

Draft 12/14/2007

Section 5.0 Introduction

5.0.1 Background

The primary goal of Maryland's stormwater management program is to maintain after development, as nearly as possible, the predevelopment runoff characteristics. Traditional stormwater management strategies treat runoff to mitigate adverse water quality and/or quantity impacts associated with new development. Designs applying these strategies often combine centralized structural practices for pollutant removal with channel erosion or flood control impoundments. These designs are less able to mimic predevelopment conditions because they focus on managing large volumes of polluted stormwater rather than treating runoff closer to the source.

A comprehensive design strategy for maintaining predevelopment runoff characteristics and protecting natural resources is available. This strategy, known as Environmental Site Design or "ESD," relies on integrating site design, natural hydrology, and smaller controls to capture and treat runoff. This chapter provides the foundation to refocus stormwater design from centralized management to more effective planning and implementation of ESD.

5.0.2 Requirements of the Stormwater Management Act of 2007

The "Stormwater Management Act of 2007" (Act), requires establishing a comprehensive process for stormwater management approval, implementing ESD to the maximum extent practicable, and ensuring that structural practices (see Chapter 3) are used only where absolutely necessary. The Act also establishes several performance standards for stormwater management plans. Designers must now ensure that these plans are designed to:

- Prevent soil erosion from development projects.
- Prevent increases in nonpoint pollution.
- Minimize pollutants in stormwater runoff from both new development and redevelopment.
- Restore, enhance, and maintain chemical, physical, and biological integrity of receiving waters to protect public health and enhance domestic, municipal, recreational, industrial and other uses of water as specified by MDE.
- Maintain 100% of the average annual predevelopment groundwater recharge volume.
- Capture and treat stormwater runoff to remove pollutants.
- Reduce downstream erosion in receiving streams.
- Prevent increases in the frequency and magnitude of out-of-bank flooding from large, less frequent storms.
- Protect public safety through the proper design and operation of stormwater management facilities.

The Act presents a new opportunity to improve Maryland's stormwater management program. The original Chapter 5 encouraged ESD through a series of optional credits for the design of nonstructural practices. Changes in response to the Act not only expand on the credits first introduced in the Manual but also allow for planning techniques to improve implementation and overall performance. The remaining sections of this chapter will further define ESD, discuss

Draft 12/14/2007

planning techniques used in its implementation, and provide design requirements for nonstructural and micro-scale practices used to treat runoff at the source. For reference purposes, the original Chapter 5 can be found in Appendix E.1.

5.0.3 Environmental Site Design

Definition

There are many stormwater design strategies that seek to replicate natural hydrology. Sometimes known as better site design, low impact development, green infrastructure, or sustainable site design, these strategies all espouse similar techniques. In each, a combination of planning techniques, alternative cover, and small-scale treatment practices is used to address impacts associated with development. For consistency, the Act adopts ESD as a more generic classification for use in Maryland.

Title 4, Subtitle 201.1(B) of the Act defines ESD as "...using small-scale stormwater management practices, nonstructural techniques, and better site planning to mimic natural hydrologic runoff characteristics and minimize the impact of land development on water resources." Under this definition, ESD includes:

- Optimizing conservation of natural features (e.g., drainage patterns, soil, vegetation).
- Minimizing impervious surfaces (e.g., pavement, concrete channels, roofs).
- Slowing down runoff to maintain discharge timing and to increase infiltration and evapotranspiration.
- Using other nonstructural practices or innovative technologies approved by MDE.

Impacts of Imperviousness

The goal of traditional site design strategies is to maximize development potential by focusing on the layout of buildings, roads, parking, and other features. Conventional development practices tend to maximize site imperviousness and contribute to many of the impacts discussed in Chapter 1. These include diminished groundwater recharge, increased flows and runoff volumes, pollutant accumulation, and elevated water temperatures.

Documentation such as the **Impacts of Impervious Cover on Aquatic Systems** (Center for Watershed Protection, 2003) and other studies of Eastern Piedmont and Coastal Plain streams in Maryland (Morgan and Cushman, 2005) and headwater streams in Montgomery County (Moore and Palmer, 2005) all indicate that stream biodiversity decreases as impervious cover increases. There is no simple formula, rule, or threshold for determining how much impervious cover may be sustained in a given watershed. Generally, stream quality and watershed health diminish when impervious cover exceeds 10% and become severely degraded beyond 25% (Center for Watershed Protection, 2003). Results from the Maryland Biological Stream Survey (MBSS) indicate that stream health is never good when watershed imperviousness exceeds 15%, (Boward, 1999). These studies establish a fundamental connection between impervious cover and watershed impairment.

Draft 12/14/2007

Integrating the fundamental principles of ESD during the planning process helps minimize the adverse impacts of imperviousness. The resulting designs reduce the need for costly infrastructure and maintenance while providing treatment closer to the source. To accomplish this, the designer must consider the basic concepts found in Section 5.1, Planning Techniques.

Addressing the Unified Sizing Criteria

Chapter 2 describes the five Unified Sizing Criteria (i.e., Re_v , WQ_v , Cp_v , Q_p , Q_f) for designing stormwater management systems in Maryland. These criteria are a fundamental part of Maryland's approach to meet pollutant removal goals, maintain recharge, reduce channel erosion, and address flooding. While the methods for calculating these volumes differ, the storage requirements for all are directly related to impervious cover. Many of the ESD planning techniques (e.g., alternative surfaces, clustering, reduced roadway widths and parking) significantly reduce the amount of impervious cover within a development. Accordingly, any significant reduction in impervious cover resulting from the implementation of ESD will reduce required volumes to be managed.

ESD also incorporates the use of nonstructural and micro-scale practices throughout a development to address stormwater management requirements. Nonstructural techniques are used to redirect runoff to permeable areas where it is either infiltrated into the soil or filtered by overland flow. Micro-scale practices capture and treat runoff from discrete impervious areas closer to the source. In both cases, impervious cover is physically disconnected from conveyance systems resulting in substantial reductions in runoff volume and pollutants.

Previously, four credits for impervious area disconnection (i.e., rooftop disconnection, non rooftop disconnection, sheetflow to buffers, and grass channel) were presented to allow designers to reduce the volumes needing structural control (see Appendix E.1). These credits allowed subtracting disconnected areas from total impervious cover when computing WQ_v and Re_v . These credits also allowed designers to consider disconnected areas as "woods in good condition" when computing post-development runoff curve numbers.

With the advances in ESD, the system of credits has evolved into the following chapter. With this evolution, there are changes in how the Unified Sizing Criteria are addressed. When impervious cover runoff is directed over permeable areas (e.g., Disconnection of Rooftop Runoff), there is significant infiltration into the ground and filtering through vegetation. This results in a considerable decrease in runoff volume and pollutants to receiving waters and an increase in local groundwater recharge. If properly designed and implemented, these practices are effective tools for addressing both the WQ_v and Re_v criteria.

Micro-scale practices (e.g., rainwater harvesting, bio-swales) are used to capture and treat runoff closer to the source, there are similar reductions in volume and pollutants delivered downstream. These practices may also be designed to increase recharge by infiltrating some or all the storage volume (e.g., landscape infiltration, enhanced filtering system). Like impervious area disconnection, properly designed and constructed micro-scale practices may be used to address both WQ_v and Re_v .

Draft 12/14/2007

Both nonstructural and micro-scale practices may be used to effectively address channel protection requirements (Cp_v). The amount of runoff delivered to receiving streams from more frequent storms that influence stream channel morphology (e.g., one-year 24 hour design storm) is significantly reduced when these practices are distributed throughout a project. However, this effect diminishes as the contiguous area of disconnected imperviousness approaches one acre (Hammer, 1972). While the volume of runoff reduced varies with local hydrologic conditions (e.g., soils, slope) and the size of the disconnected area, the amount of runoff is close to that expected from a naturally vegetated area.

Since 2000, several methods have been developed (e.g., NJDEP 2003, DNREC 2004) to calculate the effects of impervious disconnection on post-development runoff for quantity management requirements (i.e., Qp_2 , Qp_{10} , and Q_f). One of these (DNREC, 2004) distributes runoff from each disconnected impervious area as excess precipitation onto the receiving pervious area and then calculates the resultant runoff. Another (Queen Anne's County, 2007) requires the calculation of modified CN's for each disconnected impervious area for each design storm event (e.g., two-year 24 hour storm) of interest. While these and other similar models may result in more detailed runoff predictions, the calculations are complex and often require extensive computer modeling for the simplest site designs. Both the plan design and local approval processes may become more complicated with the increased use of ESD. The goal should be to develop procedures to limit, disconnect, and treat impervious cover runoff while simplifying design and approval. Local jurisdictions should use professional judgment when developing criteria for assessing the effects of disconnected imperviousness on conditions in receiving waters.

Draft 12/14/2007

Section 5.1 Planning Techniques

5.1.1 Introduction

Numerous researchers have assessed the impacts of urban development and watershed imperviousness on stream ecosystem structure and function (Hammer, 1972; Palmer et. al, 2002; and Booth, 2005). The systematic degradation of streams in urbanized watersheds is widely known as the “urban stream syndrome” (Walsh et. al, 2005). Symptoms include flashier storm hydrographs, elevated nutrient levels, altered channel geomorphology and stability, and reduced biotic richness. Stream impacts from urban development are directly related to the proximity of impervious development to stream channels, as well as hydrologic conditions and hydraulic efficiency of the storm drainage network (Walsh et. al, 2005).

These impacts underlie the importance of treating impervious area runoff prior to discharging to hydrologically connected natural drainage ways. The process of protecting streams from the impact of urban development requires widespread application of at the source approaches to drainage design. This begins with taking advantage of the existing hydrologic functions of important natural resources within the watershed.

Natural drainage corridors provide soil infiltration, depression storage, groundwater recharge, and flow attenuation. These are enhanced with the presence of vegetation. An assessment of how these characteristics contribute to the stability and health of downstream areas is needed in order to maintain these functions after development. The impacts associated with site disturbance, mass grading, and construction of efficient storm drains will be minimized by using natural conveyance through existing vegetative drainage networks.

Planning is critical and requires identifying and assessing the quality of environmentally sensitive resources and their hydrologic functions. Integrating natural resource areas into a comprehensive drainage network for on-site and downstream systems should be addressed in the first phase of site design. In addition, evaluating the distribution of on-site impervious areas will focus on strategies to reduce overall stormwater volumes during development design. The goals of this planning process include:

- Identifying and preserving natural drainage patterns.
- Developing a plan to protect environmentally sensitive areas and maximize hydrologic functions through conservation and ESD implementation strategies.
- Using ESD to connect hydrology pathways between new impervious surfaces and existing natural drainage patterns.
- Implementing clustered development and other site design techniques to minimize total site imperviousness.
- Planning for stormwater management and natural drainage pattern maintenance strategies in the first phase of project development.

Draft 12/14/2007

5.1.2 Identifying and Protecting Sensitive Resources

The first phase of the ESD planning process is to identify and map site features, including natural, historical, and cultural resources. Submitted for “concept” approval at the first stage of local development review, this map shall include existing forests, soils, wetlands, floodplains, riparian buffers, natural drainage topography, perennial and ephemeral stream systems, and drainage areas for both on-site and off-site areas. The mapping and assessment process, shall include the following:

- A natural resource map identifying on-site and adjacent streams, springs, seeps, natural drainage systems, bodies of water, wetlands, forests, riparian buffers, soils, 100-year floodplains, site topography, and a narrative of vegetation type and distribution. This map shall also be field verified by the project designer.
- An assessment of hydrology functions of existing natural resources identified above. This will include a discussion of how these functions relate to the stability and health of downstream ecosystems and how they will be used for managing runoff using ESD.
- An overlay of the proposed site development plans that demonstrates how important hydrology functions will be protected. Areas sensitive to disturbance such as steep slopes, highly erodible soils, and karst geology will also be included.
- A description of how ESD practices are integrated into the site layout process. All impervious areas should be hydrologically connected to landscaped areas, traffic islands, and other ESD practices. Protected areas such as green space and natural drainage corridors will enhance the benefits of ESD practices by providing a link between downstream ecosystems and the site development.

This process will help local jurisdictions ensure that development plans fit in with their priorities for resource protection, enhancement, and restoration. The Maryland Economic Growth, Resource Protection and Planning Act of 1992 specifies that local master plans address the protection of environmentally sensitive areas from the adverse affects of new development. Changes to this law in 2006 have further expanded the definition of sensitive areas. In addition, many counties have performed restoration assessments on targeted watersheds. The mapping and planning process described above allows individual site development to be evaluated in the context of these larger resource protection efforts.

Draft 12/14/2007

5.1.3 Expanding and Enhancing Buffers

Riparian areas offer multiple protection mechanisms to streams and wetlands, and important habitat for wildlife. In addition, they provide groundwater recharge, flood storage, nutrient cycling and denitrification, regulation of stream temperature (Groffman, 2003), and act as important corridors for movement of biota (Palmer, 2002). However, even in areas with intact riparian buffers, important functions may be compromised by the following conditions:

- Degraded streams and incised channels lead to lowering of water tables in riparian zones. This leads to a series of ecological changes (Palmer, 2002) to the composition of riparian vegetation, soil properties, nutrient cycling efficiency, and denitrification potential.
- A direct connection between storm drains and stream channels minimizes the overland flow interactions within riparian zones and alters the ecological function of these areas as indicated above (Walsh et. al, 2005).

Riparian buffer protection begins with how runoff is conveyed in upland catchment areas. More common riparian buffer protection mechanisms (e.g. revegetation and enhancement) are necessary but need to be complemented with efforts to connect drainage from upland catchments. Developing these strategies must be done during initial site planning.

