Watershed Stewards Academy Rainscaping Manual

Watershed Stewards Academy

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Introduction

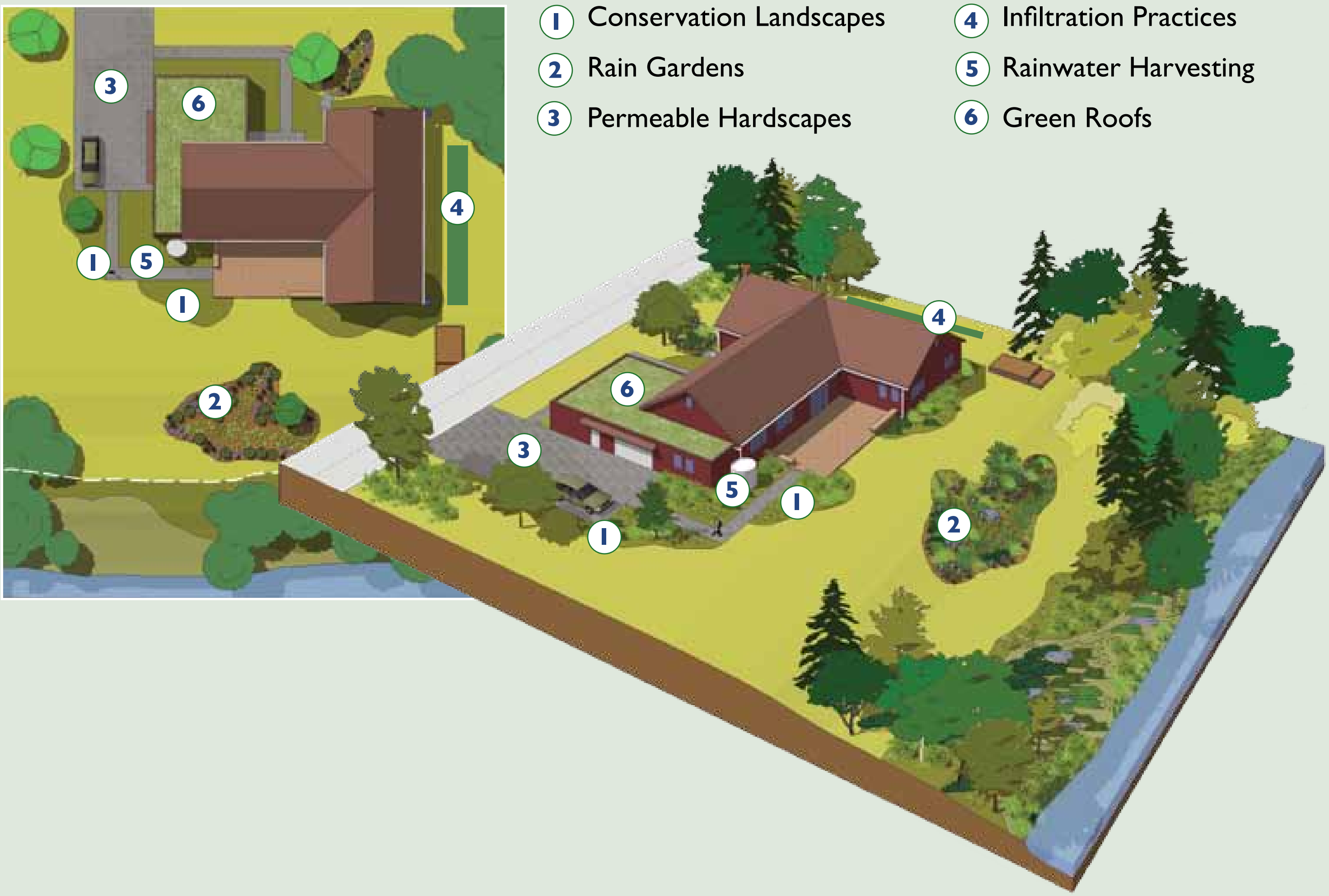


Figure I.1. *Stormwater Practices Included in the Manual*

1. Goals & Audience

The goal of this manual is to provide a resource to design, install, and maintain Conservation Landscaping and stormwater management practices suited primarily to residential and small commercial or institutional properties. These practices, when properly implemented, are attractive and functional landscape features that reduce, capture, absorb, and treat stormwater before it leaves a property.

The intended audience for this manual includes landscape contractors interested in implementing stormwater projects, but need more information and guidance on designing and building them. The content of the manual is geared to practices for residential or small-scale commercial or institutional properties, like houses of worship. However, the manual also points to other resources that apply to larger or more complex projects. These projects require additional technical expertise and/or the involvement of a licensed design professional (see **Section 6** of the Introduction and see the end of each individual chapter).

In the Chesapeake Bay watershed, one of the greatest threats to the health of the Bay and the local waterways comes from runoff from developed land, including streets, yards, driveways, rooftops, and other impervious, or hardened, surfaces and managed landscapes. These developed areas are characterized by hardened or compacted surfaces and less natural vegetation. This results in less rainwater soaking into the ground where it is naturally filtered before returning to our streams and rivers. When left untreated, such runoff can lead to increased flooding, erosion, and pollution of local creeks, streams, lakes, and the Chesapeake Bay.

In order to reduce stormwater runoff and protect and restore water quality and habitat, many local governments and watershed groups, such as Anne Arundel County and the Watershed Stewards Academy, are promoting the use of Conservation Landscaping and stormwater management practices on private properties. Small-scale practices that slow down, capture, treat, and infiltrate stormwater runoff can help combat the threats to local waterways and the Chesapeake Bay.

The emerging market for these types of practices has created a need for clear and consistent guidance on proper practice design, installation, and maintenance geared towards the landscape industry and residential, small-scale commercial and/or institutional projects. Implementation of these practices requires site-specific analyses and designs to fit the site and the client's needs and maintenance capabilities.

2. . Chapter Content

Each chapter focuses on a specific management practice. **Figure I.2** shows representative photos of each practice and the corresponding chapter number.

Each chapter also contains the following sections:

1. ***Project Complexity*** This will provide guidance to determine if the project complexity is within the scope of a contractor's abilities. Each chapter provides a table outlining if the project is SIMPLE, and thus can use the guidance in this manual, or MODERATE or COMPLEX, in which case additional professional services are likely needed from a licensed design professional and/or specialized contractor. Typically, this is the case for projects that require permits and stamped drawings from a licensed professional engineer or landscape architect, an erosion and sediment control plan, properly sized pipes and inflow and outflow features, and specialized equipment and training for installation and maintenance.
2. ***Location and Feasibility*** The practices covered in this manual require site-specific analyses of existing conditions. Considerations include soil and water table characteristics, buried and overhead utilities, surface water drainage patterns and topography, environmentally-sensitive areas to preserve, and existing native and invasive vegetation. All of these factors, as well as the client's needs, aesthetics, and landscape behavior, impact the location, suitability, feasibility, and long-term success of a practice. Each chapter describes the most important factors when choosing a location for the stormwater practice.
3. ***Design*** This section provides basic and typical design schematics and descriptions of the practice's main components. This includes simple calculations on how to estimate the size and footprint of the practice. All original landscape designs should be prepared in accordance with sustainable, conservation or ecological landscape design practices and principles.
4. ***Materials*** Standard materials needed to build each practice are listed in this section.
5. ***Construction*** This provides typical installation protocols with a step-by-step construction sequence.
6. ***Maintenance*** All landscapes and hardscapes require maintenance, whether they are designed for stormwater treatment or not. This section outlines common maintenance tasks and frequencies for each type of practice.
7. ***Resources and References*** Other literature and websites cited in the chapters are referenced in this section. Additional resources are listed for anyone interested in learning more about each specific stormwater practice.

Chapter 1. Conservation Landscapes

Conservation Landscaping is a broad term to describe landscapes that use locally-native plants, provide wildlife habitat, promote clean air and water, and utilize sustainable design principles. In the context of this manual, Conservation Landscapes describe a residential-scale practice that features landscape areas of native plants that provide more wildlife habitat and clean water value than the typical turf grass found in many American yards. Plants and healthy soils associated with these landscapes provide good ground cover, which slows down and filters pollution from stormwater runoff.

