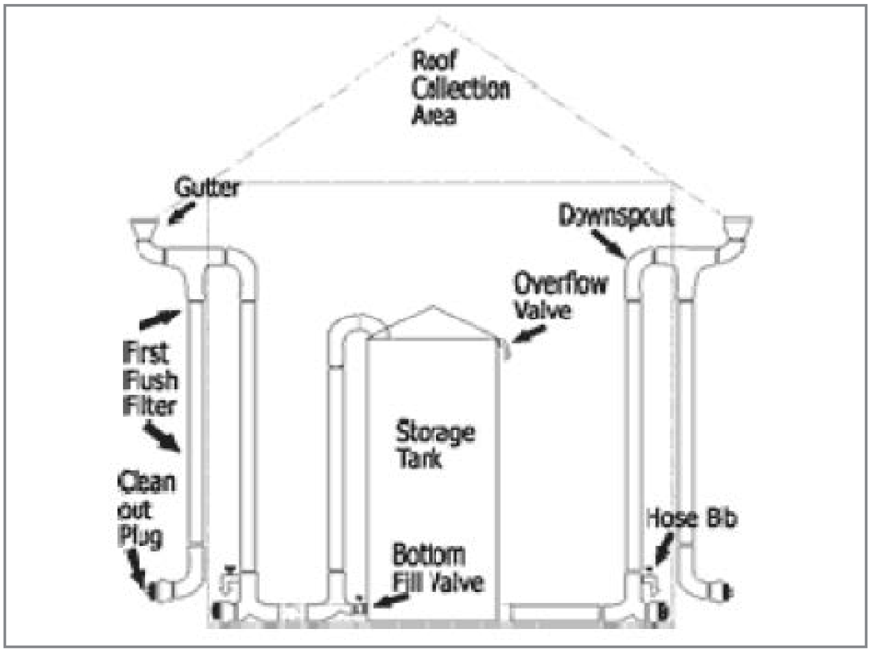

Figure 5-23: Complex water harvesting system (with roof catchment, gutter, downspout and storage tank. City of Austin Energy's Green Building Fact Sheet, 1995).

3. ***Storage - Filtration:*** Leaf screens, first-flush diverters, and roof washers should be installed on inflow lines to prevent trash and organics from entering the storage area. Permanent openings must be screened to prevent insect infestation in the piping and standpipe.

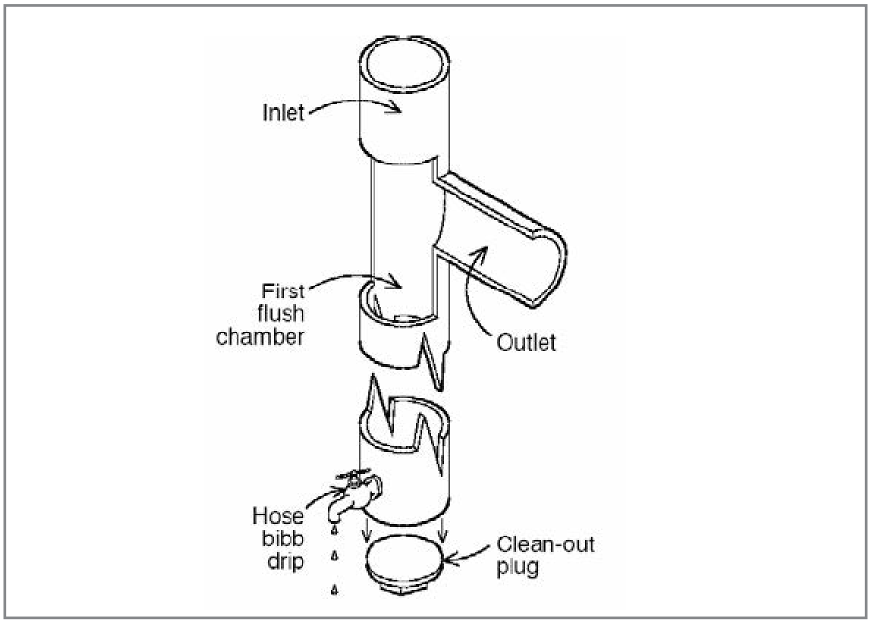

Figure 5-24: Standpipe first flush diverter. The recommended diversion of first flush ranges from one to two gallons of first-flush diversion for each 100 square feet of collection area. (TWDB, 2005)