When planning for riparian corridor protection and enhancement, an adequate buffer width needs to be established to protect streams and maximize functions (Palone and Todd, 1998). Minimum buffer widths vary and need to allow for expansion due to stream order, contributing land slopes, 100-year floodplain, wetlands, and the presence of sensitive areas such as steep slopes and erodible soils. The following table lists specific buffer functions and an associated range of minimum widths for protection:

Table 5.1 Summary of Specific Buffer Functions

Riparian Buffer Function	Range of Minimum Widths (feet)
Bank Stability and Aquatic Food Web	25 - 40
Water Temperature Moderation	25 - 60
Nitrogen Removal	40 - 140
Sediment Removal	50 - 160
Flood Mitigation	60 - 220

(Adapted from Palone and Todd, 1998)

The fundamental principles of riparian corridor protection and enhancement include:

- Demonstrating that an overland hydrologic connection will be established between natural upland drainage corridors and riparian areas.
- Evaluating existing riparian buffer functions. Site-specific factors that must be considered include stream order, contributing flow path length, depth to the water table, soils and vegetative cover.
- Maintaining and protecting greenways and natural drainage systems where riparian corridors are not located on-site.

Draft 12/14/2007

- Establishing a minimum width of riparian corridor protection. This width shall be increased for larger streams and where wetlands, 100-year floodplains, or steep slopes are present. Disturbance in these areas should be limited.
- Implementing strategies necessary for long-term protection and maintenance.

The concept approval stage described in the previous section initiates the process of providing and maintaining natural hydrology pathways between the site and downstream systems. These riparian corridor protection and enhancement principles will be incorporated into the concept approval process once the site mapping and assessment are complete. This will allow local jurisdictions to review development plans with a range of tools and strategies for resource protection and conservation.

5.1.4 Reducing Impervious Cover

Patterns of urban development such as landscape configuration, interconnectivity of impervious and open space areas, and the total amount of impervious cover are all factors in stream ecosystem health (Alberti et. al, 2006). Employing open space design techniques by concentrating development on one part of a site encourages impervious and open space areas to be hydrologically connected. This pattern not only reduces total impervious area by minimizing lot sizes, frontages, and roadway widths, but also protects environmentally sensitive areas. However, many municipal codes require strict adherence to long-standing development rules. This limits creative design and reduces incentives to implement ESD.

Conventional zoning usually dictates minimum setbacks from the front, side, and rear property lines, as well as mandatory yard widths. These standards increase the distance between lots and the overall roadway length in a subdivision. In addition, minimum roadway width and sidewalk requirements increase the total impervious area (Schueler, 1995). Table 5.2 below provides a list of better site design techniques that may be used to reduce site impervious area, protect environmentally sensitive areas, and provide more open space to communities (Center for Watershed Protection, 1998 and Schueler, 2000b).

One type of practice that encompasses many of these techniques is clustering. This practice will reduce site imperviousness by concentrating development in one area, thereby reducing the distance between individual lots and reducing the length of subdivision roadways. It will also allow for protecting open space and buffer areas and reduce clearing and grading in natural areas. Other benefits include reduced infrastructure costs and enhanced open space and greenway amenities.

Commercial and industrial development differs significantly from residential. While many of the concepts discussed above may apply, there are other opportunities to reduce impervious cover in commercial and industrial settings. Parking lots are the dominant land cover for most commercial and industrial projects. Using ESD, designers can minimize the surface area dedicated to parking and integrate the space saved into landscaped areas for natural resource protection and stormwater treatment.

Draft 12/14/2007

Parking lot size is governed usually by parking ratios, lot layout, and stall geometry. Typically, parking ratios are perceived as the minimum number of spaces that must be provided. However, these ratios should be considered as a maximum and the actual number of spaces provided be based on demand. Internal traffic patterns should consider a mixture of two-way and one-way aisles used in conjunction with angled stalls. Additionally, a fixed percentage of stalls should be dedicated to compact cars. Other options to reduce parking lot size include shared parking with adjacent properties or building garages.

Reducing the impervious area in residential, commercial, and industrial development enhances the space available for landscaped features (e.g., parking lot islands, medians, plazas). Many of the micro-scale practices discussed below are tailored to fit in these smaller landscaped areas. Distributing these practices throughout the site is an effective means to address stormwater management requirements at the source. Additionally, these smaller features can be hydrologically interconnected to more closely mimic natural watershed functions.

More details and information may be found in the book, **Better Site Design: A Handbook for Changing Development Rules in Your Community**, (Center for Watershed Protection, 1998). These techniques should all be employed during the first phases of site planning, layout, and concept approval. Local authorities need to be flexible and timely when applying existing development codes to innovative site design solutions. Below is an example of different site development strategies to show how the various features of ESD can be integrated into the design process.

Table 5.2 Summary of Site Development Strategies

Better Site Design Technique	Recommendations
Using narrower, shorter streets, rights-of-way, and sidewalks	Streets may be as narrow as 22 ft. in neighborhoods serving low traffic volumes; open space designs and clustering will reduce street lengths; rights-of-way can be reduced by minimizing sidewalk width, providing sidewalks on one side of the road, and reducing the border width between the street and sidewalks.
Cul-de-sacs	Allow smaller radii for turn arounds as low as 33 ft.; use a landscaped island in the center of the cul-de-sac and design these areas to treat stormwater runoff.
Open vegetated channels	Allow grass channels or biofilters for residential street drainage and stormwater treatment.
Parking ratios, parking codes, parking lots, and structured parking	Parking ratios should be interpreted as maximum number of spaces; use shared parking arrangements; minimum parking stall width should be less than 9 ft. and stall length less than 18 ft.; parking garages are encouraged rather than surface lots.
Parking lot runoff	Parking lots are required to be landscaped and setbacks are relaxed to allow for bioretention islands or other stormwater practices in landscaped areas.
Open space	Flexible design criteria should be provided to developers who wish to use clustered development and open space designs.

Draft 12/14/2007

Better Site Design Technique (cont.)	Recommendations
Setbacks and frontages	Relax setbacks and allow narrower frontages to reduce total road length; eliminate long driveways.
Driveways	Allow for shared driveways and alternative impervious surfaces.
Rooftop runoff	Direct to pervious surfaces.
Buffer systems	Designate a minimum buffer width and provide mechanisms for long-term protection.
Clearing and grading	Clearing, grading, and earth disturbance should be limited to that required to develop the lot.
Tree conservation	Provide long-term protection of large tracts of contiguous forested areas; promote the use of native plantings.
Conservation incentives	Provide incentives for conserving natural areas through density compensation, property tax reduction, and flexibility in the design process.

(Adapted from Center for Watershed Protection, 1998)

Draft 12/14/2007**5.1.5 Alternative Surfaces**

An effective method to reduce imperviousness in residential, commercial, and industrial applications is to use more permeable alternatives. Roofs and pavements are often-overlooked areas that may be replaced with more permeable surfaces. Green roofs are particularly useful alternatives for reducing impervious cover and provide much-needed green space in ultra-urban or high-density developments. Whether made from porous asphalt or concrete, interlocking pavers, or reinforced turfs, permeable pavements are a cost-effective alternative for parking lot and roadway surfaces.

Alternative surface variants include:

- A-1. Green Roofs
- A-2. Permeable Pavements

Draft 12/14/2007**A-1. Green Roofs**

Green roofs are alternative surface systems that replace conventional construction materials and include a protective covering of planting media and vegetation. Also known as vegetated roofs, roof gardens, or eco-roofs, these may be used in place of traditional flat or pitched roofs to reduce impervious cover and more closely mimic natural hydrology. Green roofs produce less heat than conventional systems. Therefore, they may be used to help mitigate stormwater impacts and temperature increases caused by new development.

There are two basic green roof designs that are distinguished by media thickness and the plant varieties that may be used. The more common or “extensive” green roof is a lightweight system where the media layer is between two and six inches thick. This limits plants to low-growing, hardy herbaceous varieties. An extensive green roof may be constructed off-site as a modular system with drainage layers, growing media, and plants installed in interlocking grids. Conventional construction methods may also be used to install each component separately.

“Intensive” green roofs have thicker soil layers (eight inches or greater) and are capable of supporting more diverse plant communities including trees and shrubs. A more robust structural loading capacity is needed to support the additional weight of the media and plants. Intensive green roofs are more complex and expensive to design, construct, and maintain, and are therefore, less commonly used.

Applications:

Green roofs may be used to replace most conventional roofs in both new and redevelopment applications in residential, commercial, and industrial projects. Green roofs are particularly useful for reducing impervious cover in ultra-urban or high-density areas as well. Green roofs may also mitigate temperature increases on projects located in thermally sensitive watersheds.

Performance:

When designed according to the guidance provided below, the rooftop area covered by a green roof may be subtracted from the total impervious cover when computing WQ_v . Impermeable liners are an integral component in all green roof systems. Therefore, green roofs may not be used to address Re_v requirements.

The capacity of a green roof to detain runoff is governed by planting media thickness, roof slope or “pitch”, and rainfall depth. Consequently, CN’s applied to green roofs may vary for the one, two, 10, and 100-year design storm events depending on individual design characteristics. To simplify the design and approval process, the post development CN of 75 should be used for green roofs when computing Cp_v , Q_p , and Q_f requirements.

Draft 12/14/2007

Constraints:

The following constraints are critical when considering the use of green roofs to treat stormwater runoff:

- **Infrastructure:** The location of existing and proposed utilities (e.g., HVAC, gutters, downspouts, electricity) will influence the design and construction of green roofs.
- **Structure:** Green roofs are not suitable for use on steep roofs ($> 30\%$). Sloped roofs may require additional measures to prevent sliding and ensure stability. The structure must also be capable of supporting the additional weight (live and dead load) of a green roof. Typical dead load ranges from 8 to 36 lbs/ft². Live load is a function of rainfall retention (e.g., one inch of rain equals 5.2 lbs/ft²). For redevelopment projects and existing buildings, additional measures (e.g., trusses, joists, columns) may be needed for support.
- **Waterproofing:** Materials should be durable under the conditions associated with vegetated covers. Supplemental barrier layers may be required with waterproofing membranes that may be damaged by plant roots.
- **Drainage:** Building drainage (e.g., gutters, deck drains, scuppers) must be capable of managing large rainfall events without inundating the roof.

Design Guidance:

The following conditions should be considered when designing green roofs:

- **Conveyance:** Runoff from adjacent roofs should be diverted to a stable conveyance system. If bypassing a green roof is impractical, an overflow device (e.g., gutter, deck drain) shall be used.

Runoff shall flow through and exit green roof systems in a safe and non-erosive manner. A semi-rigid, plastic geocomposite drain or mat layer should be included to convey runoff to the building drainage system. Flat roof applications may require a perforated internal network to facilitate drainage of rainfall. Overflow structures shall be capable of passing the two-year 24-hour design storm without inundating the roof. Additionally, roof flashing should extend six inches above the media surface and be protected by counter-flashing.

All green roofs shall include a waterproofing system or membrane. Materials used should be durable under vegetated cover conditions and resistant to biological and root attack. A supplemental barrier may be needed to protect the waterproofing from plant roots.

Draft 12/14/2007

- **Treatment:** Green roof systems shall meet the following conditions:
 - Planting media shall be non-soil engineered mixes conforming to the specifications found in Appendix B.4.
 - Media layers should be between two to six inches thick. Dual media systems may be applied where green roof assemblies are four inches or thicker.
 - Individual layers (e.g., root barriers, drainage mats, separation geotextiles) shall conform to the specifications found in Appendix B.4.
- **Structure:**
 - The roof structure shall be capable of bearing the maximum predicted dead and live loads associated with green roof systems. Dead load bearing capacity of the roof must be established using standardized media weights and procedures (e.g., ASTM E-2397-05, E-2399-05).
 - Green roofs with pitches steeper than 2:12 shall include supplemental measures (e.g., slope bars, rigid stabilization panels, reinforcing mesh) to enhance stability and prevent media sliding.
- **Landscaping:** Vegetation is critical to the function and appearance of any green roof. Therefore landscaping plans shall be provided according to the guidance in Appendix B.4. A vigorous, drought-tolerant ground cover shall be established using varieties of sedum, delosperma, or similar varieties native to Maryland.

Construction Criteria:

The following items should be addressed during construction of projects with green roofs:

- **Waterproofing Installation:** The waterproofing membrane should be visually inspected and tested for water tightness prior to installation of the planting mix. Any flaws, irregularities, or conditions that may cause leaks or roof damage shall be identified and repaired. Measures shall be taken to prevent membrane damage during green roof installation.
- **Slope Stabilization Measures:** Where required, slope stabilization measures should be placed prior to green roof installation. In some situations, slope stabilization may be integrated into the roof structure.
- **Green Roof Installation:** Green roof systems should be installed according to the manufacturer's instructions. Generally, root-barrier layers, walkways, and irrigation systems should be installed first.

Inspection:

- Prior to placement of the waterproofing, drainage, and treatment materials, certification shall be required that the constructed roof meets the load bearing capacity specified on the

Draft 12/14/2007

approved plans. Additionally, certification regarding the water tightness of the waterproofing membrane is required after its installation and prior to placement of the planting media and stock.

➤ Regular inspections shall be made during the following stages of construction:

- During placement of the waterproofing membrane.
- During placement of the drainage system.
- During placement of the planting media.
- Upon installation of the plant material.
- Before issuing use and occupancy approvals (new construction only).
- During the second growing season to ensure adequate vegetation survival.