(Source: Montgomery Co. Department of Environmental Protection, RainScapes)

Chapter 2. Rain Gardens

Rain Gardens are shaped as shallow landscaped depressions that receive runoff from surrounding rooftops, driveways, or yard areas. Rain Gardens typically use a special sandy soil mixture that is particularly good at filtering runoff. Similar to Conservation Landscaping, native plants are the preferred plant material.

Chapter 3. Permeable Hardscapes

Permeable Hardscapes are commonly used alternatives to traditional impervious paving materials, such as concrete or asphalt. They allow water to seep into the ground by using permeable paver stones or similar materials and a gravel layer underneath. They are used for driveways, patios, walkways, or even parking lots.

(Source: North Carolina State University, Stormwater Engineering Group)

Chapter 4. Infiltration Trench or Dry Well

These practices are stone-filled trenches or pits that temporarily collect runoff, mostly from roof downspouts, and allow the water to percolate into the ground. Some variations have turf cover.

Chapter 5. Rainwater Harvesting

Rainwater Harvesting involves collecting roof runoff in a Rain Barrel or cistern, primarily for slowly releasing water into other practices for infiltration, such as Conservation Landscapes and Rain Gardens.

(Sources: Flickr Creative Commons)

Chapter 6. Green (or Vegetated) Roofs

Vegetated Roofs replace traditional roof materials with layers of special soil mixture, plants, drainage materials, and other components. The roof temporarily stores rainwater and allows it to gradually drain off.

(Source: Living Roofs, Inc.)

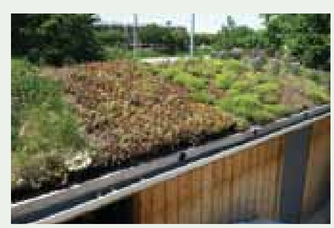


Figure I.2. *Practices Included in the Manual*

Table I.1 provides a relative comparison of each practice based on the following factors:

- ***Implementation Difficulty*** This describes the degree to which the practice requires specialized design, materials, installation expertise, and contractors. Practices with low difficulty can be implemented by most landscape contractors. Projects ranked medium and high may require the services of a design professional (e.g., engineer or landscape architect) and/or contractor with past experience and specialized capabilities.

- ***Typical Cost Range*** This range of construction costs is based on the area of the stormwater practice. For example, a 100 square foot Conservation Landscape would cost approximately $500 or more to have professionally installed by a contractor. These costs will vary significantly, depending on the contractor, practice size, materials used, and other factors. No general estimate will replace the value of a specific written estimate from an installer.

- ***Runoff Reduction Benefit*** This shows how well the practice reduces runoff volumes and, as a result, pollutant loads that may leave the property. The numbers in the table are based on research adopted by Virginia and other Chesapeake Bay states, and they relate to the drainage area for an individual practice.

Table I.1. Comparison of Practice Implementation Difficulty, Relative Cost, and Relative Stormwater Benefits

Practice	Implementation Difficulty	Typical Cost Range, Installed[1]	Potential Runoff Reduction Benefit[2]
Chapter 1 *Conservation Landscapes*	Low to Medium	$5-20 / square foot	25 - 50%[3]
Chapter 2 *Rain Gardens*	Medium	$8-25 / square foot	40-80%
Chapter 3 *Permeable Hardscapes*	Medium to High	$6-12 / square foot	45-75%
Chapter 4 *Infiltration Trenches and Dry Wells*	Medium	$18-22 / square foot	50-90%
Chapter 5 *Rainwater Harvesting*	Low to Medium (Potentially High for commercial or industrial)	$100-1,000 for residential scale $1,000 and up for commercial scale	Varies (up to 90)[4]
Chapter 6 *Green (or Vegetated) Roofs*	High	$20-35 / square foot	45-60%

1 Derived from: King, D., and P. Hagen. 2011. Costs of Stormwater Management Practices in Maryland Counties. Prepared for Maryland Department of the Environment by the University of Maryland Center for Environmental Services. Technical Report Series No. TS-626-11 of the University of Maryland Center for Environmental Science. Costs modified for Anne Arundel County, based on anecdotal data and scale considerations. Actual construction costs will vary depending on materials and contractual services.

2 Runoff reduction values from the Virginia Stormwater BMP Clearinghouse. The range presented depends on the design of the individual practice, and the drainage area contributing runoff to it. http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html

3 The cost and runoff reduction value for Conservation Landscapes is variable, depending on an installation's size, depth, and whether it collects runoff from uphill areas (e.g., yards, driveways). The upper end of the runoff reduction range is based on the Virginia BMP Clearinghouse practice known as "Sheetflow to Vegetated Filter Strip," and assumes some treatment of uphill areas. For cost, the Conservation Landscape may not necessarily treat an uphill impervious area. In these cases, it would best to use the WSA Landscape Conservation Design Tool for a more accurate estimate.

4 The runoff reduction value for Rainwater Harvesting is dependent on the size of the rooftop area captured, size of the tank, and demand or drawdown of the water stored in the tank.

3. How Stormwater Practices Differ From Common Landscaping Practices

While the practices in this manual use standard landscaping materials, there are some key differences when compared to traditional landscapes or hardscapes. Stormwater practices differ in placement, materials, function, underlying structure, installation techniques, and maintenance. These differences are illustrated in **Figure I.3** and described below:

Designed to Collect and Store Runoff Rain Gardens, and some other stormwater practices are shaped and positioned as shallow depressions to collect runoff from roof downspouts, driveways, patios, and surrounding yard areas. In contrast, traditional landscape beds are usually raised or mounded up compared to the surrounding ground such that runoff flows around, rather than into, the beds. Conservation Landscaping is designed to filter and slow down stormwater, provide habitat, avoid the use of pesticides, herbicides, and fertilizers and, once established, reduce long term maintenance and irrigation needs. Permeable Hardscapes are designed to absorb or store stormwater rather than to shed it rapidly downstream. Site work often requires extra precautions and different construction techniques to avoid sedimentation or soil compaction during installation or maintenance.

Beneath the Surface Almost all stormwater practices contain underground layers of a special soil mix and/or gravel. These layers may not be present with traditional landscaping. The underground layers require additional excavation or digging. It is critical that the underlying soil is not compacted during installation. The materials used are often specified and often can't be substituted if the practice is going to qualify as a stormwater practice. The purpose of these layers is to temporarily store runoff within the pore spaces of the layers, slow it down, and let some or all of it percolate into the ground. Each chapter in this manual contains specific details about the underground layers specific to each practice.

Plants The prevailing wisdom for vegetated stormwater practices is to use, to the extent possible, native plants. As with any plant, make sure the plant is suited for the growing conditions at the site. Native plant communities combined with healthy soils attract local pollinators and wildlife, thrive in the local climate, reduce the need for fertilizers, pesticides, herbicides, and excess water, and simulate the runoff cleansing benefits of natural ecosystems. There are many cultivars of native plants available through nurseries, so it is best to consult with a Watershed Steward or knowledgeable local nursery about the native plants available.

<table>
<tr><th>Traditional</th><th>Stormwater</th></tr>
<tr><td colspan="2">Designed to Collect & Store Runoff</td></tr>
<tr><td>
Most landscape islands are raised up on curbs and water flows around them to enter the storm sewer.</td><td>
Rain Garden is in a slight depression where it collects and treats runoff from the parking lot.</td></tr>
<tr><td>
A typical paved driveway produces a lot of stormwater runoff.</td><td>
Driveway is constructed from permeable materials to let water soak in. (Source: South River Federation)</td></tr>
<tr><td colspan="2">Beneath the Surface</td></tr>
<tr><td>
Most landscaping has a few inches of mulch placed on top of the existing soil, which may be compacted. Compacted soil is not a very good sponge for absorbing runoff.</td><td>
Depending on the practice, the design uses underground layers of a special soil mix and/or gravel to absorb stormwater and let it percolate into the ground. (Source: Alliance for the Chesapeake Bay)</td></tr>
<tr><td colspan="2">Plants</td></tr>
<tr><td>
Most landscaping uses common, commercially-available plant stock, much of which is comprised of non-native species or cultivars.</td><td>
This Conservation Landscape replicates native plant communities from the surrounding landscape.</td></tr>
</table>

Figure I.3. *Key Differences Between Traditional Landscaping and Stormwater Practices*

4. Cost-Share Eligibility

Many local governments, regional watershed associations, and other entities provide some type of incentive (e.g. technical assistance, stormwater fee "credit" or a cost-share) for homeowners, small businesses, and houses of worship to implement these practices. Often localities that fund their stormwater management programs through a stormwater utility fee offer a reduction in the fee assessed to a property or credit, when a property owner implements an on-site stormwater project. Other programs may provide up-front cost-share assistance or rebates to the property owner to offset design, material, and construction costs.