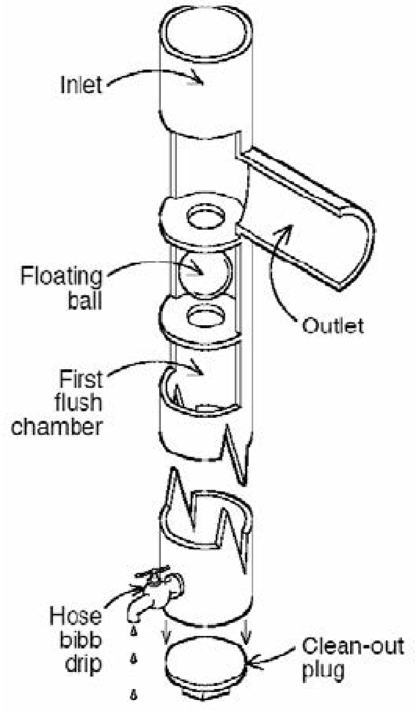

Figure 5-25: Standpipe with ball valve. The standpipe with ball valve is a variation of the standpipe filter. As the chamber fills, the ball floats up and seals on the seat, trapping first-flush water and routing the balance of the water to the tank. (TWDB, 2005)

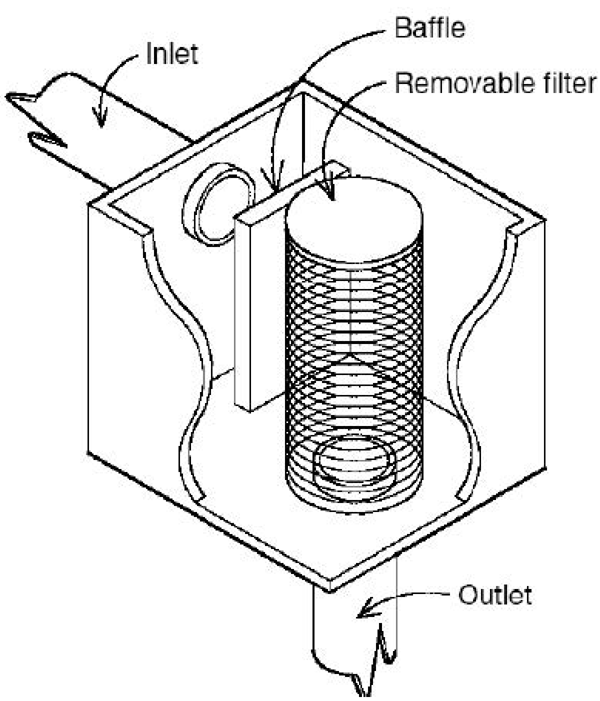

Figure 5-26: Box roof washer. Roof washers are recommended for drip irrigation systems. (TWDB, 2005)

4. ***Delivery system:*** The distribution directs water to plants from storage tanks to garden hoses, constructed (non-erosive) channels, or manual drip systems. Drip and other types of integrated distribution systems may require a small pressure pump to distribute the water. If a drip irrigation system is not used, water can gravity-flow to garden hoses. In addition, water harvested rainwater can be delivered to the house for domestic use.

5. ***Stormwater Credits:*** Stormwater credit is given when rooftop runoff is collected, stored per the volume requirements, and discharged through everyday consumption. The figure above illustrates the percentage of impervious cover reduction that can be obtained using the above listed criteria. The percentage of impervious cover reduction is based upon the percentage of rooftop runoff that is captured. A maximum reduction of 75% of rooftop impervious cover will be given. Credit is documented at the concept plan stage. Criteria for the rainwater harvesting system must be included in the deed restrictions to be eligible for stormwater credit

6. ***System Maintenance:*** The system should be checked annually and after every rainfall to ensure the system is operating optimally. The following maintenance should be conducted:

    - Keep debris out of holding areas;
    - Remove collected debris from the first-flush diversion standpipe after each rainfall event;
    - Control and prevent erosion;
    - Block and repair erosion trails;
    - Keep debris out of gutters and downspouts;
    - Flush debris from storage container bottoms;
    - Clean and maintain filters, especially those on drip irrigation systems;
    - Expand watering basins as plants grow; and
    - Roof washers must be readily accessible for regular maintenance.