Maintenance Criteria:

Green roofs require annual maintenance to ensure optimum performance. Typically, eighteen months are needed to establish adequate initial plant growth. Periodic irrigation may be needed during this time and basic weeding, fertilizing, and in-fill planting may be required as well. After plants are established, the roof should be inspected and light weeding performed once or twice per year.

Draft 12/14/2007**A-2. Permeable Pavements**

Permeable pavements are alternatives that may be used to reduce imperviousness. While there are many different materials commercially available, permeable pavements may be divided into four basic types: porous bituminous asphalt, porous concrete, interlocking concrete paving blocks or grid pavers, and reinforced turf. The first three categories consist of a porous surface course and uniformly graded stone or sand drainage system. Stormwater drains through the surface course, is captured in the drainage system, and infiltrates into the surrounding soils. Permeable pavements significantly reduce the amount of impervious cover, provide water quality and groundwater recharge benefits, and may help mitigate temperature increases.

Reinforced turf consists of interlocking concrete or plastic units with interstitial areas for growing grass. These systems are suitable for light traffic loads and are commonly used for emergency vehicle access roads and overflow or occasionally used parking. The primary benefit of reinforced turf is that it is vegetated.

Applications:

Permeable pavements are effective for reducing imperviousness in parking lots, driveways, plazas, and access roads in both new and redevelopment applications in residential, commercial, and industrial projects. They are particularly useful in high-density areas where space is limited. Rainwater passes through the permeable surface, is temporarily stored in the sub-base material, and slowly infiltrates into the underlying soils.

Performance:

When designed according to the guidance provided below, areas covered by permeable pavements may be subtracted from the total impervious cover when computing WQ_v and Re_v requirements. Post development CN's for reinforced turf applications may be assumed to be "open space in good condition" when computing Cp_v , Q_p , and Q_f requirements. The capacity of asphalt or concrete permeable pavements to capture and detain runoff is governed by the storage capacity and compaction of the sub-base. These systems may be used to address Cp_v , Q_p , and Q_f requirements if the sub-base is designed according to methods outlined in Appendix D.13 for quantity control.

Constraints:

The following constraints are critical when considering the use of permeable pavements to capture and treat stormwater runoff:

- **Space:** Permeable pavements work best when designed in a series of narrow strips. The size and distribution of paved surfaces within a project must be considered early during planning and design. Permeable pavements should not be used in areas where there are risks for foundation damage and basement flooding, interference with the operation of subsurface sewage disposal systems, or detrimental impacts to other underground structures.

Draft 12/14/2007

- **Topography:** Runoff should sheetflow onto and across permeable pavements. Contributing drainage slopes should be moderate ($\leq 10\%$). If slopes are too steep, then level-spreading devices may be needed to redistribute flow. Pavement surfaces should be gradual ($\leq 5\%$) to prevent ponding of water within the sub-base.

- **Soils:** Sandy soils are critical to successful application of permeable pavements. The HSG should be A or B.

Subsurface water conditions (e.g., water table) will help determine the stone reservoir thickness used. The probability of practice failure increases if the reservoir intercepts groundwater. Therefore, sub-base inverts should be above local groundwater tables.

- **Drainage Area:** Permeable pavements are an at source practice for reducing impervious cover and addressing water quality and recharge requirements. As the impervious area draining to each practice increases, practice effectiveness weakens. Therefore, runoff from adjacent areas should be limited.
- **Hotspot Runoff:** Permeable pavements should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that may contaminate groundwater.
- **Structure:** Most permeable alternatives have a lower load bearing capacity than conventional pavements. Therefore, applications should be limited to locations that do not receive heavy vehicle traffic and where sub soils are not compacted.
- **Operation:** Permeable pavements are highly susceptible to clogging and subject to owner neglect. Individual owners need to be educated to ensure that proper maintenance and winter operation activities will allow the system to function properly.

Design Guidance:

The following conditions should be considered when designing permeable pavements:

- **Conveyance:** Runoff shall enter, flow through, and exit permeable pavements in a safe and non-erosive manner. Permeable pavements should be designed off-line whenever possible. Runoff from adjacent areas should be diverted to a stable conveyance system. If bypassing these areas is impractical, then runoff shall sheetflow onto permeable pavements.

Pavement surfaces consisting of asphalt or concrete shall have a permeability of eight inches per hour or greater to convey water into the sub-base rapidly. The slope of the permeable pavement shall be at least 1% but no greater than 5%. Any grade adjustments requiring fill shall be accomplished using the sub-base material. Permeable pavements may be placed in sloped areas by terracing levels along existing contours.

Draft 12/14/2007

Asphalt or concrete pavement systems shall include an alternate mode for runoff to enter the sub-base reservoir. In curbless designs, this may consist of a two-foot wide stone edge drain. Raised inlets may be required in curbed applications.

The bottom of the sub-base shall be level to enhance distribution and reduce ponding within the reservoir. A network of perforated pipes may be used to uniformly distribute runoff over the bed bottom. Perforated pipes shall also be used to connect structures (e.g., cleanouts, inlets) located within the permeable pavement section.

Asphalt or concrete pavements shall include an overflow system. This shall be designed to ensure that water surface elevations do not rise into the pavement. Overflow structures may include inlets, edge drains, or similar devices that will convey excess runoff safely to a stable outfall.

➤ **Treatment:** All asphalt and concrete permeable pavement systems shall meet the following conditions:

- The sub-base of asphalt and concrete systems shall be designed to capture and store the WQ_v . The storage volume is determined for the sub-base and sand and gravel layers in the bottom of the facility only. Storage calculations shall account for the porosity of the gravel and sand.
- Applications that exceed 10,000 ft² shall be designed to exfiltrate the WQ_v through the floor of the practice using the design methods outlined in Appendix D.13.
- A minimum 12" layer of a clean, uniformly graded aggregate with a porosity (n) of 40% (1.5" to 2" stone is preferred) is required below the pavement surface.
- Alternative subsurface storage devices may be used to enhance capacity.
- A 12" layer of sand or pea gravel (1/8" to 3/8" stone) may be used to act as a bridging layer between the sub-base reservoir and subsurface soils.

➤ **Soils:**

- Permeable pavements should be installed in HSG A or B.
- Permeable pavements shall not be placed on areas of compacted fill.
- For asphalt or concrete applications that exceed 10,000 ft², underlying soils shall have an infiltration rate (f) of 0.52"/hr or greater. This rate may be initially determined from NRCS soil textural classification and subsequently confirmed by geotechnical tests in the field as required in Chapter 3.3.1.
- For asphalt and concrete, the invert of the sub-base reservoir shall be at least four feet above (two feet on the lower Eastern Shore) the seasonal high water table.

Draft 12/14/2007

➤ **Setbacks:**

- Asphalt and concrete pavements shall be located down gradient of building structures and be setback at least 10 feet from buildings, 50 feet from confined water supply wells, 100 feet from unconfined water supply wells, and 25 feet from septic systems.
- Asphalt and concrete pavements should also be sized and located to meet minimum local requirements for underground utility clearance.

➤ **Structure:** All permeable pavement systems shall be capable of bearing the anticipated vehicle and traffic loads. Pavement systems conforming to the specifications found in Appendix B.4 should be structurally stable for typical (e.g., light duty) applications.

➤ **Landscaping:** Permeable pavement shall be identified on landscaping plans. Trees and shrubs should not be located adjacent to asphalt and concrete where damage by root penetration and clogging from leaves are a concern.

Construction Criteria:

The following items should be addressed during construction of projects with permeable pavement:

- **Erosion and Sediment Control:** Final grading for installation shall not take place until the surrounding site is stabilized. If this cannot be accomplished, runoff from disturbed areas should be diverted around proposed pavement locations.
- **Soil Compaction:** Sub soils shall not be compacted. Construction shall be performed with lightweight, wide tracked equipment to minimize compaction. Excavated materials shall be placed in a contained area.
- **Filter Cloth:** Filter cloth shall not be used between the sub-base and sub soils.
- **Distribution Systems:** Distribution pipes should be checked to ensure that both the material and perforations meet specifications (see Appendix B.4). The upstream ends of distribution pipes should be capped prior to installation. All pipes used shall be installed flat along the bed bottom.
- **Sub-Base Installation:** Sub-base aggregate should be clean, washed, and free of fines. The sub-base shall be placed in lifts and lightly rolled according to the specifications.

Inspection:

- Regular inspections shall be made during the following stages of construction:
 - During excavation to sub grade.
 - During placement and backfill of any drainage or distribution system(s).
 - During placement of the sub-base material.

Draft 12/14/2007

- o During placement of the surface material.
- o Upon completion of final grading and establishment of permanent stabilization.

Maintenance Criteria:

The following procedures should be considered essential for maintaining permeable pavement systems:

- Pavements should be used only where regular maintenance can be performed. Maintenance agreements should clearly specify how to conduct routine tasks to ensure long-term performance of these systems.
- Asphalt and concrete surfaces should be swept and vacuumed to reduce sediment accumulation and ensure continued surface porosity. Sweeping should be performed at least twice annually with a commercial cleaning unit. Washing systems and compressed air units should not be used to perform surface cleaning.
- Drainage pipes, inlets, stone edge drains, and other structures within or draining to the sub-base should be cleaned out at regular intervals.
- Trucks and other heavy vehicles can grind dirt and grit into the porous surfaces, leading to clogging and premature failure. These vehicles should be prevented from tracking and spilling material onto the pavement.
- Deicers should be used in moderation. When used, deicers should be non-toxic and organic and can be applied either as blended magnesium chloride-based liquid products, or as pretreated salt. Snow plowing should be done carefully with blades set one-inch higher than normal. Plowed snow piles and snowmelt should not be directed to permeable pavement.
- Reinforced turf should be mown regularly and clippings removed from the application area.

Draft 12/14/2007**Section 5.2 Treatment Using Nonstructural and Micro-Scale Practices****5.2.1 Introduction**

Disconnecting impervious cover and treating urban runoff closer to its source are the next steps for implementing ESD after all planning options have been exhausted. Using nonstructural techniques (e.g., disconnection of rooftop runoff, sheetflow to buffers) and micro-scale practices (e.g., rain gardens, bio-swales) throughout a development is an effective way to accomplish this goal. Nonstructural practices may be used to disconnect impervious cover and direct runoff over vegetated areas to promote overland filtering and infiltration. Micro-scale practices are useful for capturing and treating runoff near the source. Whether runoff is directed over permeable areas or captured in small water quality treatment practices, there are reductions in both volume and pollutants delivered to receiving streams. Accordingly, these practices may be used to address both WQ_v and Re_v when designed and implemented properly. When the contributing impervious area is small, both nonstructural and micro-scale practices may be effective for addressing Cp_v requirements too.

Nonstructural and micro-scale practices are an integral part of stormwater management plans using ESD strategies. Therefore, the use of these practices shall be documented at the concept and final design stages and verified with “as-built” certification. If practices are not implemented as planned, then volumes used to design structural practices shall be increased appropriately to meet Re_v , WQ_v , Cp_v , and Q_p where applicable.

Draft 12/14/2007**5.2.2 Nonstructural Practices**

Nonstructural practices combine relatively simple features, grading, and landscaping to divert runoff into vegetated areas and away from conventional storm drain systems. Runoff flows over these areas, filters through the vegetation, and soaks into the ground. Runoff should be conveyed as sheetflow into and through these areas. As depth and velocity of flow increase, runoff concentrates and the ability of vegetation to filter and detain runoff diminishes rapidly. Consequently, requirements and conditions for nonstructural practices reflect the need to maintain sheetflow conditions.

Nonstructural practice variants include:

- N-1 Disconnection of Rooftop Runoff
- N-2 Disconnection of Non-Rooftop Runoff
- N-3 Sheetflow to Buffers

Draft 12/14/2007**N-1. Disconnection of Rooftop Runoff**

Rooftop disconnection involves directing flow from downspouts to vegetated areas where it can soak into or filter over the ground. This disconnects the rooftop from the storm drain system and reduces both runoff volume and pollutants delivered to receiving waters. Rooftop disconnection is dependent on several site conditions (e.g., permeable flow path length, soils, slopes, compaction) to function well.

Applications:

There are many opportunities for disconnecting rooftops in both new and redevelopment designs. Runoff may be directed to undisturbed natural areas (e.g., vegetated buffers), landscaped areas (e.g., lawns, grass channels), compensatory practices (rain gardens, dry wells), or any combination of these options. Rooftop disconnection is possible in commercial, industrial, and residential settings given the constraints listed below.

Performance:

When adequately disconnected, the contributing rooftop area may be subtracted from total impervious cover when computing WQ_v . Disconnected rooftops may also be used to meet Re_v requirements (see Chapter 2). Post-development CN's for disconnected rooftop areas may be assumed to be "open space in good condition" when computing Cp_v , Q_p , and Q_f requirements.

Constraints:

The following constraints are critical when considering the use of rooftop disconnection to capture and treat stormwater runoff:

- **Space:** A permeable, vegetated area equal to the minimum flow path length needed for treatment must be available down gradient from the downspout to effectively disconnect rooftop runoff. If the flow path is insufficient, additional treatment may be provided using micro-scale practices.
- **Topography:** Runoff must be conveyed as sheetflow across open areas to maintain proper disconnection. Additionally, disconnected downspouts should be located on gradual slopes ($\leq 5\%$) and directed away from buildings to both maintain sheetflow and prevent water damage to basements and foundations. If slopes are too steep ($> 5\%$), a series of terraces or berms may be required to maintain sheetflow. These terraces may be readily constructed of landscaping stones or timber.
- **Soils:** Downspout disconnections work best in undisturbed, sandy soils that allow runoff to infiltrate. Clayey soils or soils that have been compacted by construction equipment greatly reduce the effectiveness of this practice.