Check with the local stormwater department to ascertain whether cost-share assistance or a utility fee credit is available. The Chesapeake Stormwater Network has a list of organizations that offer financial, technical, or other assistance. Go to: *http://chesapeakestormwater.net/be-bay-friendly/directory-residential-bmp-programs/.*

Another good resource for Anne Arundel County Rain Gardens and the local approval process can be found here: *http://www.aacounty.org/DPW/Highways/RainGarden.cfm*

5. Chesapeake Bay Clean-Up Goals

Most of the practices in this manual -- if designed, installed, and maintained properly -- can be counted towards the local Chesapeake Bay pollutant reduction targets. These are required through water quality permits, stormwater management programs and/or Watershed Implementation Plans (WIP). Check with the local government stormwater program to determine which practices have local incentives. Special protocol or construction techniques are may be required and there may be specific reporting guidelines.

Counting Your Practice All the practices described in this manual reduce pollutants to local waterways and the Chesapeake Bay. Anne Arundel County, and other jurisdictions, can count these practices in their overall plan to reduce pollutants from the community. The *Stormwater Management and Restoration Tracker (SMART) Tool* was developed by University of Maryland Extension as an online portal for private property owners in Maryland and Virginia to report a wide variety of types of stormwater management practices that are built on their property.

Once the user enters the relevant details, the tool computes the estimated average annual nitrogen and phosphorus pollution load reduction that will be achieved by the practice over its lifetime. The SMART Tool continues to evolve; visit *http://www.extension.umd.edu/watershed/smart-tool* to find the latest version of the tool and to see a complete list of the types of stormwater practices that can be submitted.

Local jurisdictions may have their own means of tracking projects. For Anne Arundel County, visit *http://www.aarivers.org*

6. Resources for More Complex Projects

As stated earlier, the practices and methodologies outlined in this manual are primarily suitable for residential and small commercial or institutional properties. Landscape professionals using this manual may be confronted with larger or more complex projects that require additional design, installation, and/or maintenance expertise, equipment, or permits to comply with local or state regulations. This is particularly true for projects that must undergo a plan review process, require erosion and sediment control plans, and/or must adhere to local or state stormwater standards. The beginning of each chapter in this manual provides some guidance for the user to assess the technical complexity of a given project and the need for additional expertise and resources, such as a local or state stormwater management design manual.

For more detailed specifications, the following are offered as good sources the Chesapeake Bay watershed:

- Anne Arundel County, Design Manual and Standard Specifications and Details for Construction (Chapter VI) & Stormwater Management Practices & Procedures Manual:
  http://www.aacounty.org/DPW/Engineering/DesignManual.cfm

- Department of Environment, Maryland Stormwater Design Manual, Volumes I and II:
  http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Pages/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.aspx

- Virginia Department of Environmental Quality, Virginia Stormwater BMP Clearinghouse (NOTE: not applicable from a regulatory standpoint in Maryland, but contains some updated stormwater practice specifications as a general reference):
  http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html

Other resources specific to small-scale homeowner stormwater practice implementation in the Chesapeake Bay watershed include:

- Chesapeake Stormwater Network, Homeowner Guide For a More Bay-Friendly Property:
  http://chesapeakestormwater.net/2013/04/homeowner-bmp-guide/

- RiverWise manual & website
  http://stormwater.allianceforthebay.org

- Montgomery County, MD Rainscapes: *http://www.montgomerycountymd.gov/dep/water/rainscapes.html*

- Low Impact Design Center: *http://www.lid-stormwater.net/index.html*

- Anne Arundel County Watershed Protection and Restoration Program:
  http://www.aarivers.org

Conservation Landscapes

(Source: Chesapeake Horticultural Services LLC)

Purpose & Benefits

- Pollinator & wildlife habitat
- Attractive landscaping feature, with native flowering plants
- Stormwater runoff and pollution reduction
- Reduce water, pesticide and fertilizer use; less time and money spent on these inputs
- Promotes healthy soils & air quality
- Control of invasive plants
- Less maintenance on the long-term

Description

Conservation Landscapes can range from the relatively simple practice of replacing existing turf, invasive plants, or impervious surface with landscaped areas of native plants and trees to the more comprehensive and integrated sustainable design and management approach. Conservation Landscapes feature native plants and trees, many of which flower at different times during the growing season. Unlike many traditional landscaped areas, Conservation Landscapes are situated slightly below the existing ground level so runoff from rooftops, driveways, and surrounding yard areas can spread out and soak into the landscaped area. Native plants provide habitat for beneficial pollinators and songbirds, and, once established, do not require chemical fertilizers, pesticides or excess watering. The deep roots of most native plants, and associated healthy soils, allow runoff to soak into the ground at a much higher rate than traditional lawns. In yards with poor soil, compost amendments can enhance stormwater infiltration capabilities of Conservation Landscapes. *Consider pairing a Conservation Landscape with a Rain Barrel or cistern to increase the stormwater captured.* Conservation Landscapes are also referred to as *BayScapes*, *RainScapes*, and *Bay-Friendly Landscapes*.

What to Expect

Native plants used in Conservation Landscapes come in a variety of shapes, colors, and sizes. The design of the landscape can match the aesthetic preferences and maintenance skills of the property owner. Designs can range from natural-looking meadows or wooded strips to more traditional mulched landscape beds. Generally, Conservation Landscapes require a similar level of maintenance as what is needed for conventional landscape beds, and often less.