5.9 NATURAL AREA PRESERVATION

DEFINITION OF NATURAL AREA PRESERVATION

A stormwater credit is given when natural areas are conserved at development sites, thereby retaining pre development hydrologic and water quality characteristics. For low impact development compliance, the preserved area is included in the impervious cover calculations to determine the gross development and cluster development impervious cover levels. The credit for stormwater basin volume is computed by subtracting the preserved area from the area draining to individual water quality basins. This credit is granted for all preservation areas permanently protected under conservation easements or other locally acceptable means. Examples of natural area conservation include:

- Wooded and meadow areas protected from disturbance
- Wetlands and associated buffers
- Creek buffers
- Other lands in protective easement (floodplains, open space, steep slopes)
- Stream systems

DAeff = DATOT - ANA

Where: DAeff = Effective drainage area
ANA = Natural area preserved
DATOT = Total drainage area

To receive the credit, the proposed preservation area:

- Must not be disturbed during project construction (e.g., cleared or graded) except for temporary impacts associated with selective management of invasive vegetation such as ashe juniper and incidental utility construction or mitigation projects (selective clearing of invasive vegetation shall be performed in a manner so as to not disturb the soil);
- Must be protected by having the limits of disturbance clearly shown on all construction drawings and be delineated in the field except as provided for above;
- Must be located within an acceptable conservation easement or other enforceable instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked (Note: managed turf (playgrounds, regularly maintain open areas) is not an acceptable form of vegetation management); and
- Must be located on the development project.

Example calculation: The required water quality volume for a ten-acre site with three acres of impervious area and three acres of protected conservation area before the credit would be:

Impervious cover = 30%
1.5-inch storm runoff volume = 0.48 inches based on Equation 4-9
Water quality volume = (0.48 inches) * (10 acres) * (43,560/12) = 17,424 cubic- feet.

Applying the credit, three acres of conservation area is subtracted from total site area, which yields a smaller water quality basin volume. The impervious cover amount is not revised to reflect the smaller drainage area:

DAeff = (10 acres) – (3 acres) = 7 acres
Effective impervious cover = 30%
1-year runoff volume = 0.48 inches based on Equation 4-9
Water Quality Volume = (0.48 inches) * (7 acres) * (43,560/12) = 12,196 cubic-feet.

The BMP water quality storage volume is reduced by 30% in this example.

5.10 DISCONNECTION OF ROOFTOP RUNOFF

DEFINITION OF DISCONNECTION OF ROOFTOP RUNOFF CREDIT

A credit is given when rooftop runoff is disconnected and then directed to a pervious area where it can either infiltrate into the soil or filter over it. The credit is typically obtained by in areas with slopes less than 5% to promote overland filtering on single family residential lots.

If a rooftop is adequately disconnected, the disconnected impervious area can be deducted from total impervious cover (therefore potentially gaining compliance with the Low Impact Development impervious cover levels or reducing BMP volume). This credit is restricted to single family lots.

Table 5-1: Rooftop Disconnection Impervious Cover Credit

Disconnection Length Provided	0 to 14 ft.	15 to 29 ft.	30 to 44 ft.	45 to 59 ft.	61 to 74 ft.	> 75 ft.
% Impervious Cover Credit per By Disconnect (No Storage Volume)	10%	20%	40%	60%	80%	100%
Dry Well, Rainwater Collection, Rain Garden Storage Volume Required to achieve 100% Impervious Cover Credit in Combination with flow length	104 cu-ft.	83 cu-ft.	62 cu-ft.	42 cu-ft.	21 cu-ft.	0 cu-ft.

Source: LCRA Highland Lakes Water Quality Technical Manual.

Ar = ART * %ICD

Where: Ar = Allowable reduction in impervious cover

ART = Area of roof-top

%ICD = Impervious cover credit factor per the above Table

RESTRICTIONS ON THE CREDIT

The rooftop disconnection is restricted to single-family lots and subject to the following restrictions:

- The contributing area of rooftop to a disconnected discharge shall be 800 square feet or less;
- The length of "disconnection" shall be 75 feet or greater, or compensated using the above table;
- Disconnections will only be credited for lot sizes greater than 5,000 sq. ft;
- The length of "disconnection" shall be on an average slope of less than 5%;
- The entire vegetative "disconnection" shall have a minimum soil depth of 4 to 6 inches. Builders and owners will import soil if needed to achieve sufficient soil depth. Soil shall satisfy the import soil specifications found in the following Soil Amendment Credit
- The disconnection must drain continuously through a vegetated swale or across the vegetated landscape to the roadside curb, conveyance system, or BMP;
- The vegetated landscape should use appropriate turf grasses;
- Downspouts must be at least 10 feet away from the nearest impervious surface to discourage "re-connections;"
- Dry wells, French drains, rainwater collection tanks, or rain gardens (small bioretention areas) may be utilized to compensate for areas with disconnection lengths less than 75 feet. The volume shall be equal to the requirements found in the above table to receive 100% reduction in impervious cover. See Schematic of Dry Well in Figure 5.27;