Draft 12/14/2007

- **Drainage Area:** For simple disconnections (e.g., without compensatory practices), the rooftop area to each downspout should be small enough to prevent flow concentration onto the permeable treatment area. Disconnections may not be feasible for large rooftops or those with a limited number of downspouts.
- **Hotspot Runoff:** Disconnections should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that are found in typical stormwater runoff.
- **Reconnections:** Disconnections are ineffective if runoff flows onto impervious areas located directly below the downspout. This practice may not be feasible if there are large areas of imperviousness close to downspouts.

Design Guidance:

The following conditions should be considered when designing rooftop disconnections:

- **Conveyance:** Runoff from disconnected downspouts must drain in a safe and non-erosive manner through vegetated areas (e.g., open space, swales, filter strips) to the property line or downstream BMP.
- **Treatment:** Disconnections shall meet the following conditions:
 - A pervious area at least 75 ft. (60 ft. for Eastern Shore projects) long should be available down gradient of disconnected downspouts.
 - Disconnections should be located on an average slope of 5% or less. Terraces, berms, or similar grade controls may be used where average slopes exceed 5%.
 - The drainage area to each disconnected downspout should be 500 ft² or less to prevent flow concentration.
 - Disconnected downspouts should be at least 10 ft. from the nearest impervious surface of similar or lower elevation to prevent reconnection.
- **Landscaping:** Disconnections should be directed over HSG A or B (e.g., sands, sandy loams, loams). Soils that are compacted by construction equipment may need to be tilled and/or amended to increase permeability. Groundcover should be provided after any soil amendments are used. Turf grass is the most common groundcover in residential applications. However, trees and shrubs as well as other herbaceous plants will enhance infiltration and evapotranspiration of runoff.

Draft 12/14/2007

Construction Criteria:

The following items should be addressed during the construction of projects with planned rooftop disconnections:

- **Erosion and Sediment Control:** Erosion and sediment control practices (e.g., sediment traps) should not be located in vegetated areas receiving disconnected runoff.
- **Site Disturbance:** To minimize disturbance and compaction, construction vehicles and equipment should avoid areas receiving disconnected runoff. Should areas receiving disconnected runoff become compacted, scarifying the surface or rototilling the soil to a depth of four to six inches will be necessary to ensure permeability. Additionally, amendments may be needed for tight, clayey soils.

Inspection:

A final inspection shall be conducted before use and occupancy approval to ensure that permanent stabilization has been established.

Maintenance Criteria:

Maintenance of areas receiving disconnected runoff is generally no different than that required for other lawn or landscaped areas. The areas receiving runoff should be protected from future compaction (e.g., by planting trees or shrubs along the perimeter). In commercial areas, foot traffic should be discouraged as well.

Draft 12/14/2007**N-2. Disconnection of Non-Rooftop Runoff**

Non-rooftop disconnection involves directing flow from impervious surfaces to vegetated areas where it can soak into or filter over the ground. This disconnects these surfaces from the storm drain system, reducing both runoff volume and pollutants delivered to receiving waters. Non-rooftop disconnection is commonly applied to smaller or narrower impervious areas like driveways, open section roads and small parking lots and is dependent on several site conditions (e.g., permeable flow path length, soils, slopes, compaction) to function well.

Applications:

There are many opportunities for disconnecting impervious surfaces in both new and redevelopment designs. Runoff may be directed as sheetflow to undisturbed natural areas (e.g., vegetated buffers) or landscaped areas (e.g., lawns, grass channels). Non-rooftop disconnection is possible in commercial, industrial, and residential settings given the constraints listed below.

Performance:

When adequately disconnected, the contributing impervious area may be subtracted from total impervious cover when computing WQ_v . Disconnected surfaces may also be used to meet the Re_v . Post-development CN's for disconnected impervious areas may be assumed to be "open space in good condition" when computing Cp_v , Q_p , and Q_f requirements.

Constraints:

The following constraints are critical when considering the use of non-rooftop disconnection to capture and treat stormwater runoff:

- **Space:** A permeable, vegetated area equal to the minimum flow path length needed for treatment must be available down gradient of the impervious cover to effectively disconnect runoff. If the flow path length is insufficient, additional treatment may be provided using micro-scale practices.
- **Topography:** Runoff must be conveyed as sheetflow across open areas to maintain proper disconnection. Additionally, disconnections should be located on gradual slopes ($\leq 5\%$) and directed away from buildings to both maintain sheetflow and prevent water damage to basements and foundations. If slopes are too steep ($> 5\%$), a series of terraces or berms may be required to maintain sheetflow. These terraces may be readily constructed of landscaping stones or timber.
- **Soils:** Non-rooftop disconnection works best in undisturbed, sandy soils that allow runoff to infiltrate. Clayey soils or soils that have been compacted by construction greatly reduce the effectiveness of this practice.

Draft 12/14/2007

- **Drainage Area:** The area to each discharge location should be small enough to prevent flow concentration onto permeable treatment areas. Disconnections may not be feasible for large blocks of impervious cover or areas with limited discharge points.
- **Hotspot Runoff:** Disconnections should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that are found in typical stormwater runoff.

Design Guidance:

The following conditions should be considered when designing non-rooftop disconnections:

- **Conveyance:** Runoff from disconnected impervious areas must drain as sheetflow through vegetated areas (e.g., open space, swales, filter strips) to the property line or downstream BMP.
- **Treatment:** Disconnections shall meet the following conditions:
 - The flow path or “disconnection” through vegetated areas must be equal to or greater than the flow path through the contributing length of imperviousness.
 - Disconnections should be located on an average slope of 5% or less. Terraces, berms or similar grade controls may be used where average slopes exceed 5%.
 - The drainage area to each disconnection should be 1,000 ft² or less to prevent flow concentration.
 - Disconnected downspouts should be at least 10 ft. from the nearest impervious surface of similar or lower elevation to prevent reconnection.
- **Landscaping:** Disconnections should be directed over HSG A or B (e.g., sands, sandy loams, loams). Soils that are compacted by construction equipment may need to be tilled and/or amended to increase permeability. Groundcover should be provided after any soil amendments are used. Turf grass is the most common groundcover in residential applications. Trees and shrubs as well as other herbaceous plants will enhance infiltration and evapotranspiration of runoff.

Construction Criteria:

The following should be addressed during construction of projects with non-rooftop disconnections:

- **Erosion and Sediment Control:** Erosion and sediment control practices (e.g., sediment traps) should not be located in areas designated for non-rooftop disconnections.
- **Site Disturbance:** To minimize disturbance and compaction, construction vehicles and equipment should avoid areas receiving disconnected runoff. Should areas receiving disconnected runoff become compacted, scarifying the surface or rototilling the soil to a

Draft 12/14/2007

depth of four to six inches will be necessary to ensure permeability. Additionally, amendments may be needed for tight, clayey soils.

Inspection:

A final inspection shall be conducted before use and occupancy approval to ensure that permanent stabilization has been established.

Maintenance Criteria:

Maintenance of areas receiving disconnected runoff is generally no different than that required for other lawn or landscaped areas. The areas receiving runoff should be protected from future compaction (e.g., by planting trees or shrubs along the perimeter). In commercial areas, high foot traffic should be discouraged as well.

Draft 12/14/2007

N-3. Sheetflow to Buffers

Stormwater runoff is effectively treated when flow from pervious and impervious surfaces is directed to vegetated buffers where it can soak into or filter over the ground. Promoting sheetflow into buffers is commonly applied where development is located adjacent to protected areas and is dependent on several site conditions (e.g., buffer size, contributing flow path length, slopes, compaction) to function well.

Applications:

Sheetflow to buffers can be used in most development situations provided that site conditions allow implementation. Wherever streams and other areas are mapped for conservation during project planning, there are opportunities to use sheetflow to buffers given the constraints listed below.

Performance:

When directed into a natural buffer meeting the criteria below, any contributing impervious area may be subtracted from total impervious cover when computing the WQ_v . These impervious surfaces may also be used to meet the Re_v . Post-development CN's for areas directed into buffers may be assumed to be "meadow in good condition" when computing Cp_v , Q_p , and Q_f requirements.

Constraints:

The following constraints are critical when considering the use of sheetflow to buffers to treat stormwater runoff:

- **Space:** Buffers need to be wide enough to effectively treat runoff and protect natural resources. Flow path lengths from impervious and pervious areas should be minimized to prevent concentration and erosive conditions. Buffers receiving runoff should also meet all applicable State and local size requirements.
- **Topography:** Runoff should enter buffers as sheetflow to enhance performance and prevent erosion. If slopes are too steep to maintain sheetflow ($> 5\%$), then level-spreading devices will be needed to redistribute flow prior to entering designated buffers.
- **Hotspot Runoff:** Sheetflow to buffers should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that are found in typical stormwater runoff.
- **Easements:** Public maintenance access and formal, legal protection are essential for long-term viability of buffers. An acceptable conservation easement or other enforceable instrument that ensures perpetual protection shall protect natural or constructed buffers receiving runoff.

Draft 12/14/2007

Design Guidance:

The following conditions should be considered when designing sheetflow to buffers:

- **Conveyance:** Runoff from contributing areas must sheetflow into buffers. Either the average contributing overland slope should be 5% or less or a level-spreading device must be used.
- **Treatment:** Designs using sheetflow to buffers shall meet the following conditions:
 - Buffers should meet all applicable State and local criteria for minimum size;
 - Widths should be at least 50 ft. as measured from the centerline of the buffer.
 - Contributing flow path lengths from treated areas should be 150 ft. or less for pervious areas and 75 ft. or less for impervious areas to prevent concentration.
- **Landscaping:** Landscaping plans should clearly specify how vegetation within buffers will be established and managed. These plans should include plants that are native or adapted to Maryland. Managed turf (e.g., playgrounds, regularly mown and maintained open areas) is not an acceptable form of vegetation management.

Construction Criteria:

The following should be addressed during construction of projects with sheetflow to buffers:

- **Erosion and Sediment Control:** Erosion and sediment control plans shall clearly indicate where buffers are located and what measures will be used for protection during construction. Buffers shall be clearly marked in the field and not receive runoff prior to project completion. Erosion and sediment control practices shall not be located within buffers.
- **Site Disturbance:** Buffers should not be disturbed (e.g., cleared or graded) during construction. Temporary impacts associated with incidental utility construction or mitigation and afforestation projects shall be immediately repaired and stabilized.

Inspection:

- Regular inspections shall be made during the following stages of construction:
 - During initial grading operations to ensure that buffers are clearly marked in the field.
 - Before use and occupancy approval to ensure that permanent stabilization has been established.

Maintenance Criteria:

Buffers shall remain unmanaged other than routine debris removal and repairing areas of concentrated flow. Invasive and noxious plant removal and bi-annual mowing for meadow

Draft 12/14/2007

buffers may be needed. Signs should be maintained and supplemental plantings performed as needed.

Draft 12/14/2007**5.2.3 Using Micro-Scale Practices to Treat Runoff**

Micro-scale practices are small water quality treatment devices used to capture and treat stormwater runoff from discrete impervious areas (e.g., less than one acre). These practices typically include natural systems, vegetation, and soils and may be interconnected to create a more natural drainage system. In many cases, they may resemble the larger structural practices (e.g., infiltration, filters, dry swales) described in Chapter 3. However, the design variants listed below can be distributed throughout a project to provide stormwater management at the source while their structural relatives are typically used as “end-of-pipe” treatment for larger drainage areas.

Micro-scale practice variants include:

- M-1 Rainwater Harvesting
- M-2 Submerged Gravel Wetlands
- M-3 Landscape Infiltration
- M-4 Infiltration Berms
- M-5 Dry Wells
- M-6 Micro-Bioretenention
- M-7 Rain Gardens
- M-8 Swales
- M-9 Enhanced Filters

Draft 12/14/2007**M-1. Rainwater Harvesting (Cisterns and Rain Barrels)**

Rainwater harvesting practices intercept and store rainfall for future use. Stored water may be used for outdoor landscaping irrigation, car washing, or non-potable water supply. The capture and re-use of rainwater promotes conservation, as well as reduces runoff volumes and the discharge of pollutants downstream.

Applications:

Rainwater harvesting can be applied on residential, commercial, municipal, or industrial sites. For small-scale residential applications, rain barrels are typically used to provide storage of rooftop runoff. These systems are generally designed for outdoor use. However, because water demand varies seasonally, other treatment practices may be needed for dewatering during winter months.

Larger storage tanks or cisterns are used in commercial or industrial applications. These systems use the captured rainwater for non-potable water supply, providing a year round constant demand. The complexity of the sizing, installation, and accessories of this type of application make it more realistic for commercial operations. Separate plumbing, pressure tanks, pumps, and backflow preventers are necessary for indoor applications.

Performance:

The pollutant removal capability of rainwater harvesting systems is directly proportional to the amount of runoff captured, stored, and re-used. Therefore, when designed according to the guidance provided below, harvesting will provide treatment for the required WQ_v .

The contributing rooftop area draining to a rain barrel or cistern may be subtracted from the total impervious cover when computing WQ_v . In addition, Re_v requirements may be met only when stored water is used on landscaped areas. Post development CN's for rooftop areas draining to a rainwater storage system may be assumed to be "open space in good condition" when computing Cp_v , Q_p , and Q_f requirements.