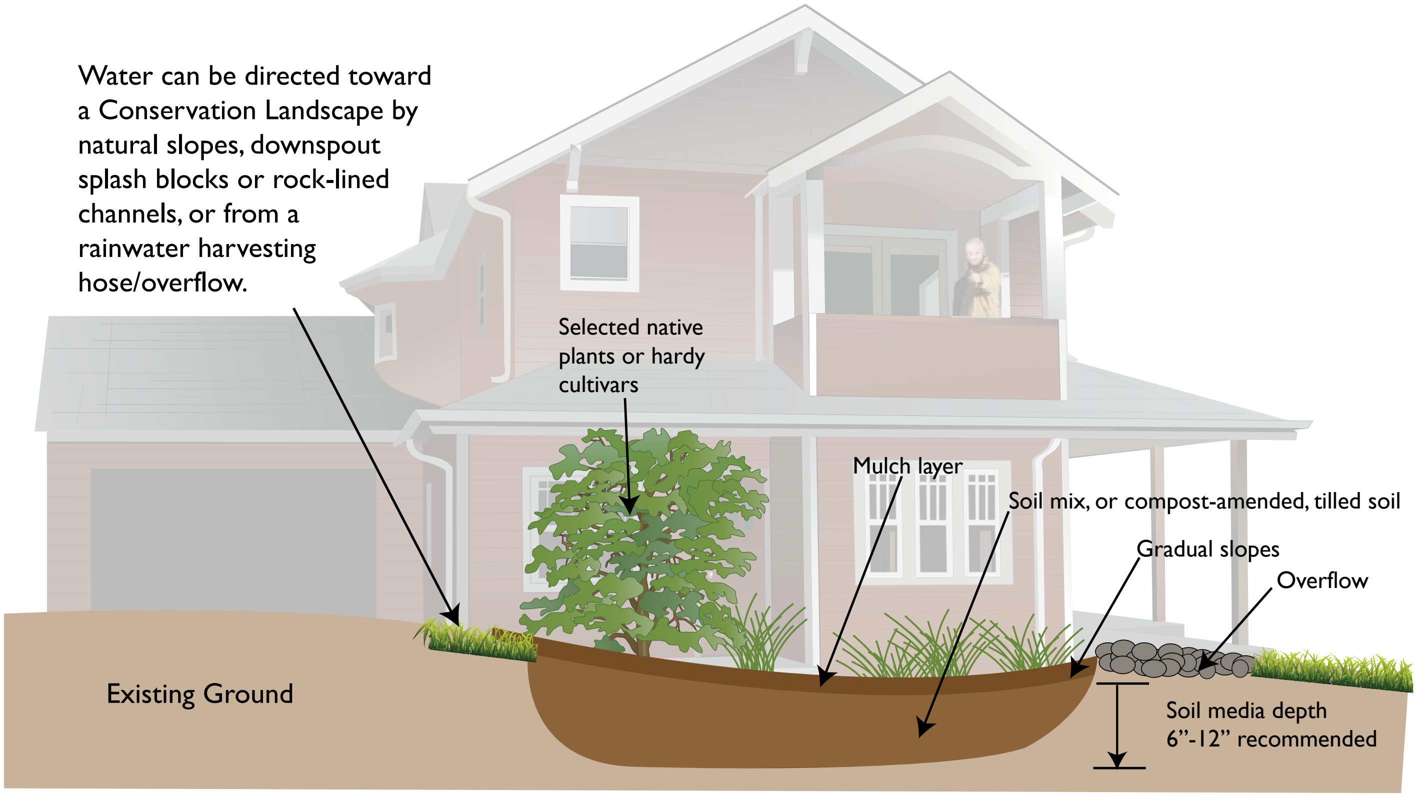


Figure 1.1. *Overview of a Conservation Landscape*

1.1. Complexity

A Conservation Landscape is one of the simplest practices presented in this manual. It can be used on any residential property with some amount of outdoor green space. Many Conservation Landscape methods are simple enough for the "do-it-yourselfers". However, some designs can be more complicated if the property owner desires specific coordination of bloom times and colors, plant heights, and other aesthetic elements. Based on these factors, the contractor should consider whether or not the project needs to be designed by a professional landscape designer and/ or installed by a landscape contractor. **Table 1.1** provides some guidance.

Figure 1.2. *Example of Conservation Landscape*

A Steward or homeowner with experience in landscaping can undertake a simple Conservation Landscape project. Consult a landscape contractor or design professional for moderate to complex projects, or when the project requirements are uncertain.

Table 1.1. Design Complexity for Conservation Landscapes

Design Complexity	Description	Guidance
Simple	• Plant selection based on locally available natives and site conditions • Plant layout is relatively simple (see online **WSA Conservation Landscape Design Tool** (Design Tool) for templates)	• Design can be done by anyone with some knowledge of native plants and experience with landscaping • The design should consist of a sketch plan, with material types and quantities (see **Design Tool** for assistance) • Installation can be accomplished by a landscape contractor or homeowner • Digging up and removing the existing turf and associated root mat will likely be the most labor-intensive part
Moderate to High	• Plants chosen based on elements such as specific bloom colors and timing or maximum height of plants • Other advanced aesthetic or habitat goals • Applications involving most or all of a property; integration with hardscapes, structural elements, or other advanced design/engineering features	• Make list of goals and desires for the Conservation Landscape • Enlist a licensed landscape architect or professional landscape designer if questions arise regarding site and soil conditions, or if site slopes are steeper than 5% • Consult with a professional engineer if there are sensitive surroundings, such as nearby wetlands or floodplains, or if the soil and groundwater conditions raise concerns

1.2. Location & Feasibility

Complete an assessment of the entire site based on guidance in **Appendix A** prior to designing any stormwater management practices on a client's property. Once the assessment is complete, consider the following specific factors when choosing the location(s) for a Conservation Landscape:

Downhill from Impervious & Yard Areas
If possible, Conservation Landscapes should be placed to receive some runoff from uphill impervious surfaces, such as a rooftop or driveway, and surrounding yard areas. However, this is not an absolute necessity, and very successful

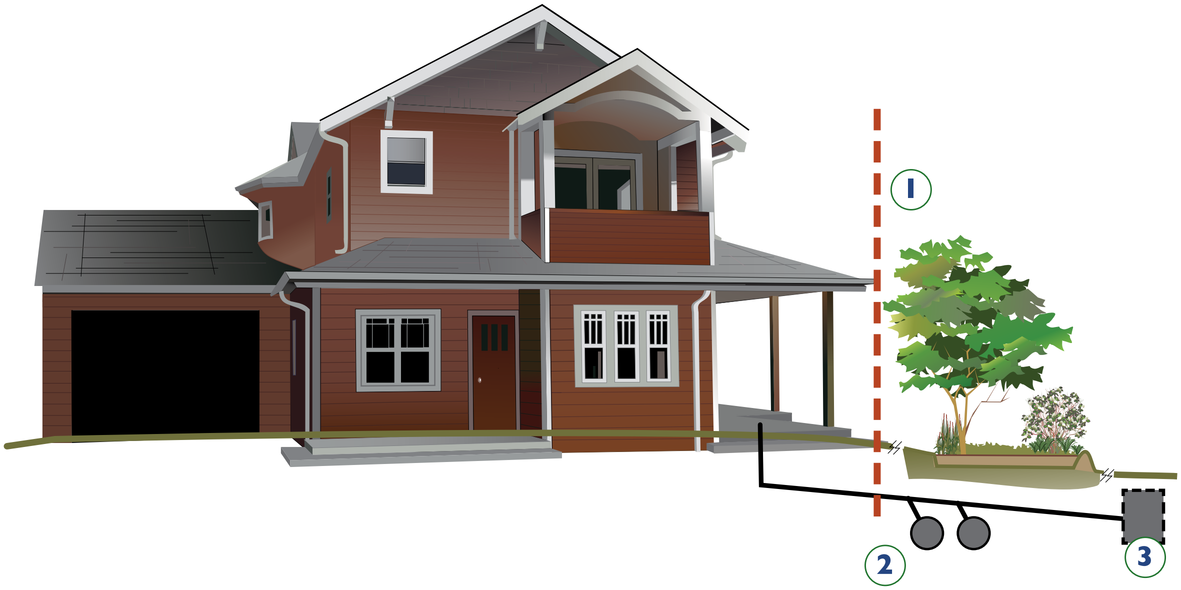
Do:

- Test soil to determine need for soil amendments
- Locate Conservation Landscapes in a low spot that will collect stormwater runoff from the site
- Consider including a Rain Barrel at downspouts that can drain to the Conservation Landscape

Don't:

- Direct runoff toward a building foundation
- Locate Conservation Landscapes above underground utility lines
- Locate Conservation Landscapes where the excavation will damage tree roots

Where NOT to Locate a Conservation Landscape



1. Within 10 feet of a building foundation
2. Over utilities
3. Near an existing or reserve septic drainfield or tank
4. Near Wells- Stay back 50 feet from confined wells, or 100 feet from unconfined wells

Conservation Landscapes can be installed simply to replace existing turf or other land covers. In addition, smaller Conservation Landscapes (e.g., 60 or 90 square feet) should not be designed to accept runoff from large roofs, driveways, and other impervious surfaces because the landscape area will become overwhelmed with runoff water. If installing a Conservation Landscape near a downspout, consider also installing a Rain Barrel or cistern on the downspout to slow water before it enters the Conservation Landscape. The Rain Barrel or cistern can be calibrated to allow water to drain out slowly over approximately two days. Doing so will increase infiltration of the roof runoff.

Size Conservation Landscapes can be any size that fits into an existing property. Yards with large open spaces may be more suitable for uniform meadow plantings that can be mowed annually, while small sections of yard may be more appropriate for plantings in mulch beds that can be maintained by hand. The *WSA Conservation Landscape Design Tool* contains plant layout templates for various landscape sizes (60, 90, 120, and 180 square feet) in different configurations. If large areas are to be cleared and graded, check with the local government to see if an erosion and sediment control permit is required.

Replace Turf Conservation Landscapes are often installed to replace turf grass areas, such as in the example shown in **Figure 1.3.** Turf can be removed with various methods, some of which are described in **Section 1.6.**

Figure 1.3: *Residential yard in Montgomery County, MD converted from turf grass to Conservation Landscape*
(Source: Montgomery Co. Department of Environmental Protection, RainScapes)

Proximity to Utilities Always call Miss Utility before choosing where to locate the Conservation Landscape, to avoid damaging underground utilities. Most Conservation Landscapes will disturb the uppermost 6 to 12 inches of the soil, and may interfere with shallow utilities. Also, be aware that Miss Utility may not always mark private cable, propane, and similar lines, so some additional site work may be necessary to locate these.