- For those rooftops draining directly to a creek buffer, a rooftop disconnection credit can be used;
- Credit is documented during the development permit process and verified with the final grading plan as part of the development permit; and
- When more than one downspout drains in one direction, the shortest disconnection length will be used in the above table to determine the impervious cover deduction. For example, if the front and back downspout on one side of the house both drain towards the street (flow is combined), the distance from the front downspout to the street will be used as the disconnection length.

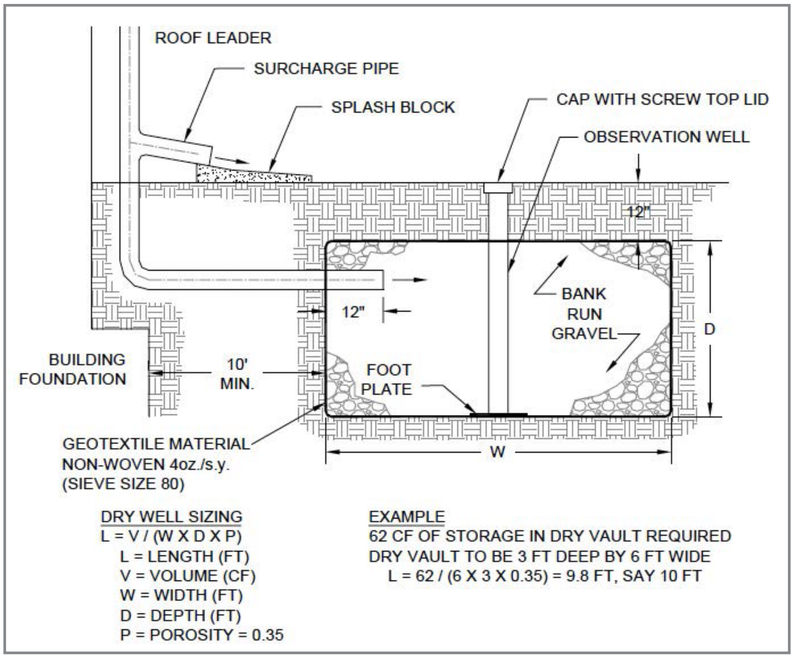

Figure 5-27: Schematic of Dry Well

Example calculation: the required water quality volume before the credit for a ten acre site with 30 single family lots would be:

Impervious cover = 3 acres = 30%
1.5-inch storm runoff volume = 0.48 inches based on Equation 2-9
Water quality volume = (0.48 inches) * (10 acres) * (43,560/12) = 17,424 cubic- feet.

Applying the credit, each single-family lot has a travel length of 35 feet from the house to the roadside curb and the lawns satisfy the vegetative cover requirement by using turf grasses. The designer chooses not to incorporate additional storage (dry wells, rain gardens, etc.) to increase credit. Thus, each house impervious cover is reduced by 40% per Table 5-1.

House roof area = 2000 square feet
40% impervious cover credit for roof from above table
Ar = Allowable impervious cover reduction per house = (2000) * (0.40) = 800 square feet
Impervious cover with credit = (3 acres) – ((30 lots) * (800 sq. ft)) = 2.45 acres
Effective impervious cover = 25%
1.5-inch storm runoff volume = 0.41 inches based on Equation 4-9
Water Quality Volume = (0.41 inches) * (10 acres) * (43,560/12) = 14,974 cubic-feet.

The BMP water quality storage volume is reduced by 14% in this example.

5.11 SOIL AMENDMENT

DEFINITION OF SOIL AMENDMENT AND CONSERVATION LANDSCAPING CREDITS

A credit is given when lawns and landscape areas within the development utilize the Soil Amendment or Conservation Landscaping guidance in this section. The benefit of these designs over more traditional lawns is the placement of sufficient soil depth and appropriate vegetation that promotes infiltration and less stormwater runoff.