Constraints:

The following constraints are critical when considering the use of rainwater harvesting techniques to capture and re-use stormwater runoff:

- **Space:** Lack of space and the presence of surrounding trees can limit the opportunities for rain barrels and cisterns. Leaves and woody debris from overhead trees can clog the storage tanks or attract birds whose droppings may contaminate the tank. Space limitations can be overcome if storage is provided on the roof or underground. The proximity to building foundations also needs to be considered for dewatering and overflow conditions.

Draft 12/14/2007

- **Topography:** Locating storage tanks in low areas may increase the volume of rainwater stored but will require pumping for distribution. To prevent erosion on sloped surfaces, a bermed or concave holding area down gradient can store water for landscape irrigation.
- **Drainage Area:** The drainage area to each storage tank needs to consider year-round water demands. When rain barrels are disconnected to vegetated areas during the non-growing season, the drainage area to each rain barrel needs to be small enough to prevent concentrated flow during dewatering operations.
- **Operation:** Rain barrels and other storage tanks must be operated and maintained throughout the year. This includes any necessary dewatering in between rain events so that the required storage volume is available. Where freezing and ice formation are concerns, rainwater harvesting systems should be located underground or indoors.

Rain barrels are subject to elimination and/or neglect by homeowners. Education is needed to ensure that captured runoff will flow to pervious surfaces and overall system function is sustained.

Design Guidance:

The following conditions should be considered when designing rainwater harvesting systems:

- **Conveyance:** Conveyance to rainwater harvesting storage tank consists of gutters, downspouts, and pipes. A stable discharge shall be provided to pervious areas for any necessary dewatering between storm events. An overflow shall be provided to pass larger storm events. The overflow should be near the top of the storage unit and may consist of plastic hoses or similar materials to direct runoff safely to a stable outfall that causes no problems to down gradient properties.
- **Treatment:** Rainwater harvesting systems shall meet the following conditions:
 - Screens and filters shall be used to remove sediment, leaves, and other debris from runoff for pretreatment and can be installed in the gutter or downspout prior to storage.
 - Rain barrels and cisterns shall be designed to capture and treat the WQ_v .
 - Where rainwater harvesting systems are connected to indoor plumbing, the Re_v requirement shall be addressed separately.
 - The design shall plan for dewatering to vegetated areas.
 - The design of large commercial and industrial storage systems shall be based on water supply and demand calculations. Stormwater management calculations shall include the discharge rate for distribution and demonstrate that captured rainwater will be used prior to the next storm event.
 - Large capacity systems will require dead storage below the outlet and an air gap at the top of the tank. Gravity-fed systems should provide a minimum of six inches of dead storage. For systems using a pump, the dead storage depth will be based on the pump specifications.

Draft 12/14/2007

- **Distribution System:** Most outdoor distribution is gravity fed or can be operated with a pump. For underground tanks or cisterns, a pump, pressure tank, and backflow preventer will be needed.
- **Dewatering:** During the non-growing season, irrigation systems are typically turned off and may need to be dewatered.
- **Observation Wells:** An observation well consisting of an anchored, six-inch diameter perforated pipe is required. The top of the observation well shall be at least six inches above grade.
- **Safety:** Above ground home storage tanks shall have secured openings small enough to prevent child entry. For underground systems, manholes shall be secured to prevent access.
- **Operation:** Rainwater storage designs need to consider the potential for freezing. These systems may need to be located indoors or underground below the frost line if freezing conditions are expected.
- **Mosquitoes:** Screens should be provided to prevent mosquitoes and other insects from entering the tanks.
- **Setbacks:** Overflow devices shall be designed to avoid ponding or soil saturation within 10 ft. of building foundations.

Construction Criteria:

The following should be addressed during construction of projects with rainwater harvesting systems:

- **Site Disturbance:** Underground storage tanks shall be placed on or in native soils. If placement on fill material is necessary, a geotechnical analysis may be needed.
- **Storage Tanks:**
 - Cisterns may be ordered from a manufacturer or constructed on-site. Typical materials used to construct cisterns are fiberglass, wood, metal, or reinforced concrete.
 - Rain barrels can be purchased or custom made from large, plastic (55-gallon) drums.
 - Storage tanks should be designed to be watertight and all materials should be sealed with a water safe, non-toxic substance.
 - Storage tanks shall be protected from direct sunlight and shall be opaque to prevent the growth of algae.
 - The top of underground tanks shall be beneath the frost line.
- **Pressurization:** Depending on the use of stored water, pressurization may be required. To add pressure, a pump or pressure tank can be used.

Draft 12/14/2007

Inspection:

Prior to operation, certification shall be required that the constructed system meets the conditions specified on the approved plans. Additionally, certification regarding the water tightness of the underground storage tank is required after its installation.

Maintenance Criteria:

The following items should be addressed to ensure proper maintenance and long-term performance of rainwater harvesting systems:

- Leaf screens, gutters, and downspouts should be cleaned to prevent clogging. Built-up debris can also foster bacterial growth in gutters or downspouts.
- Storage tank lids and mosquito screens should be inspected and cleaned.
- Damaged components should be replaced as needed.
- To avoid freezing of components, above-ground systems should be disconnected, drained, and cleaned at the start of the Winter season.
- Below-ground system connections should be checked for frozen lines and ice blockages during Winter.
- A manhole shall be provided for cisterns for cleaning, inspection, and maintenance. A drain plug shall also be provided to allow the system to be completely emptied if needed.
- Indoor systems may require more specific maintenance.

Draft 12/14/2007**M-2. Submerged Gravel Wetlands**

A submerged gravel wetland is a small-scale filter using wetland plants in a rock media to provide water quality treatment. Runoff drains into the lowest elevation of the wetland, is distributed throughout the system, and discharges at the surface. Pollutant removal is achieved in a submerged gravel wetland through biological uptake from algae and bacteria growing within the filter media. Wetland plants provide additional nutrient uptake and physical and chemical treatment processes allow filtering and absorption of organic matter.

Applications:

A submerged gravel wetland can be located in limited spaces, typically set aside for site landscaping such as traffic islands or roadway medians. These systems are best suited for Maryland's Eastern Shore or areas where a high water table or poorly drained soils are present. This practice is not recommended for individual lots in a residential subdivision. Depending on individual site soil characteristics, a larger drainage area may be required to maintain saturated conditions within the wetland.

Performance:

When designed according to the guidance provided below, submerged gravel wetlands will provide treatment for the required WQ_v . In some cases Re_v may be met. Because these systems must be designed off-line and the contributing drainage areas are larger, other practices may be needed to address Cp_v and Q_p .

Constraints:

The following constraints are critical when considering the use of submerged gravel wetlands to capture and treat stormwater runoff:

- **Space:** Additional space is needed for pretreatment measures to prevent sediment or debris from entering and clogging the gravel bed.
- **Topography:** While surrounding local slopes should be relatively flat (<2%), there needs to be sufficient elevation drop to maintain positive drainage to and through the filter media.
- **Soils:** The HSG should be C or D. A high groundwater table, hard pan, or other confining layer should be present to maintain submerged flow conditions.
- **Drainage Area:** The drainage area should be large enough (e.g., one acre) to maintain submerged flow conditions.
- **Hotspot Runoff:** Submerged gravel wetlands should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that may contaminate groundwater.

Draft 12/14/2007

- **Wetland Vegetation Establishment:** Use of native wetland plant stock obtained from a local aquatic plant nursery is recommended for establishing vegetation. Design variations may use wetland mulch or topsoil on top of the gravel, which may allow for successful seed germination. However, use of the rock media for establishing wetland conditions requires specific planting stock. Frequent inspection and maintenance will be necessary until wetland plantings are well established.

Design Guidance:

The following conditions should be considered when designing submerged gravel wetlands:

- **Conveyance:** Pretreated stormwater enters via piped or overland flow and discharges into the gravel-filled chamber. A perforated pipe (4 to 6-inch preferred) at the base of the gravel layer allows for flow-through conditions and maintains a constant water surface elevation. Discharges that exceed the WQ_v exit to a stable outfall at non-erosive velocities. These systems should be located off-line.
- **Treatment:** Submerged gravel wetlands shall meet the following conditions:
 - Pretreatment shall be provided for 10% of the total WQ_v . An above-ground forebay area or below ground pretreatment chamber may be used.
 - Storage for 75% of WQ_v for the entire drainage area contributing to the wetland shall be provided. Temporary storage of WQ_v may be provided above the gravel bed. Temporary ponding depth shall not be greater than the tolerance levels of the wetland vegetation.
 - Storage calculations shall account for the porosity of the gravel media.
 - The gravel substrate shall be no deeper than four feet.
 - Surface area requirements for stormwater wetlands in Chapter 3 do not apply to this practice because pollutant removal primarily takes place within the enhanced surface area of the rock media.
- **Flow Splitter:** A flow splitter should be provided to divert the WQ_v to the submerged gravel wetland (see Details No. 5 and No. 6, Appendix D.8).
- **Treatment Cells:** Multiple treatment cells are optional and may be separated by earth berms.
- **Observation Wells:** An observation well consisting of an anchored, six-inch diameter perforated pipe is required. The top of the observation well shall be at least six inches above grade.
- **Landscaping:** A minimum of three different types of wetland species is required and replacement plantings may be necessary.

Draft 12/14/2007

Construction Criteria:

The following items should be addressed during the construction of projects with submerged gravel wetlands:

- **Site Disturbance:** All on-site disturbed areas shall be stabilized prior to allowing runoff to enter the newly constructed wetland.
- **Erosion and Sediment Control:** The proposed location of a submerged gravel wetland must be protected during construction. Surface runoff must be diverted away from the practice during grading operations. Flow splitters and other conveyance infrastructure shall be blocked.

Wetland construction shall be performed with lightweight, wide-tracked equipment to minimize disturbance and compaction. Excavated materials shall be placed in a contained area. Any pumping operations shall discharge filtered water to a stable outlet.

- **Gravel Media:** The aggregate shall be composed of an 18 to 48 inch layer of clean washed, uniformly graded material with a porosity of 40%. Rounded bank run gravel is recommended.

Inspection:

- Regular inspections shall be made during the following stages of construction:
 - During excavation to sub-grade.
 - During placement of backfill of perforated inlet pipe and observation wells.
 - During placement of geotextiles and all filter media.
 - During construction of any appurtenant conveyance systems such as diversion structures, inlets, outlets, and flow distribution structures.
 - Upon completion of final grading and establishment of permanent stabilization.

Maintenance Criteria:

The following items should be addressed to ensure proper maintenance and long-term performance of submerged gravel wetlands:

- During the first year of operation, inspections should be conducted after every major storm and poorly established areas revegetated.
- Sediment accumulation in the pretreatment areas should be removed as necessary.
- Signs of uneven flow distribution within the wetland may mean that the gravel or underdrain is clogged. The gravel and/or underdrain may need to be removed, cleaned, and replaced.

Draft 12/14/2007

- A dense stand of wetland vegetation should be maintained through the life of the facility with plantings replaced as needed.
- Inlets and outlets to each submerged gravel wetland cell should be free from debris to prevent clogging.
- Erosion at inflow points should be repaired. Flow splitters should be functional to prevent bypassing of the facility.

Draft 12/14/2007**M-3. Landscape Infiltration**

Landscape infiltration utilizes on-site vegetative planting areas to capture, store, and treat stormwater runoff. Rainwater is stored initially, filters through the planting soil and gravel media below, and then infiltrates into native soils. These practices can be integrated within the overall site design by utilizing a variety of landscape features for storage and treatment of stormwater runoff. Storage may be provided in constructed planters made of stone, brick, concrete, or in natural areas excavated and backfilled with stone and topsoil.

Applications:

Landscape infiltration can be best implemented in residential and commercial land uses. Residential areas with compact housing such as clustered homes and townhouses, can utilize small green spaces for landscape infiltration. Because space in these instances prevents structural pretreatment, the drainage area to these practices should be limited to less than 10,000 ft². Larger drainage areas may be allowed where soil testing is performed and pretreatment forebays can be implemented. Successful application is dependent upon soil type and groundwater elevation.

Performance:

When designed according to the guidance provided below, landscape infiltration will provide treatment for the required WQ_v and Re_v . Post-development CN's for areas served by landscape infiltration may be assumed to be "open space in good condition" when computing Cp_v , Q_p , and Q_f requirements.

Constraints:

The following constraints are critical when considering the use of landscape infiltration to capture and treat stormwater runoff:

- **Space:** Landscape infiltration should not be used in areas where operation may create a risk for basement flooding, interfere with the operation of subsurface sewage disposal systems, or other underground structures. The initial site planning process shall consider landscaping opportunities where these practices may be implemented.
- **Topography:** Steep terrain affects the successful performance of landscape infiltration. These practices should be constructed without a slope. If slopes entering these practices are too steep, then level-spreading devices such as check dams, terraces, or berms may be needed to maintain sheetflow.
- **Soils:** Permeable soils are critical to the successful application of landscape infiltration. The HSG should be A or B.

Draft 12/14/2007

- **Drainage Area:** Drainage areas less than 10,000 ft² are most appropriate for landscape infiltration. Larger drainage areas may require pretreatment and soils testing to verify the infiltration rates.
- **Hotspot Runoff:** Landscape infiltration should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that may contaminate groundwater.
- **Infrastructure:** Landscape designers should consider overhead electrical and telecommunication lines when selecting plant materials.