Proximity to Buildings Conservation Landscapes can be installed adjacent to house foundations or other structures. However, the surface of the Conservation Landscape should slope away from the structure to ensure that stormwater will not get into the foundation. If the building's downspouts discharge roof runoff onto the ground (i.e., they are "disconnected" rather than piped directly to an underground storm water drain), it is recommended that downspouts extend 5 feet from foundations and 10 feet if a basement is present (see **Figure 1.4**). See **Table 1.2** for more ideas on how to manage runoff from downspouts.

Figure 1.4: *Downspout piped directly to underground storm drain*
(Source: City of Savannah, GA).

Disconnected downspout with extension pipe away from foundation
(Source: Ted Millich)

Table 1.2. Dealing with Roof Runoff: Downspout Disconnection

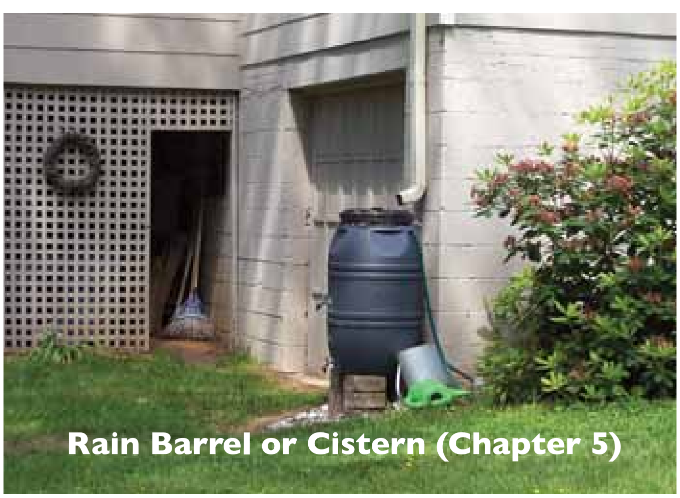
Downspout disconnection refers to directing roof gutter downspouts to well vegetated areas (such as Conservation Landscapes) instead of to the storm drain pipe network so that stormwater has a chance to soak into the ground and be filtered by vegetation. This manual often highlights the same theme: downspouts **can be directed to many different types of landscapes and stormwater features,** as illustrated below.

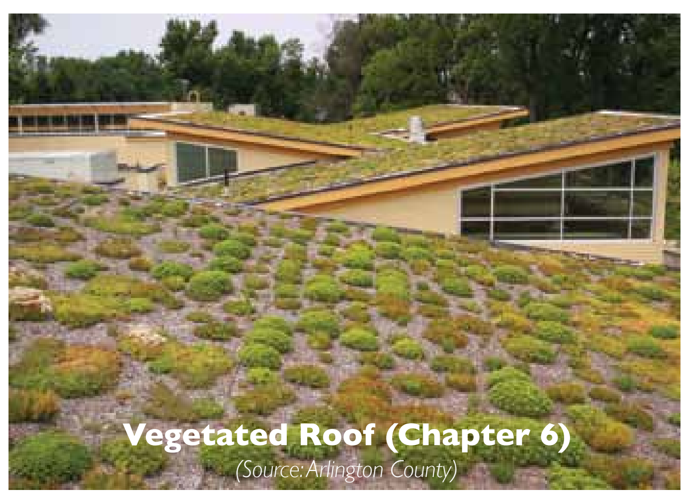

Conservation Landscape (This Chapter)
(Source: Chesapeake Horticultural Services LLC)


Rain Garden (Chapter 2)

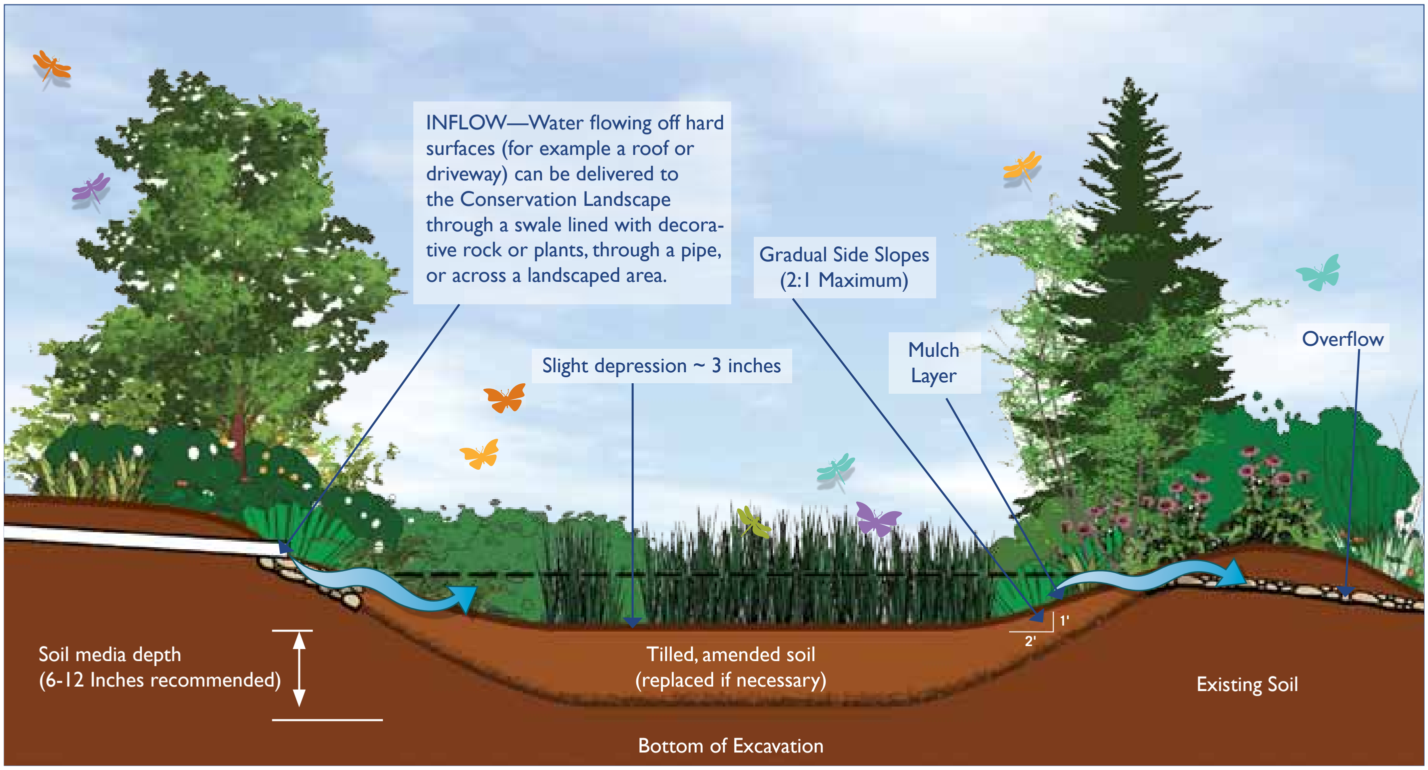

Permeable Hardscape (Chapter 3)


Infiltration Trench (Chapter 4)


Rain Barrel or Cistern (Chapter 5)


Vegetated Roof (Chapter 6)
(Source: Arlington County)

Design Elements of a Conservation Landscape



1.3. Design

As you prepare a Conservation Landscape design for your client to create an area that also functions as a stormwater management practice, consider the following factors:

Runoff & Sizing A **Conservation Landscape Worksheet** accompanies this manual to help calculate the optimal size of the landscape for absorbing stormwater runoff from its respective drainage area. Of course, sizing the landscape according to the drainage area size is optional. If space or cost constraints ultimately determine the size of the practice, this worksheet can be used simply to determine material quantities needed for a landscape of a given size, estimate costs for those materials, and estimate the amount of material (i.e., soil and turf) that may need to be removed from or recycled on the site due to excavation and soil replacement. Finally, the worksheet estimates how much nutrient and sediment pollution the Conservation Landscape can reduce by absorbing stormwater runoff from the drainage area that flows to it. The **Conservation Landscape Worksheet** can be found at www.aawsa.org.