The Soil Amendment Credit relies on native soils, appropriate soil depths, and low maintenance turf grasses to reduce the runoff volume. The stormwater credit for Soil Amendment is the reduction of project impervious cover by 2%.

The Conservation Landscaping Credit is based upon planting a reduced turf area and incorporating native plants, shrubs, trees and perennials to retain stormwater on site and require minimal chemicals to sustain a native and colorful landscape. The stormwater credit for Conservation Landscaping is the reduction of impervious cover by 5%.

These credits can be used to gain compliance with the Low Impact Development approach or reduce the stormwater basin water quality volume.

Ar = AD * 0.02

Where: Ar = Allowable reduction in impervious cover

AD = Area of development

RESTRICTIONS ON THE CREDIT

The soil amendment credit is subject to the following restrictions:

- Home-builders coordinate with the jurisdictional stormwater authority during soil placement. This coordination will be identified as a permit condition and will allow inspection of the soil depth and quality prior to grass placement.
- The soil amendment requirement shall be noted on the plat and included in the development deed restrictions.

Example calculation: the required water quality volume before the credit for a ten (10) acre site with 30 single family lots would be:

Impervious cover = 3 acres = 30%

1.5-inch storm runoff volume = 0.48 inches based on Equation 4.9

Water quality volume = (0.48 inches) * (10 acres) * (43,560/12) = 17,424 cubic- feet.

Applying the credit, the developer and home-builders agree to place grass and soil per the soil amendment specifications. Thus, the project impervious cover is reduced by 2%.

In this example, Ar = (10 acres) * (0.02) = 0.2 acres

Effective impervious cover = (3 acres) – (0.2 acres) = 2.8 acres = 2.8/10 = 28%

1-year Runoff Volume = 0.45 inches based on Equation 4.9

Water Quality Volume = (0.45 inches) * (10 acres) * (43,560/12) = 16,444 cubic-feet.

The BMP water quality volume is reduced by 5% in this example.

This option is intended to provide builders and homeowners with a well-designed and resource efficient landscape.

DESCRIPTION

Naturally occurring undisturbed soil and vegetation provide important stormwater functions including: water infiltration; nutrient, sediment, and pollutant adsorption; sediment and pollutant biofiltration; water interflow, storage and transmission; and pollutant decomposition. These functions are largely lost when development strips away native soil and vegetation and replaces it with minimal topsoil and sod. Not only are these important stormwater functions lost, but such landscapes themselves become pollution- generating pervious surfaces due to the increased use of pesticides, fertilizers and other landscaping and household/ industrial chemicals, the concentration of pet wastes, and added pollutants that accompany roadside litter.

Establishing soil quality and depth regains greater stormwater functions in the post development landscape, provides increased treatment of pollutants and sediments that result from development and habitation, and minimizes landscaping chemical need. As a result, these preventative measures effectively reduce pollution. Soil amendment and the usage of appropriate turf provide a practical and cost-effective mechanism to mitigate stormwater runoff pollution and treatment.

Establishing a minimum soil quality and depth will provide improved on-site management of stormwater flow and water quality. Soil organic matter can be attained through materials such as composted herbaceous and woody material, biosolids, and forest product residuals. It is important that the materials used to meet the soil quality and depth requirements are appropriate and beneficial to the establishment of plant cover. Likewise, imported topsoil should improve conditions and avoid excessive percentages of clay fines.

DESIGN GUIDELINES

The soil amendment credit is subject to the following guidelines and restrictions:

1. ***Stockpile Topsoil:*** Salvaged topsoil from the site should be used whenever possible. In any areas requiring grading, remove and stockpile topsoil on site in a designated controlled area to be reapplied to other portions of the site where feasible. Stockpiled soils must be protected from erosion with appropriate temporary erosion controls and cannot be placed adjacent to surface waters, within the buffer zones or in areas with concentrated flow.

2. ***Soil Depth:*** All newly planted turf areas will have a minimum soil depth of 6 to 8 inches. Builders and owners will import soil if needed to achieve sufficient soil depth. Soil in these areas may be either native soil from the site or imported, improved soil.

3. ***Import Soil:*** Topsoil must be weed free, contain a minimum of 20% compost by volume, contain less than 20% clay, and be free of stones, stumps, roots or other similar objects larger than one (1) inch. If on-site soils do not meet these specifications, topsoil per the above specs must be added. Sandy loam is not an approved soil and caliche is not considered a soil.