Design Guidance:

The following conditions should be considered when designing landscape infiltration:

- **Conveyance:** Stormwater runoff is collected in landscaped areas where water will sheetflow across the facility, percolate through the planting media, and infiltrate into underlying soils. A flow splitter should be used to divert runoff in excess of the WQ_v away from the facility at non-erosive velocities to a stable, downstream conveyance system. If bypassing the practice is not feasible, an internal overflow device such as an elevated yard inlet may be used.
- **Treatment:** Landscape infiltration shall meet the following design criteria:
 - The drainage area to any individual practice shall be 10,000 ft² or less.
 - Pretreatment measures should be implemented where feasible along the main stormwater runoff collection system. These include installing gutter screens, a removable filter screen on rooftop downspout pipes, a sand layer or pea gravel diaphragm at the inflow, or a two to three-inch surface mulch layer.
 - The landscape infiltration facility shall be designed to capture and treat the WQ_v. Temporary storage of the WQ_v may be provided above the facility.
 - Underlying soils should allow infiltration into the ground within 48 hours.
 - A 12 to 18-inch layer of planting soil shall be provided as a filtering media at the top of the facility.
 - A minimum 12-inch layer of gravel is required below the planting soil.
 - A one-foot layer of clean sand is required at the bottom to allow for a bridging medium between the existing soils and stone within the bed.
 - The storage area for the WQ_v is determined for the entire system and includes the temporary ponding area, the soil, and the sand and gravel layers in the bottom of the facility. Storage calculations shall account for the porosity of the gravel and soil media.
- **Soils:** Landscape infiltration should be installed in HSG A or B. The depth from the bottom of the facility to the seasonal high water table, bedrock, hard pan, or other confining layer shall be greater than or equal to four feet (two feet on the lower Eastern Shore).

Draft 12/14/2007

- **Flow Splitter:** A flow splitter should be provided to divert excess runoff away from landscape infiltration. An elevated yard inlet may also be used in the facility for this purpose.
- **Setbacks:**
 - Landscape infiltration shall be located down gradient of building structures and shall be setback at least 10 feet from buildings, 50 feet from confined water supply wells, 100 feet from unconfined water supply wells, and 25 feet from septic systems.
 - Landscape infiltration should be sized and located to meet minimum local requirements for clearance from underground utilities.
- **Observation Wells:** An observation well consisting of an anchored, six-inch diameter perforated pipe is required. The top of the observation well shall be at least six inches above grade.
- **Landscaping:** Landscaping plans shall be provided according to the guidance in Appendix A. Plant tolerance to saturated and inundated conditions shall be considered as part of the design. A dense and diverse planting plan will provide an aesthetically pleasing design, which will enhance property value and community acceptance.

Construction Criteria:

The following items should be addressed during construction of projects with landscape infiltration:

- **Erosion and Sediment Control:** Final grading for landscape infiltration shall not take place until the surrounding site is stabilized. If this cannot be accomplished, runoff from disturbed areas should be diverted around the proposed location of the facility.
- **Soil Compaction:** Construction of the landscape infiltration facility shall be performed with lightweight, wide-tracked equipment to minimize disturbance and compaction. Excavated materials shall be placed in a contained area.
- **Planter Boxes:** Planters boxes may be made of stone, brick, or concrete.
- **Filter Cloth:** Landscape infiltration may be constructed as an excavated trench in natural ground and backfilled with sand, gravel, and planting soil. These applications should use non-woven filter cloth to line the sides of the facility to prevent clogging. Filter cloth shall not be installed on the bottom of the practice.
- **Gravel and Filter Media:** See Appendix B.4.B. for material specifications for the sand, gravel, and planting soil media.
- **Landscape Installation:** The optimum planting time is during the autumn months. Spring is also acceptable but may require watering.

Draft 12/14/2007

Inspection:

- Regular inspections shall be made during the following stages of construction:
 - During excavation to subgrade.
 - During placement of backfill and observation well.
 - During placement of filter fabric, soil, and gravel media.
 - During construction of appurtenant conveyance structures.
 - Upon completion of final grading and establishment of permanent stabilization.

Maintenance Criteria:

The following items should be addressed to ensure proper maintenance and long-term performance of landscape infiltration:

- During the first year of operation, inspection frequency should be after every major storm and poorly established areas revegetated.
- Sediment accumulation on the surface of the facility should be removed and the top two to three inches of surface layer replaced as needed.
- The top few inches of the planting soil should be removed and replaced when water ponds for more than 48 hours or there is algal growth on the surface of the facility.
- If standing water persists after filter media has been maintained, the gravel, soil, and sand may need to be removed, cleaned, and replaced.
- Occasional pruning and replacement of dead vegetation is necessary. If specific plants are not surviving, more appropriate species should be used. Watering may be required during prolonged dry periods.

Draft 12/14/2007**M-4. Infiltration Berms**

An infiltration berm is a mound of earth composed of soil and stone that is placed along the contour of a relatively gentle slope. This practice may be constructed by excavating upslope material to create a depression and storage area above a berm or earth dike. Stormwater runoff flowing downslope to the depressed area filters through the berm in order to maintain sheetflow. Infiltration berms should be used in conjunction with practices that require sheetflow (e.g., sheetflow to buffers) or in a series on steeper slopes to prevent flow concentration.

Application:

Infiltration berms may be used on gently sloping areas in residential, commercial, open space, or wooded land use conditions. They must be installed along the contour in order to perform effectively. The purpose of this practice is to augment natural stormwater drainage functions in the landscape by promoting sheetflow and dissipating runoff velocities.

Performance:

These berms do not provide sufficient storage to meet the WQ_v requirements. They may, however, be incorporated into the design of other practices such as micro-bioretenion, rain gardens, or landscape infiltration to enhance pollutant removal. Calculations may be submitted on a case-by-case basis to show that the required Re_v storage is provided. Cp_v and Q_p shall be addressed separately.

Constraints:

The following constraints are critical when considering the use of infiltration berms to treat stormwater runoff:

- **Space:** The presence of large trees may limit the use of infiltration berms along a hillside. Berms may be threaded carefully along the contour of wooded slopes in order to avoid disturbing existing vegetation.
- **Topography:** Infiltration berms shall not be installed on slopes greater than 10% to prevent erosion at the upstream toe of the berm.
- **Soils:** Infiltration berms shall not be installed on slopes where soils have low shear strength (or identified as “slope prone” or “landslide prone”).
- **Drainage Area:** The drainage area shall be small enough to prevent flow concentration upslope of the berm.
- **Hotspot Runoff:** When infiltration berms are designed in conjunction with other infiltration practices, they should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that may contaminate groundwater.

Draft 12/14/2007

- **Storage Capacity:** Infiltration berms have relatively limited capacity to meet WQ_v requirements as a stand-alone practice. They may provide storage for pretreatment, address Re_v , or be incorporated within the design of other practices.

Design Guidance:

The following conditions should be considered when designing infiltration berms:

- **Conveyance:** Stormwater runoff from impervious areas is intercepted by infiltration berms that are placed on the contour to prevent erosive, concentrated runoff patterns. Runoff flows to a depressed area immediately above the berm where velocities are reduced, stormwater flows through the berm, and sheetflows downslope. Stormwater discharges greater than the two-year, 24 hour design storm should flow over the crest of the berm at non-erosive velocities.
- **Treatment:** Infiltration berms shall meet the following conditions:
 - A maximum berm height of 24 inches is recommended to prevent excessive ponding.
 - Berms shall be installed along the contour at a constant elevation and be level.
 - A berm will consist of a six-inch layer of compacted topsoil with a gravel or aggregate interior.
 - Side slopes should be very shallow and a ratio of 3:1 is recommended for mowed berms. The design shall consider soils suitable to resist slope failure and slumping.
 - When used in a series along a slope, the elevation at the downstream toe of each berm shall be the same elevation as the crest of the next berm downslope.
 - The berm shall be graded so that a concave shape is provided at the up gradient toe.
 - The crest of the berm shall be asymmetric in shape and should be two feet wide.
 - Velocities for the two-year, 24 hour storm event shall be non-erosive.
 - The storage volume created behind and up to the crest of the berm may be used for pretreatment or Re_v requirements.
- **Soils:** Subsurface soils shall be uncompacted and may need to be scarified in order to encourage infiltration.
- **Plant Materials:** Berms should be planted with native meadow vegetation, shrubs, and trees. Turf grass may be used on berms that are to be mown.

Construction Criteria:

The following items should be addressed during construction of projects with infiltration berms:

- **Erosion and Sediment Control:** Final grading for landscape berms shall not take place until the surrounding site is stabilized. If this cannot be accomplished, runoff from disturbed areas should be diverted around proposed locations.

Draft 12/14/2007

- **Soil Compaction:** Existing soils in the location of proposed berms should be scarified to maximize infiltration. Construction shall be performed with lightweight, wide-tracked equipment to minimize disturbance and compaction.
- **Gravel and Soil Media:** See Appendix B.4.B for material specification for the gravel and planting soil media.
- **Landscape Installation:** The optimum planting time is during the autumn months. Spring is also acceptable but may require watering.
- **Implementation with Other Practices:** When infiltration berms are incorporated into a system with other practices, the Construction Criteria for that practice should be used.

Inspection:

- Regular inspections shall be made during the following stages of construction:
 - During placement of filter fabric, gravel media, and soil.
 - Upon completion of final grading and establishment of permanent stabilization.

Maintenance Criteria:

The following items should be addressed to ensure proper maintenance and long-term performance of infiltration berms:

- Berms should be inspected regularly to ensure ponding water does not create nuisance conditions.
- Signs of concentrated flow and other surface erosion should be repaired to promote sheetflow.
- A dense mat of vegetation should be present at all times. Vegetation should be replaced as needed.
- When infiltration berms are incorporated in a system with other practices, the Maintenance Criteria for that practice should be used.

Draft 12/14/2007**M-5. Dry Wells**

A dry well is an excavated pit or structural chamber filled with gravel or stone and provides temporary storage of stormwater runoff from rooftops. The storage area may be constructed as a shallow trench or a deep well. Rooftop runoff is directed to these storage areas and infiltrates into the surrounding soils prior to the next storm event. The pollutant removal capability of dry wells is directly proportional to the amount of runoff that is stored and allowed to infiltrate.

Applications:

Dry wells can be used in both residential and commercial sites and are best suited for treating runoff from small drainage areas such as a single rooftop or downspout. Dry wells are not appropriate for treating runoff from large impervious areas such as a parking lot. Successful application is dependent upon soil type and groundwater elevation.

Performance:

When designed according to the guidance provided below, dry wells will provide treatment for the required WQ_v and Re_v . Post-development CN's for areas served by a dry well may be assumed to be "open space in good condition" when computing Cp_v , Q_p , and Q_f requirements.

Constraints:

The following constraints are critical when considering the use of dry wells to capture and infiltrate stormwater runoff:

- **Space:** Dry wells should not be used in areas where their operation may create a risk for basement flooding, interfere with the operation of subsurface sewage disposal systems, or affect other underground structures. There are limited opportunities for dry well implementation in high-density neighborhoods.
- **Topography:** Steep terrain affects the successful performance of a dry well. Installation on slopes greater than 20% should be avoided.
- **Soils:** Permeable soils are critical to the successful application of dry wells. The HSG should be A or B.
- **Drainage Area:** Small drainage areas (e.g., 500 ft²) are most appropriate for dry well applications.
- **Hotspot Runoff:** Dry wells should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that may contaminate groundwater.

Draft 12/14/2007

- **Operation:** Dry wells are subject to neglect by homeowners. Education is needed to ensure that proper maintenance will allow the system to continue to function properly.

Design Guidance:

The following conditions should be considered when designing dry wells:

- **Conveyance:** Rooftop runoff is collected through gutters and downspouts and discharged directly into a dry well. The downspout extends underground and across the entire length of a dry well. An overflow pipe is also installed to pass excess runoff generated from larger storms. Discharge from the overflow shall be directed to an above ground splash pad and conveyed in a non-erosive manner to a stable outfall.
- **Treatment:** Dry wells shall meet the following conditions:
 - Pretreatment measures shall be installed to allow filtering of sediment, leaves, or other debris. This may be done by providing gutter screens and a removable filter screen installed within the downspout pipe. The removable filter screen should be installed below the overflow outlet and easily removed so that homeowners can clean the filter.
 - A dry well shall be designed to capture and store the WQ_v . The storage area for the WQ_v includes the sand and gravel layers in the bottom of the facility. Storage calculations shall account for the porosity of the gravel and sand media.
 - The drainage area should be small enough to allow infiltration into the ground within 48 hours (e.g., 500 ft² to each downspout).
 - Storage depths greater than 4.5 ft. are not recommended due to soil compaction.
 - The length of a dry well should be longer than the width to ensure proper water distribution and maximize infiltration.
 - A one-foot layer of clean sand is required in the bottom of a dry well to allow for bridging between the existing soils and trench gravel.
- **Soils:** Dry wells should be installed in HSG A or B. The depth from the bottom of a dry well to the seasonal high water table, bedrock, hard pan, or other confining layer shall be greater than or equal to four feet (two feet on the lower Eastern Shore).
- **Setbacks:**
 - Dry wells shall be located down gradient of building structures and shall be setback at least 10 feet from buildings, 50 feet from confined water supply wells, 100 feet from unconfined water supply wells, and 25 feet from septic systems.
 - Dry wells are required to be setback a minimum of 100 feet from slopes of 15% and 200 feet from slopes of 25%.
- **Observation Wells:** An observation well consisting of an anchored, six-inch diameter perforated pipe is required. The top of the observation well shall be at least six inches above grade.

Draft 12/14/2007

- **Underground Distribution Pipe:** This pipe (4 to 6 inch diameter) will be perforated to fill the trench along its entire length.
- **Landscaping:** A minimum one-foot of soil cover shall be provided from the top of the trench to the ground surface elevation. The soil should be stabilized with a dense cover of vegetation. In areas where frost heave is a concern, soil cover may need to be as much as four feet. In these cases, a geotechnical engineer should be consulted.