Plant Species and Layout It is important to take into account conditions at the site, such as exposure to sun, soil type, how wet or dry the area is, aesthetics, and wildlife objectives when selecting the appropriate plant species for a Conservation Landscape. Native plant species with high habitat value, suited to site conditions, and planted in layers and zones of similar native plant communities are preferred over non-native species, but some ornamental species may be used for landscaping effect if they are not aggressive or invasive. See **Section 1.5** and the Design Tool for more guidance and the references at the end of this chapter for more plant resources.

Plant Heights When choosing where to install Conservation Landscapes and which plants to use, consider the typical maximum height for each type of plant. Certain tree species, for example, may grow quite tall and shade out other plants, block views, and get in the way of aerial electric and cable wires. Only use tall tree species where appropriate. Landscaped areas next to driveways or parking areas should not block ingress and egress or sightlines.

WSA Conservation Landscape Design Tool

See the online Design Tool for help in choosing plant species and layout based on sun exposure, soil permeability, space available, and drainage area to the site. A total of 22 templates are available.

Soils Conservation Landscapes can be tailored to any soil type and soil infiltration rates. A soil test can help determine plants suitable to the site and what types of amendments (e.g., compost, lime) may be needed to improve the fertility of the soil for plant growth and infiltration of water into the soil. The first rule of thumb is to use existing soil and reestablish soil health with soil amendments if there is little or no topsoil, the organic content is low, or the pH is less than 4.5 or greater than 8.0. Many clay soils can be amended with organic content to improve infiltration; however compacted soils will not successfully sustain plant life or allow infiltration of water into the ground. Compacted soils should be amended with organic compost and aerated, tilled, plowed or hand turned with a shovel or fork to re-introduce space between the soil particles and improve infiltration. In some cases, where topsoil is missing, new high quality, sandy loam topsoil should be brought in. Many university extension agencies provide soil testing services to the public at a low cost. Along with test results, they also usually provide recommendations for how to improve the soil structure and quality. Also, see **Appendix B** for information on testing soil texture and infiltration rates.

Excess Material As mentioned above, the *Conservation Landscape Worksheet* accounts for the quantity of soil and turf that may need to be removed from the landscape to make room for adding compost, mulch, plants, and possibly new soil while keeping the surface level at least 1-2 inches below surrounding grade. The plan for construction should address the excess material. Several options may be available: (1) keep it on site for future use, such as for raised garden beds or fill (cover with tarp to avoid erosion); (2) offer it for free through local or online classifieds; or (3) haul it to an appropriate local landfill, which will likely charge a fee. Speak with the homeowner to decide which option works best.

Erosion Control If the Conservation Landscape receives stormwater directly from gutter downspouts, the design will need to incorporate a pad of cobble stone (sometimes called river rock, or river jack) or some other means at the mouth of the downspout to reduce flow velocity and prevent erosion. See **Figure 1.5** for an example and **Section 1.6 (Step 5)** for installation instructions. Where a Conservation Landscape is located next to a sidewalk, patio or driveway, consider including a similar treatment to prevent erosion at the edge where the bed meets the hardscape until the plant material is established and mature.

In addition -- depending on the size of the installation, anticipated weather, and number of days needed for installation -- it may be advisable to place silt fence downhill from the Conservation Landscape excavation and/or stockpiles of excavated material. Take all precautions necessary to not contribute sediment to downhill storm drainage systems and waterways.

Figure 1.5:
River cobble at downspout to slow down roof runoff before it enters a Conservation Landscape. Ideally, this downspout would extend to route water further away from the building foundation before it reaches the stone.

1.4. Materials

The following is a list of materials needed for constructing a Conservation Landscape. Note that some of these materials are optional, based on site conditions. The *Conservation Landscape Worksheet* will help determine specific quantities for each item, based on the size of the landscape area.

Table 1.3. Material Specifications for Conservation Landscapes

Material	Specifications	Size	Depth	Notes
Soil mix (optional)	Rain Garden soil mix from vendor or sandy loam topsoil	N/A	Replace existing soil to a depth of approximately 12 inches	Recommended strongly if topsoil is missing, is full of rock, shale or construction debris, or otherwise has poor infiltration rates
Compost (optional)	The material should be well composted and free of viable weed seeds Fresh manure should not be used for compost because of high bacteria and nutrient levels	N/A	Add 2 inches of compost across landscape surface area and incorporate into top 6 inches of soil	Follow recommendations from the soil test if compost amendments are suggested
Plants	See **Section 1.5** below	Variable	N/A	Potted plants, plugs, or seeds
Ground cover	*Options:* double-shredded hardwood mulch, leaf mulch, or seed mix	N/A	2 – 3 inches	Mulch should be aged a minimum of 6 months
Cobble/Stone (optional)	Washed river rock, large gravel, or small rip-rap	3 – 5 inch diameter stone	1 or 2 layers deep	Use at downspouts, inlets, and where landscaping meets hardscape areas as needed to dissipate flow and prevent soil erosion Install filter fabric secured with landscape staples below the stones to keep them in place and to prevent weed growth

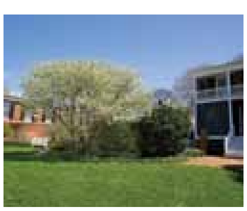
1.5. Plants

Figure 1.6. *A variety of plant types used in a residential Conservation Landscape*
(Source: Montgomery Co. Department of Environmental Protection, RainScapes)

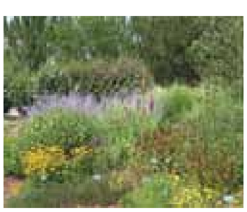
Some common Conservation Landscape planting strategies:

Tree, shrub and herbaceous plants/grasses (referred to in the Design Tool as "Typical") These have a balanced mix of plant types for variety and cooperative function. They can produce a natural effect, simulating the structure and function of a native forest plant community. Requires regular maintenance in the form of weeding, thinning, pruning, mulching, and other activities that are routine for other landscaped areas.

Simple meadow This is a lower maintenance approach that focuses on the herbaceous layer and may resemble a wildflower meadow. The goal is to establish a more natural look, and, once the grasses are established, maintenance can largely consist of mowing the area annually in the early spring.

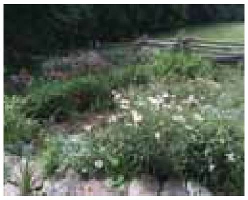


Flowering tree focal point garden A small or medium tree is accented with perennials/ herbaceous plants. This garden may have more mulched areas than other options, so weeding and re-mulching would be expected.



Butterfly garden Largely a modification of the tree, shrub, herbaceous option, but with plants selected for pollinators and wildlife.

Woody screen Some Conservation Landscapes can be naturalized screens, consisting largely of trees with understory shrubs and ground covers. The idea is to create a property screen or, more appropriately, a natural buffer area along streams, swales, wetlands, or other natural areas. Once established, maintenance would consist of periodic thinning and control of invasive plants.



Hybrid There are many options for Conservation Landscape concepts. The designer may mix and match the concepts above or design something suited to the particular property.

Match The Conservation Landscape Design with the Owner's Maintenance Capabilities

Conservation Landscapes often require much less maintenance than traditional landscaped beds, but until established, they do require some watering, weeding, mulching, and occasional thinning of plants, depending on the aesthetic goals of the garden. Often, people do not consider the long-term maintenance responsibilities when these practices are first installed. Conservation Landscapes designed with tightly-spaced herbaceous plants (e.g., a meadow) require less maintenance than those with more complicated designs. Investigate the planting templates in the *Design Tool,* and make sure the selection is a good match for the owner.

1.6. Construction

Local jurisdictions may require a permit or permission before a practice can be installed. Once site suitability and appropriate location have been confirmed:

Step 1 - Outline the Conservation Landscape area
Clearly mark both the boundaries of the Conservation Landscape and any nearby underground utilities (call Miss Utility at least two business days before digging). Also try to identify private propane, cable, electric, and other small lines. Make sure to have a plan and phone numbers of who to call in case there is any damage to utilities. Also mark areas that should not be disturbed during installation (e.g. environmentally sensitive areas, soil around root zones of mature trees, and existing vegetation).