4. ***Import Soil Application:*** Topsoil that is added to the site shall be incorporated in a 2 to 3- inch scarified transition layer to improve drainage. Do not scarify within a drip line of existing trees to be retained.

5. ***Soil Inspection:*** Home-builders should coordinate with the jurisdictional stormwater authority after topsoil has been spread on the site immediately prior to laying sod.

6. ***Turf:*** Turf is required and shall be Bermuda, buffalo, or zoysia sod.

7. ***Slope Limitation:*** The soil amendment cannot be used on slopes greater than 20%, in areas subject to concentrated flows or any sensitive areas to minimize potential discharge of soil to waterways.

8. ***Roadside Revegetation:*** Utilizing native seed in revegetation of roadsides and other areas helps preserve ecosystem integrity. Native grasses and wildflowers are well adapted to the environment and provide a low maintenance, resilient long-term landscape. A recent study conducted by the Landscape Restoration Program at the Lady Bird Johnson Wildflower Center demonstrated that commercial grass mixes consisting of native plant species seeds performed as well or better than mixes containing Bermuda grass, a popular and widely used invasive grass species.

Conservation Landscaping

Ar = AD * 0.05

Where: Ar = Allowable reduction in impervious cover

AD = Area of development

RESTRICTIONS ON THE CREDIT

The conservation landscaping credit is subject to the following restrictions:

- Home-builders coordinate with the jurisdictional stormwater authority during landscape installation. This coordination will be identified as a permit condition and will allow inspection of soil depth and quality prior to grass placement.
- The soil amendment requirement shall be noted on the plat and included in the development deed restrictions.

Example calculation: the required water quality volume before the credit for a ten (10) acre site with 30 single family lots would be:

Impervious cover = 3 acres = 30%
1-year runoff volume = 0.48 inches based on Equation 4.9
Water quality volume = (0.48 inches) * (10 acres) * (43,560/12) = 17,424 cubic- feet.

Applying the credit, the developer and home-builders agree to install conservation landscaping per the specifications. Thus, the project impervious cover is reduced by 5%.

In this example, Ar = (10 acres) * (0.05) = 0.5 acres
Effective impervious cover = (3 acres) – (0.5 acres) = 2.5 acres = 2.5/10 = 25%
1-year Runoff Volume = 0.41 inches based on Equation 4.9
Water Quality Volume = (0.41 inches) * (10 acres) * (43,560/12) = 14,974 cubic-feet.

The BMP water quality volume is reduced by 14% in this example.

DESCRIPTION

Native vegetation is best suited to local climate and soils. Existing native vegetation should be conserved and protected where possible. Where new planting is required, the use of native plants will increase plant survival and decrease the cost of subsequent plant replacement. Reapplication of organic compost or mulch every few years may be necessary to maintain positive soil infiltration characteristics. The initial costs of native plants, trees, shrubs, and soil amendments are recouped through significant reductions in water, fertilizer and pesticide use, as well as increased plant survival within the first few years after planting.

Conservation landscaping and native vegetation are equally appropriate in large-scale landscapes, such as parks, schools, commercial sites, parking lots, apartment complexes and in small residential landscapes.

Four major components that increase landscape sustainability are: adequate quantity of high- quality soil, implementation of efficient irrigation, appropriate turf and plant choice, and installation. Along with obtaining a stormwater credit and protecting water quality, this landscape option will save the homeowner time and money through reduced lawn watering requirements and mowing needs. Below is a sample design comparison between a conservation landscape design and a conventional landscape design for a lot with a front yard measuring 70 feet wide and 50 feet deep. The conservation option is composed of shrubs, perennials and ground covers that are watered every 14 days and turf that is watered once a week. The conventional lot front yard is comprised mainly of turf and a few shrubs watered three times a week.

Figure 5-28: Sample Costs Over 10 years (Actual Costs Will Vary)

	Soil Amendment Landscape	Conventional Landscape
Installation Cost	$3,293	$2,440
Yard Care Time	425 hours	615 hours
Water Cost	$360	$1,440
Treatment Cost	$50	$500
Total Time and Cost	**$3,703**	**$4,380**

As shown above, the conservation option costs $677 less and requires 190 hours less yard care and maintenance.