Construction Criteria

The following items should be addressed during construction of projects with dry wells:

- **Erosion and Sediment Control:** Final grading for proposed dry wells shall not take place until the surrounding site is completely stabilized. If this cannot be accomplished, runoff from disturbed areas should be diverted away.
- **Soil Compaction:** Construction of a dry well shall be performed with lightweight, wide-tracked equipment to minimize disturbance and compaction. Excavated materials shall be placed in a contained area.
- **Underground Chamber:** A subsurface prefabricated chamber may be used.
- **Dry Well Bottom:** The bottom shall be as level as possible to minimize pooled water in small areas that may reduce overall infiltration and longevity.
- **Filter Cloth:** Non-woven filter cloth should be used to line the top and sides of the dry well to prevent the pore space between the stones from being blocked by the surrounding native material. Filter cloth shall not be installed on the bottom of the well.
- **Gravel Media:** The aggregate shall be composed of an 18 to 48-inch layer of clean washed, uniformly graded material with 40% void capacity. Rounded bank run gravel is recommended.

Inspection:

- Regular inspections shall be made during the following stages of construction:
 - During excavation to subgrade.
 - During placement of backfill of perforated inlet pipe and observation well.
 - During placement of geotextiles and all filter media.
 - During construction of appurtenant conveyance.
 - Upon completion of final grading and establishment of permanent stabilization.

Draft 12/14/2007

Maintenance Criteria:

The following items should be addressed to ensure proper maintenance and long-term performance of dry wells:

- Privately owned practices must have a maintenance plan and shall be protected by easement, deed restriction, ordinance, or other legal measures preventing its neglect, adverse alteration, and removal.
- Dry wells shall be inspected and cleaned annually. This includes pipes, gutters, downspouts, and all filters.
- Ponding, standing water, or algal growth on the top of a dry well may indicate failure due to sedimentation in the gravel media. If water ponds for more than 48 hours after a major storm or more than six inches of sediment has accumulated, the gravel media should be excavated and replaced.

Draft 12/14/2007

M-6. Micro-Bioretenention

Micro-bioretenention practices capture and treat runoff from discrete impervious areas by passing it through a filter bed mixture of sand, soil, and organic matter. Filtered stormwater is either returned to the conveyance system or partially infiltrated into the soil. Micro-bioretenention practices are versatile and may be adapted for use anywhere there is landscaping.

Applications:

Micro-bioretenention is a multi-functional practice that can be easily adapted for new and redevelopment applications in commercial and industrial projects. Stormwater runoff is stored temporarily and filtered in landscaped facilities shaped to take runoff from various sized impervious areas. Micro-bioretenention provides water quality treatment, aesthetic value, and can be applied as concave parking lot islands, linear roadway or median filters, terraced slope facilities, residential cul-de-sac islands, and ultra-urban planter boxes.

Performance:

When designed according to the guidance below, micro-bioretenention practices will provide treatment for the required WQ_v . These practices may also be used to address Re_v if designed to infiltrate (e.g., enhanced filter). Post-development CN 's for impervious areas treated using micro-bioretenention practices may be assumed to be "open space in good condition" when computing Cp_v requirements.

Constraints:

The following constraints are critical when considering the use of micro-bioretenention to capture and treat stormwater runoff:

- **Space:** The surface area of a typical micro-bioretenention filter is dependent on the area of the contributing imperviousness. The size and distribution of open areas within a project (e.g., parking lot islands, landscaped areas) must be considered early during a project's planning and design if these practices are considered.
- **Topography:** Slopes of contributing areas and filter beds should be gradual ($< 5\%$). If slopes are too steep, then level-spreading devices may be needed to redistribute flow prior to filtering. If slopes within micro-bioretenention practice are too steep, then a series of check dams, terraces, or berms may be needed to maintain sheetflow internally.

There should also be an elevation difference between the inflow and outflow of a micro-bioretenention practice to allow flow through the filter. This difference is critical when designing downstream conveyance systems (e.g., grass channels, storm drains).

- **Soils:** Soil conditions are a crucial determining factor for micro-bioretenention because specific applications will be affected. When located in sandier soils, these practices may be

Draft 12/14/2007

used to promote recharge (see M-3, Landscape Infiltration). If clayey soils are encountered, an underdrain system may be needed to convey water downstream. Also, elevated groundwater may limit filter bed thickness and excavated applications.

Subsurface water conditions (e.g., water table) will help determine the thickness of filter beds used. The probability of practice failure increases if the filter bed intercepts groundwater. Therefore, micro-bioretenction practice inverts should be above local groundwater tables.

- **Drainage Area:** The drainage area to micro-bioretenction practices should be limited. As the impervious area draining to each practice exceeds ½ acre, practice effectiveness weakens and larger systems designed according to Chapter 3 should be considered.
- **Hotspot Runoff:** Micro-bioretenction practices that are designed to promote infiltration of runoff into the ground should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that may contaminate groundwater.
- **Infrastructure:** The location of existing and proposed buildings and utilities (e.g., water supply wells, sewer, storm drains, electricity) will influence the design and construction of micro-bioretenction. Landscape designers should also consider overhead electrical and telecommunication lines when selecting trees to be planted.

Design Guidance:

The following conditions should be considered when designing micro-bioretenction practices:

- **Conveyance:** Micro-bioretenction systems should be designed off-line whenever possible. A flow splitter should be used to divert excess runoff away from the filter media to a stable, downstream conveyance system. If bypassing a micro-bioretenction practice is impractical, an internal overflow device (e.g., elevated yard inlet) may be used.

Runoff shall enter, flow through, and exit micro-bioretenction practices in a safe and non-erosive manner. Inflow may be through depressed curbs with wheel stops, curb cuts, or conveyed directly using downspouts, covered drains, or catch basins. Depending on site layout and the size and shape of the impervious area being treated, overflow structures should be located to maximize internal flow paths through the filter media. An underdrain system may be necessary to discharge treated stormwater safely downstream. Underdrains may be interconnected to other micro-scale practices as part of a treatment system or directly to the storm drain.

Draft 12/14/2007

- **Treatment:** Micro-bioretentation practices shall meet the following conditions:
 - The drainage area to any individual practice shall be 20,000 ft² or less.
 - Micro-bioretentation practices shall capture and store at least 75% of the WQ_v.
 - The filter bed surface area (ft²) shall be at least 10% of the impervious drainage area and the surface ponding depth 12 inches or less.
 - Filter beds should be between 24 and 48 inches deep.
 - Filter beds should not intercept groundwater. If designed as infiltration practices, filter bed inverts shall be separated at least four feet vertically (two feet on the lower Eastern shore) from the seasonal high water table.
 - A surface mulch layer (maximum 2 to 3 inches thick) should be provided to enhance plant survival and inhibit weed growth.
 - The filtering media, mulch, and underdrain systems shall conform to the specifications found in Appendix B.4.
- **Setbacks:**
 - Micro-bioretentation practices should be located down gradient and setback at least 10 feet from structures. Micro-bioretentation variants (e.g., planter boxes) that must be located adjacent to structures should include an impermeable liner.
 - Micro-bioretentation practices shall be located at least 30 feet from water supply wells and 25 feet from septic systems. If designed to infiltrate, then the practice shall be located at least 50 feet from confined water supply wells and 100 feet from unconfined water supply wells.
 - Micro-bioretentation practices should be sized and located to meet minimum local requirements for clearance from underground utilities.
 - Any trees planted in micro-bioretentation practices shall be located to avoid future problems with overhead electrical and telecommunication lines.
- **Landscaping:** Vegetation is critical to the function and appearance of any micro-bioretentation system. Therefore, landscaping plans shall be provided according to the guidance in Appendix A. Native and adapted plants are preferred, hardier, and usually require minimal nutrient or pesticide application. Also, aesthetically pleasing landscape designs generally enhance property value and community acceptance.

Construction Criteria:

The following items should be addressed during construction of projects with micro-bioretentation:

- **Erosion and Sediment Control:** Micro-bioretentation practices should not be constructed until the contributing drainage area is stabilized. If this is impractical, runoff from disturbed areas should be diverted away and no sediment control practices should be used near the proposed location.

Draft 12/14/2007

- **Soil Compaction:** Excavation should be conducted in dry conditions with equipment located outside of the practice to minimize bottom and sidewall compaction. Only lightweight, low ground-contact equipment should be used within micro-bioretenction practices and the bottom scarified before installing underdrains and filtering media.
- **Underdrain Installation:** Gravel for the underdrain system should be clean, washed, and free of fines. Underdrain pipe should be checked to ensure that both the material and perforations meet specifications. The upstream ends of the underdrain pipe should be capped prior to installation
- **Filter Media Installation:** Bioretention soils may be mixed on-site before placement. However, soils should not be placed under saturated conditions. The filter media should be placed and graded using excavators or backhoes operating adjacent to the practice and be placed in horizontal layers (12 inches per lift maximum). Proper compaction of the media will occur naturally. Spraying or sprinkling water on each lift until saturated may quicken settling times.
- **Landscape Installation:** The optimum planting time is during the autumn months. Spring planting is also acceptable but may require watering.

Inspection:

- Regular inspections shall be made during the following stages of construction:
 - During excavation to subgrade and placement and backfill of underdrain systems.
 - During placement of filter media.
 - During construction of appurtenant conveyance.
 - Upon completion of final grading and establishment of permanent stabilization.

Maintenance Criteria:

The following items should be addressed to ensure proper maintenance and long-term performance of micro-bioretenction practices:

- The top few inches of filter media should be removed and replaced when water ponds for more than 48 hours. Silts and sediment should be removed from the surface of the filter bed when accumulation exceeds one inch.
- Where practices are used to treat areas with higher concentrations of heavy metals (e.g., parking lots, roads), mulch should be replaced annually. Otherwise, the top two to three inches should be replaced as necessary.
- Occasional pruning and replacement of dead vegetation is necessary. If specific plants are not surviving, more appropriate species should be used. Watering may be required during prolonged dry periods.

Draft 12/14/2007**M-7. Rain Gardens**

A rain garden is a shallow, excavated landscape feature or a saucer-shaped depression that temporarily holds runoff for a short period of time. Rain gardens typically consist of an absorbent-planted soil bed; a mulch layer; a gravel filter chamber; and planting materials such as shrubs, grasses, and flowers. An overflow conveyance system is included to pass larger storms. Captured runoff from downspouts, roof drains, pipes, swales, or curb openings temporarily ponds and slowly filters into the soil over 24 to 72 hours.

Applications:

Rain gardens can be primary or secondary practices on residential, commercial, industrial, or institutional sites. This practice is typically used to treat runoff from small impervious areas like rooftops, driveways, and sidewalks. Rain gardens can also be used in retrofitting and redevelopment applications and in series where existing slopes require energy dissipation.

Performance:

When designed according to the guidance below, the contributing impervious area may be subtracted from total impervious cover when calculating WQ_v . This practice also may be used to address Re_v . Post development CN's for areas served by rain gardens may be assumed to be "open space in good condition" when computing Cp_v , Q_p , and Q_f requirements.

Constraints:

The following constraints are critical when considering the use of rain gardens to capture and treat stormwater runoff:

- **Topography:** Rain gardens require relatively flat slopes ($< 5\%$) to accommodate runoff filtering through the system. Some design modifications can address this constraint through the use of infiltration berms, terracing, and timber or block retaining walls on moderate slopes.
- **Soils:** Clayey soils or soils that have been compacted by construction equipment greatly reduce the effectiveness of this practice. Loosening of the compacted soils may improve drainage capability.
- **Drainage Area:** The drainage area to a rain garden should be relatively small. A single rain garden should be designed to receive flow from a drainage area equal to or less than 2,000 ft^2 .
- **Infrastructure:** The location of existing and proposed buildings and utilities (e.g., water supply wells, sewer, storm drains, electricity) will influence rain garden design and construction. Landscape designers should also consider overhead electrical and telecommunication lines when selecting trees to be planted.

Draft 12/14/2007

➤ **Location:**

- Lot by lot use is not recommended in residential subdivisions due to removal by homeowners.
- Rain garden excavation in areas with heavy tree cover may damage adjacent tree root systems.

Design Guidance:

The following conditions should be considered when designing rain gardens:

- **Conveyance:** Conveyance to and from a rain garden shall ensure non-erosive conditions. Energy dissipation shall be provided for downspout discharges using a plunge area, rocks, splash blocks, stone dams, etc. Runoff shall enter a rain garden at the surface through grass swales and/or a gravel bed. A minimum internal slope of one percent should be maintained and a shallow berm surrounding the rain garden is recommended to avoid short-circuiting. For sloped applications, a series of rain gardens can be used as “scalloped” terraces to convey water non-erosively.
- **Treatment:** Rain gardens shall meet the following conditions:
- The drainage area to a rain garden serving a single lot in a residential subdivision shall be 2,000 ft² or less. The maximum drainage area to a rain garden for all other applications is 10,000 ft². Micro-bioretenion (M-6) or bioretention (F-6) should be considered when these requirements are exceeded.
 - Rain gardens shall capture and store at least 75% of the WQ_v.
 - Excavated rain gardens work best where HSG A and B are prevalent. In areas of HSG C and D, at-grade applications should be considered.
 - A minimum six to twelve-inch layer of planting soil shall be placed at the invert.
 - A mulch layer two to three inches deep shall be applied to the planting soil to maintain soil moisture and to prevent premature clogging.
 - The planting soil and mulch shall conform to the specifications found in Appendix B.4.
- **Landscaping:** A rain garden should be located in full to partial sun, at least two feet above the seasonal high water table and be 12 to 18 inches deep. Landscaping plans shall clearly specify how vegetation will be established and managed. Plants selected for use in a rain garden should tolerate both saturated and dry conditions and are native or adapted to Maryland. Neatly trimmed shrubs, a crisp lawn edge, stone retaining walls, and other devices can be used to keep a rain garden neat and visually appealing.