Figure 1.7. *Killing turf grass with newspaper and mulch cover, (a.k.a., "sheet mulching").*
(Source: Eve's Garden Design)

Step 2 - Remove the Turf If turf grass needs to be removed, several methods can be used, as outlined below. These "physical" methods are preferable to using herbicides, since the intention of the practice in the first place is to protect water quality.

(1) Sheet mulching- uses cardboard or sheets of newspaper to smother and kill the grass (see **Figure 1.7**).

- First, cut the grass as short as possible and water down the area well.
- Lay down the cardboard or newspaper (about 10 sheets thick) like shingles, with some overlap. If there is a breeze, water down the paper to keep it from blowing away.
- Add a layer of 3 – 5 inches of mulch on top of the paper to keep it in place.

- Wait 2 – 4 months to allow the grass to die off. When ready to install the Conservation Landscape, remove the sheet mulch or install potted plants (or plugs) directly by cutting holes into the newspaper or cardboard.

(2) Solarizing - Using stapled down sheets of black or clear plastic over the grass (see **Figure 1.8**). Over time, heat from the sun will kill the grass. Remove the plastic before planting. As with sheet mulching, be sure to start the process at least two months in advance of installing the Conservation Landscape to allow time for the grass to die off.

(3) Mechanical methods - Using a sod cutter to remove turf (see **Figure 1.9**.) or using shovels to cut out grass roots by hand. This method is needed if grass is not killed in advance.

Figure 1.8. *"Solarizing" turf grass with plastic to kill it.* *(Source: Ted Millich)*

Figure 1.9. *Using a sod cutter to remove turf prior to planting a Conservation Landscape.*

Step 3 - Loosen the Soil If the site is heavily compacted, deep-till the bed to a depth of approximately 8 to 12 inches, using a rotary tiller (or, for small areas, by hand using shovels and forks). If needed, add 2 inches of a suitable compost mix evenly across the Conservation Landscape while tilling.

Step 4 - Remove Excess Soil Most Conservation Landscapes will match the existing shape of the land. If possible, the surface of the Conservation Landscapes should be a few inches lower than the surrounding area, so that water flows into the landscaping area. As mentioned earlier, the design should account for removal and disposal or reuse/composting of any soil and/or turf grass. When grading the area to achieve the desired final elevations and slopes, avoid compacting the soil with heavy equipment.

Do:

- Call Miss Utility before digging
- Remove all turf grass in landscape area
- Water plants during first month

Don't:

- Compact the soil with heavy equipment during construction
- Add fertilizer if using compost.

Step 5 - Install Stone, if applicable If the volume and speed of water flowing into the landscape appears to have the potential to cause erosion, add river cobble stone at downspouts and any other inlets or edges where water is concentrated.

To install:

1. Dig a concave channel 1 – 2 feet wide with the outer edges of the channel approximately 6 inches deep and the center approximately 8 inches deep. Fan out the width of the channel as it enters the landscape, to encourage the incoming water to spread out.
2. Lay landscape fabric down onto the surface of the excavated area and secure it with landscape staples. This fabric will prevent the stones from sinking into the ground over time.

3. Add approximately 3 – 5 inches of stone (1 or 2 layers) on top of the fabric and tamp it down.
4. After installing the stone, check to make sure the stone is low enough in the ground to not block flow from getting into the Conservation Landscape. **Figure 1.5** shows an example of cobble stone stabilization.

Step 6 - Install Plants and Mulch Install native plants per grower's instructions and add 2 – 3 inches of hardwood, composted leaf mulch, and/or other recommended organic mulch around them to retain soil moisture and reduce weed growth. Alternatively, plant an appropriate seed mix using grower's instructions (e.g., native meadow seed mix) and cover with straw or biodegradable erosion control matting.

Step 7 - Water Water plants immediately, then approximately once every three days for the first month (depending on rainfall).

1.7. Maintenance

Maintenance of Conservation Landscapes is very similar to the maintenance of traditional landscape beds. Those performing maintenance on Conservation Landscapes need to be able to differentiate between native plants and non-native plants to know which are desirable and undesirable.

Table 1.4. Recommended Maintenance for Conservation Landscapes

Maintenance Tasks	Frequency
• Water once every three days for the first month and then weekly during the first growing season (April-October), depending on rainfall • Expect up to 10% of the plant stock to fail in the first year, and plan accordingly for replacement plants	Upon establishment
• Check inlets and overflow areas for debris or leaves that are blocking flow • Check and repair erosion areas	After heavy rains in first month; periodically in subsequent years
• Remove weeds by hand	Monthly for first growing season; every 3 months or as needed in subsequent years
• For "meadow" type Conservation Landscapes consisting of grasses, mow in early spring • For other types of landscapes, check for winter damage and add mulch to bare spots as desired (2–3 inches) • Cut back perennials and remove dead growth	March or April
• Add reinforcement planting to maintain the desired vegetation density • Prune trees and shrubs; thin herbaceous plants as desired	Fall
• Remove invasive and non-native plants using recommended control methods • Remove any dead or diseased plants • Dead-head flowers • Stabilize any eroded or bare areas • Remove trash	As needed

1.8. Resources & References

Albemarle County, VA, *Piedmont Native Plant Data Base*
http://www.albemarle.org/nativeplants/

Alliance for Chesapeake Bay, *BayScapes Homeowners' Guide to Designing Your Property*
http://allianceforthebay.org

Chesapeake Conservation Landscaping Council, *Conservation Landscaping Guidelines: The Eight Essential Elements of Conservation Landscaping*
http://www.chesapeakelandscape.org

Association of Professional Landscape Designers (APLD) – sustainability resources and guides developed for APLD certified landscape designers
http://apld.org/?p=sustainability

Ladybird Johnson Plant Database
http://www.wildflower.org/plants/

North American Native Plant Society
http://www.nanps.org/

USDA, *Plants Database*,
http://plants.usda.gov/java/

U.S. Fish and Wildlife Service, *Native Plants for Wildlife Habitat and Conservation Landscaping*
http://www.fws.gov/chesapeakebay/bayscapes/bsresources/bs-nativeguides.html

Rain Gardens

(Source: Albemarle County, VA)

Purpose & Benefits

- Stormwater runoff reduction
- High pollutant removal
- Pollinator habitat
- Attractive landscaping feature

Description

A Rain Garden is a shallow landscaped depression that receives runoff from surrounding rooftops, driveways, or yard areas. Compared with traditional landscaping, which is usually raised a few inches above the surrounding landscape, Rain Gardens are graded as shallow depressions that accumulate runoff from surrounding areas. A Rain Garden simulates the runoff treatment provided by natural areas, such as forests or meadows (but of course, should not replace existing wooded areas). The primary component of a Rain Garden is the filter bed, which can consist of the existing soil (if it percolates well) or an assembled mixture of sand, soil, and organic material, topped with a surface mulch layer and plants.

What to Expect

During storms, runoff temporarily ponds 4 to 12 inches above the mulch layer and then filters through the bed within 1 to 2 days (this is not enough time for mosquitoes to breed). Plants in a Rain Garden must withstand both dry and wet conditions and will need to be thinned and/or replanted over time. Weeds will need to be removed by hand.