Source: LCRA, Texas Hill Country Landscape Option, 2005

DESIGN GUIDELINES

The soil amendment credit is subject to the following guidelines and restrictions:

1. ***Stockpile Topsoil:*** Salvaged topsoil from the site should be used whenever possible. In any areas requiring grading, remove and stockpile topsoil on site in a designated controlled area to be reapplied to other portions of the site where feasible. Stockpiled soils must be protected from erosion with appropriate temporary erosion controls and cannot be placed adjacent to surface waters, within the buffer zones or in areas with concentrated flow.

2. ***Soil Depth:*** All newly planted turf areas will have a minimum soil depth of 6 to 8 inches. Builders and owners will import soil if needed to achieve sufficient soil depth. Soil in these areas may be either native soil from the site or imported, improved soil.

3. ***Import Soil:*** Topsoil for turf areas must be weed free, contain a minimum of 20% compost by volume, contain less than 20% clay, and be free of stones, stumps, roots or other similar objects larger than one (1) inch. If on-site soils do not meet these specifications, topsoil per the above specs must be added. Sandy loam is not an approved soil and caliche is not considered a soil.

4. ***Import Soil Application:*** Topsoil that is added to the site shall be incorporated in a 2 to 3- inch scarified transition layer to improve drainage. Do not scarify within a drip line of existing trees to be retained.

5. ***Soil Inspection:*** Home-builders should coordinate with jurisdictional stormwater authority after topsoil has been spread on the site immediately prior to laying sod.

6. ***Turf:*** Turf shall be Bermuda, buffalo, or zoysia sod. A maximum 30% of the lot can be covered in turf. The remainder of the lot will follow the Hill Country Landscape Option that relies on native trees, shrubs, and perennials.

7. ***Irrigation:*** Spray irrigation shall be limited to 2.5 times the foundation footprint with a maximum of 12,000 square feet. The footprint may include the house and garage but not the driveway or patio.

8. ***Undisturbed Area Requirement:*** For lots greater than 15,000 square feet, no less than 25% of the lot shall remain in a natural condition (no grading, planting sod, etc.). Removal of scrub brush and other invasive species can be performed by hand clearing methods to restore native vegetation and grasses. This area shall not be irrigated. Deed restrictions and plat notes will be necessary to ensure natural area preservation.

5.12 DEALING WITH MULTIPLE STORM WATER CREDITS

Site designers are encouraged to perform a development design that works with natural topography, soils, and vegetation to utilize as many credits as possible. Greater reductions in stormwater storage volumes can be achieved when credits are combined (e.g., disconnecting rooftops and protecting natural conservation areas). The use of multiple credits can gain compliance with the Low Impact Development (LID) approach or significantly reduce water quality basin size and cost.

Example: Combined Use of Multiple Stormwater Credits to Achieve Alternate Standards Compliance

Development area = 10 acres
40 single-family lots
Lot sizes average 9,500 square feet (70 feet by 135 feet)
Lot impervious cover = 2,500 square feet/lot per Table 4-2
Use roadside swales, not curb and gutter to gain Alternate Standards Compliance
Proposed impervious cover = 3.4 acres = 34%
Maximum allowed impervious cover for Low Impact Development = 20%
Need to use Stormwater Credits to achieve 20% effective impervious cover

Use pervious pavement credit for driveways; receive 90% I.C. credit for pervious pavement area
Driveway Area = 800 square feet (50 feet long by 16 feet wide)
Ar = Allowable impervious cover reduction = (40 lots) * (800 sq ft) * (0.90) = 0.66 acres

Use roof-top disconnection credit for lots with slopes less than 5%

Flow length from home to street = 50 feet, however only 30 lots meet 5% slope limitation
Designer chooses not to include rainwater gardens or dry wells to gain additional credit
Impervious cover reduction = 60% per Table 5-1
Roof Area = 2500 – 800 (driveway area) = 1,700 square feet
Ar = Allow. Imp. Cover Reduction. = (30 lots) * (1,700 sq ft) * (0.60) / 43,560 = 0.70 ac
ICeff = (IC TOT) – (Sum of Ar) = (3.4 acres) - (0.70 + 0.66) = 2.0 acres
ICeff = Effective Impervious Cover = 2.0 / 10 = 20 %

Combining pervious driveways and disconnected impervious cover create a development project where the Low Impact Development approach is met and the project does not need to construct stormwater basins.

No water quality design for permanent BMPs is necessary. The designer may proceed to the preparation of an erosion and sedimentation control plan and coordinate with the jurisdictional stormwater authority to develop appropriate water quality education programs for residents.