Draft 12/14/2007

Construction Criteria:

The following items should be addressed during the construction of projects with rain gardens:

- **Erosion and Sediment Control:** Rain gardens should not be constructed until the contributing drainage area is stabilized. During construction, runoff should be diverted away and the use of heavy equipment avoided to minimize compaction.
- **Planting Soil:** Planting soil should be mixed on-site prior to installation. If poor soils are encountered beneath the rain garden, a four-inch layer of washed gravel ($\frac{1}{8}$ to $\frac{3}{8}$ inch gravel preferred) may be used below the planting soil mix.
- **Landscape Installation:** The optimum planting time is during autumn months. Spring planting is also acceptable but may require watering.

Inspection:

- Regular inspections shall be made during the following stages of construction:
 - During excavation to subgrade and placement of planting soil.
 - Upon completion of final grading and establishment of permanent stabilization.

Maintenance Criteria: The following items should be addressed to ensure proper maintenance and long-term performance of rain gardens:

- Rain garden maintenance is generally no different than that required of other landscaped areas.
- Privately owned practices must have a maintenance plan and shall be protected by easement, deed restriction, ordinance, or other legal measures preventing its neglect, adverse alteration, and removal.
- The top few inches of the planting soil should be removed and replaced when water ponds for more than 48 hours. Silts and sediment should be removed from the surface of the bed as needed.
- Where practices are used to treat areas with higher concentrations of heavy metals (e.g., parking lots, roads), mulch should be replaced annually. Otherwise, the top two to three inches should be replaced as necessary.
- Occasional pruning and replacement of dead vegetation is necessary. If specific plants are not surviving, more appropriate species should be used. Watering may be required during prolonged dry periods.

Draft 12/14/2007**M-8. Swales**

Swales are channels that provide conveyance, water quality treatment, and flow attenuation of stormwater runoff. Swales provide pollutant removal through vegetative filtering, sedimentation, biological uptake, and infiltration into the underlying soil media. Three design variants covered in this section include grass swales, wet swales, and bio-swales. Implementation of each is dependent upon site soils, topography, and drainage characteristics.

Applications:

Swales can be used for primary or secondary treatment on residential, commercial, industrial, or institutional sites. Swales can also be used for retrofitting and redevelopment. The linear structure allows use in place of curb and gutter along highways, residential roadways, and along property boundaries. Wet swales are ideal for treating highway runoff in low-lying or flat terrain with high groundwater. Bio-swales can be used in all soil types due to the use of an underdrain. Grass swales are best suited along highway and roadway projects.

Performance:

When designed according to the guidance provided below, swales will provide treatment for the required WQ_v within dry or wet cells formed by check dams or other similar structures. They may also be used to meet Re_v requirements depending on the soil conditions and the design variant chosen. The contributing impervious area may be subtracted from total impervious cover when calculating WQ_v .

Swales should not be designed to meet Cp_v , Q_p , or Q_f requirements except under extremely unusual conditions. Swales may be used to convey runoff for these larger storm events, however, the WQ_v should be treated separately. This can be accomplished with a flow splitter or diversion so that the entire design storm is passed safely.

Constraints:

The following constraints are critical when considering the use of swales to capture and treat stormwater runoff.

- **Topography:** Care should be taken when using swales in rugged terrain. Steep slopes will increase velocity, erosion, and sediment deposition thus shortening the design life of the swale.
- **Soils:** Design variants are dependent upon soil types. Grass swales work best in HSG A or B and wet swales are best suited for HSG C or D. Bio-swales typically include an underdrain and may be installed in all soil types. Extreme temperatures and frozen ground need to be considered when calculating design volumes.

Draft 12/14/2007

- **Drainage Area:** The drainage area contributing to all design variants should be less than $\frac{1}{2}$ acre. Larger drainage areas should be subdivided or the practices in Chapter 3 considered.
- **Hotspot Runoff:** Swales should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that may contaminate groundwater.
- **Location:** The location of swales needs to be considered carefully. Wet swales are not recommended for residential developments due to the potential nuisance or mosquito breeding conditions. Swales along roadways can be damaged by off-street parking and are susceptible to winter salt applications. Also, the choice of vegetation and landscaping can be limited in adjacent areas.

Design Guidance:

The following conditions should be considered when designing swales:

- **Conveyance:** Stormwater discharged into and through swales needs to be non-erosive. Sheetflow should be promoted wherever possible using precise grading, level earthen weirs, or pea gravel diaphragms. If concentrated flow is delivered from curb cuts or storm drain pipes, some form of energy dissipation (e.g., plunge pools or rip-rap) is needed.
- **Treatment:** All swales shall meet the following criteria:
 - Swales shall have a bottom width between two and eight feet.
 - The channel slope shall be less than or equal to 4.0%.
 - The maximum flow velocity for the WQ_v shall be less than or equal to 1.0 fps.
 - Swales shall be designed to safely convey the 10-year, 24-hour storm at a non-erosive velocity with six inches of freeboard.
 - Channel side slopes shall be 3:1 or flatter.
 - A thick vegetative cover is required for proper function.

The following criteria apply to each specific design variant:

Grass swales: For linear applications, grass swales shall be as long as the treated surface (e.g., roadways). For non-linear applications, a minimum residence time of ten minutes is required. This time shall be measured from downstream end of the impervious area to the outflow of the channel. The flow path through the contributing length of imperviousness shall be 50 ft. or less.

Wet swales: Wet swales should be installed in areas with a high groundwater table and shall be designed to store at least 75% of the WQ_v . Check dams or weirs may be used to enhance storage.

Draft 12/14/2007

Bio-swales: Bio-swales shall be designed to temporarily store at least 75% of the WQ_v . A two to four-foot deep layer of filter media and an underdrain system shall be provided and shall conform to the specifications found in Appendix B.4.

- **Check Dams:** Check dams or weirs may be used to enhance storage or provide grade control in steeper applications. Where used, these structures should be anchored into the swale wall and notched to allow passage of larger design storms with a minimum six-inch freeboard. Plunge pools or other energy dissipation may be required where the elevation difference between the tops of weirs to the downstream channel invert is a concern.
- **Landscaping:** Landscaping plans shall specify proper grass or wetland plantings based on the design variant chosen and anticipated hydrologic conditions along the channel (see Appendix A). Native species are best for survival and enhancing bio-diversity and wildlife.

Construction Criteria:

Construction specifications for swales can be found in Appendix B.3. In addition, the following items should be addressed during the construction of projects with swales:

- **Erosion and Sediment Control:** Swales are often used for conveying runoff to sediment trapping devices during site construction. Care should be taken to ensure proper construction where stormwater management swales are used for this purpose. After the drainage area is completely stabilized, accumulated sediment should be removed and the swale excavated to the required dimensions. Any required infrastructure (e.g., check dams, underdrains) may then be installed, the bottom and side slopes scarified, and a good stand of vegetation established.

Inspection:

- Regular inspections shall be made during the following stages of construction:
 - During placement and backfill of underdrains and the installation of diaphragms, forebays, check dams, or weirs.
 - Upon completion of final grading and establishment of permanent stabilization.

Maintenance Criteria:

The following items should be addressed to ensure proper maintenance and long-term performance of swales:

- For grassed swales, regular mowing (at least bi-annually) is critical in order to reduce competition from weeds and irrigation may be needed during dry weather to establish vegetation. Sparsely vegetated areas need to be re-seeded to maintain dense coverage.
- If water does not drain within 48 hours, the bottom soil should be tilled and revegetated.

Draft 12/14/2007

- Inspections should be performed once a year to assess slope integrity, vegetative health, soil stability, compaction, erosion, ponding, and sedimentation. Periodic removal of sediment, litter, or obstructions should be done as needed. Eroded side slopes and the swale bottom should be repaired and stabilized where needed.

Draft 12/14/2007**M-9. Enhanced Filters**

An enhanced filter is a modification that takes advantage of soil conditions below a specific practice to provide water quality treatment and groundwater recharge in a single facility. This design variant uses a stone reservoir under a conventional filtering device to collect runoff, remove nutrients anaerobically, and allow infiltration into the surrounding soil.

Applications:

The structural stormwater filtering systems in Chapter 3 and the micro-filtering structures above can be modified relatively easily for most development projects. Depending on soil conditions, a stone reservoir can be sized appropriately to provide Re_v for the drainage area to the system. These practices are subject to the same constraints and design requirements as conventional and micro-scale filters.

Performance:

When designed according to the guidance provided below, enhanced filters may be used to address Re_v for the contributing impervious area using the percent volume method. When coupled with another properly designed structural or micro-scale practices, the combined system will provide treatment for the required WQ_v .

Constraints:

The following constraints are critical when considering the use of enhanced filters to capture and treat stormwater runoff:

- **Space:** The surface area of a typical enhanced filter is dependent on the design of the practice above. Similarly, the size and distribution of open areas within a project (e.g., parking lot islands, landscaped areas) must be considered early during a project's planning and design if these practices are used.

Enhanced filters should not be used in areas where their operation may create a risk for basement flooding, interfere with the operation of subsurface sewage disposal systems, or affect other underground structures.

- **Soils:** Soil conditions are important when designing enhanced filters. Local soil type is a primary factor for determining Re_v and in sizing the stone reservoir.

Subsurface water conditions (e.g., water table) will help determine the stone reservoir thickness used. The probability of practice failure increases if the reservoir intercepts groundwater. Therefore, enhanced filter practice inverts should be above local groundwater tables.

Draft 12/14/2007

- **Hotspot Runoff:** Enhanced filters should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants that may contaminate groundwater.
- **Infrastructure:** The location of existing and proposed buildings and utilities (e.g., water supply wells, sewer, storm drains, electricity) will influence the design and construction of enhanced filters.

Design Guidance:

The following conditions should be considered when designing enhanced filters:

- **Conveyance:** All structural and micro-scale filters should be designed off-line whenever possible. A flow splitter should be used to divert excess runoff away from the filter media to a stable, downstream conveyance system. If bypassing these practices is impractical, internal overflow devices (e.g., elevated yard inlet) may be used.

Runoff shall enter the stone reservoir in a safe and non-erosive manner. Typically, runoff flows through the upper scale practice, into the stone reservoir and infiltrates into the ground. As the reservoir fills, an underdrain system is used to discharge treated stormwater safely downstream. Underdrains may be connected to other micro-scale practices or open or closed storm drain systems.

- **Treatment:** Enhanced filters shall meet the following conditions:
 - Enhanced filters should be coupled with properly designed filters to address both WQ_v and Re_v requirements.
 - At a minimum, enhanced filter reservoirs shall be designed to store the Re_v . The stone reservoir volume is equal to the surface area multiplied by depth divided by the porosity (n) of the stone [Volume = Surface Area (ft²) x Depth (ft)/0.4].
 - The stone reservoir (#57 stone preferred) should be at least 12 inches thick below the underdrain.
 - A 12-inch layer of sand or pea gravel ($\frac{1}{8}$ to $\frac{3}{8}$ inch stone) may be used to act as a bridging layer between the stone reservoir and subsurface soils.
 - The invert of the stone reservoir shall be separated at least four feet (two feet on the lower Eastern Shore) from the seasonal high water table.
- **Setbacks:**
 - Enhanced filters shall be located at least 25 feet from septic systems, 100 feet from unconfined water supply wells, and 50 feet from confined water supply wells.
 - Enhanced filters should be sized and located to meet minimum local requirements for clearance (both vertical and horizontal) from sewer and water lines. Designs may need to include special protection if underground utilities cross through enhanced filters.

Draft 12/14/2007

- **Observation Wells:** An observation well consisting of an anchored, six-inch diameter perforated pipe is required. The top of the observation well shall be at least six inches above grade.

Construction Criteria:

The following items should be addressed during the construction of projects with enhanced filtering practices:

- **Erosion and Sediment Control:** Enhanced filters should not be used as sediment control practices (e.g., sediment traps). Construction runoff should be directed away after initial rough grading. Enhanced filters should not be constructed until the contributing drainage area is stabilized.
- **Soil Compaction:** Existing soils in the location of enhanced filters should be scarified to maximize infiltration. Construction shall be performed with lightweight, wide-tracked equipment to minimize disturbance and compaction.
- **Reservoir Installation:** Stone for the reservoir system should be clean, washed, and free of fines. Stone should be placed in horizontal layers (six inches per lift maximum) over the entire area of the practice using excavators or backhoes operating adjacent to the practice.

Inspection:

- Regular inspections shall be made during the following stages of construction:
 - During excavation to subgrade.
 - During placement of gravel, and installation of underdrain systems and observation wells.
 - At all stages required for the practice above.

Maintenance Criteria:

Enhanced filters require minimal maintenance in addition to that needed for the practice above to ensure optimum performance. Generally, maintenance is the same as that used to keep the primary practice in good condition. Additional measures include making sure there is no water in the observation well. The presence of water 48 hours after a rain event indicates that the enhanced filter may be clogged and need replacement.

Draft 12/14/2007

Section 5.3 Reserved for Redevelopment

Section 5.4 Reserved for Existing Development and Retrofitting

Section 5.5 Reserved for Special Criteria for Sensitive Waters