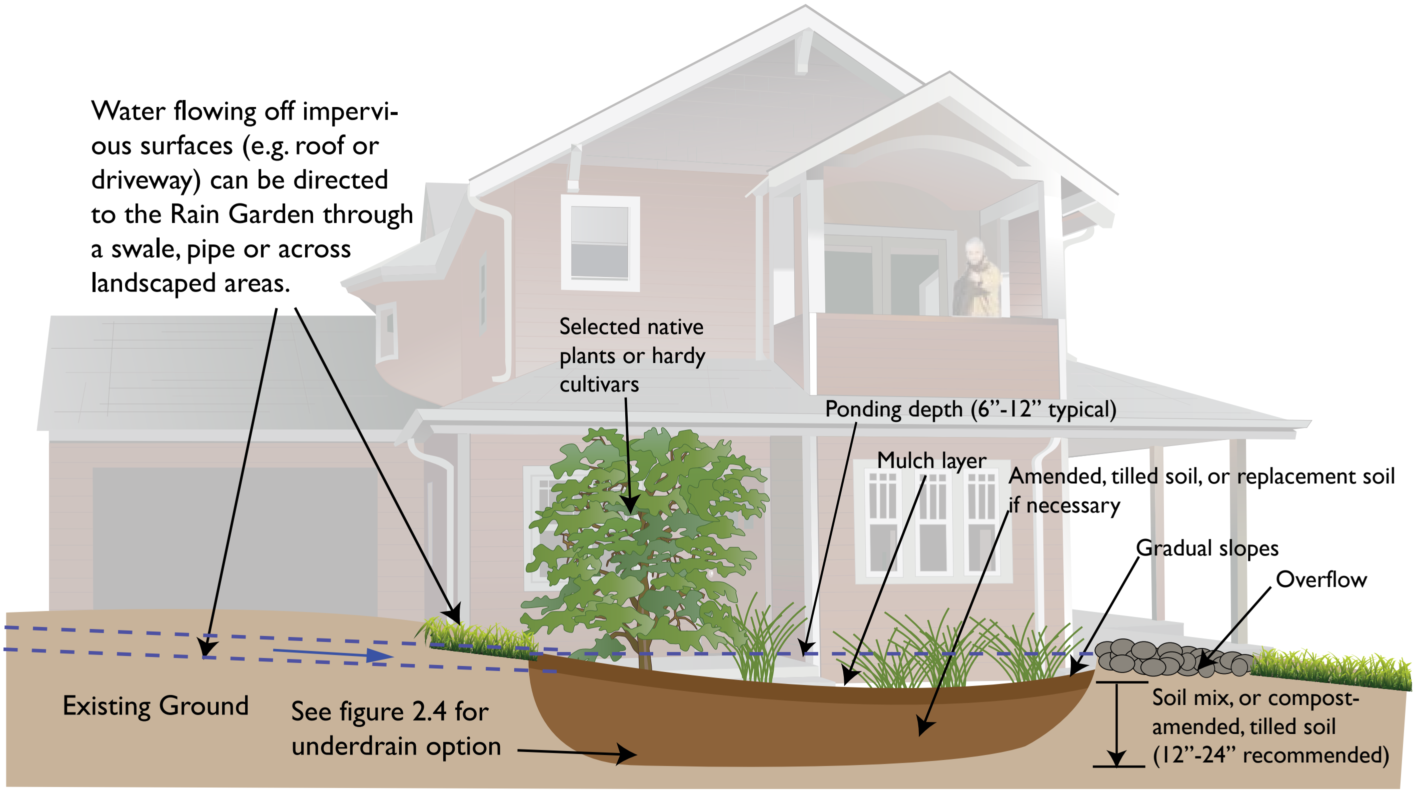


Figure 2.1. *Overview of a Rain Garden*

Adapted from Washington State University Extension, 2013

2.1. Complexity

Rain Gardens are intended to be relatively simple practices, typically ranging in size from 60 to 180 square feet, and often used in residential or small commercial applications.

Typical Rain Garden requirements:

1. Small or medium-sized excavation equipment to dig the hole for the Rain Garden
2. Purchase of materials, such as mulch and native plants adapted to the conditions of the site
3. Special soil mix if the existing soil does not percolate well
4. If needed, an underdrain system to allow the garden to drain properly after storms if the existing soils percolate very poorly.

As Rain Gardens become bigger and more complex, they are often referred to as "Bioretention Cells." As the scale, size, and complexity of the system increases, the contractor should consider whether the practice needs to be designed by an engineer or landscape architect. **Table 2.1** provides some guidance.

> **Understand the Complexity of the Rain Garden Project**
> **The intent of this guide is for practices in the SIMPLE category.** If the practice is moderate or complex, consult with an appropriate design professional.

> A Steward or homeowner with experience in landscaping can undertake a simple Rain Garden project. Consult a landscape contractor or design professional for moderate to complex projects, or when the project requirements are uncertain.



Table 2.1. Design Complexity for Rain Gardens

Design Complexity	Description	Guidance
Simple	• Small Rain Garden in residential or small-scale commercial setting • Usually 60 to 180 square feet • Treats rooftops, driveways, very small parking areas, yard areas, with a total drainage area of less than ¼ acre (or 2000 square feet of impervious surface), to each Rain Garden location • Most of the water will enter the Rain Garden as sheetflow (as opposed to water entering in pipes), with the exception of roof downspouts • No underdrain	• Design can be done by anyone with some experience in laying out Rain Gardens, such as a landscape contractor who has done similar projects • The design should consist of a sketch of the site showing setbacks, existing utilities, etc. See **Appendix A** for guidance on site assessments • Sketch of a plan view and cross-section of the Rain Garden, with material types and quantities • Construction can be accomplished by a landscape contractor. Homeowners or volunteers can do the mulching and planting, once the base of the garden is constructed. • Needs maintenance plan
Moderate	• Larger than a residential setting, such as a small business with 10 or more parking spaces, travelways, and rooftops larger than a typical residence • The practice size may range from around 200 square feet to 1,500 square feet. • Water may enter as sheet flow or through small pipes from parking or other impervious areas • May have underdrain	• Design should be provided by a landscape designer, landscape architect, engineer, or other stormwater management specialist. • Check local codes for specific site conditions or design elements that may require an engineer to be involved • Design should include plan and profile views with elevations, materials specifications, and construction details (including erosion and sediment control features during construction) • Needs maintenance plan • Construction will likely require a contractor with a wider variety of equipment
Complex	• Larger commercial or institutional applications, treating parking lots and travelways, larger rooftops, and other areas of impervious cover. • Sized based on state or local stormwater design specifications for Bioretention or similar practices, and may require plan review by the local stormwater program • Any Rain Garden or Bioretention over 1,500 square feet	• Will usually require a licensed landscape architect or engineer and a contractor with capabilities for general site development, with adherence to appropriate state standards (MDE, 2009 or VA DEQ, 2013). • Needs maintenance plan • Construction will likely require a contractor with a wider variety of equipment

Where NOT to Locate a Rain Garden

1. Within 10 feet of a building foundation
2. Over Utilities
3. Near the edge of steep slopes or bluffs
4. Near an existing or reserve septic drainfield or tank
5. In low spots that do not drain well
6. Within 2 feet of high ground water level
7. Under a tree, or in other areas that would require disturbing healthy native vegetation
8. Where there is high groundwatrer during the winter
9. Near Wells- Stay back 50 feet from confined wells, or 100 feet from unconfined wells

Figure 2.2. *Examples of site constraints for locating a Rain Garden*
(Source: Washington State University Extension, 2013)

2.2. Location & Feasibility

When deciding where to build a Rain Garden, consider the siting constraints illustrated in **Figure 2.2,** and also the following considerations:

Shape of the Land A Rain Garden needs to be located in a low spot where stormwater runoff from the surrounding landscape and/or rooftops can drain to it. For the footprint of the Rain Garden itself, look for a relatively flat area, as the basin of the Rain Garden should be as flat as possible. For sites with more slope (up to 12%), Rain Gardens can be split into individual cells that step down a gradual slope. When the uphill cell(s) fill up with water, they can spill over into channels that move the water to the next downhill cell.

Proximity to Buildings To avoid the risk of seepage into basements, do not install Rain Gardens adjacent to building foundations. Recommended setbacks from foundations are:

- 10 feet if Rain Garden is downhill from building (preferred).
- At least 25 feet if the Rain Garden is uphill from the building. This is not a preferred option, but can be used if an overflow channel directs water away from the building and to a downhill channel, driveway, or street.

Do:

- Conduct a full site assessment to choose best spot for Rain Garden
- Place Rain Garden in a low spot
- Consider "treatment train" options, such as catching roof runoff in Rain Barrels and draining those into the Rain Garden

Don't:

- Place Rain Garden in a soggy area (poorly drained soil) that stays wet for many days after rain
- Place Rain Garden within 10 feet of building foundation
- Place Rain Garden under tree canopy, above utilities or septic fields, or next to wells

Other Setbacks For lots with individual wells, locate the Rain Garden at least 50 feet away from the well. Also, keep Rain Gardens outside the drip line of existing trees to avoid damaging tree roots during excavation and do not place them over septic fields.

Proximity to Utilities Interference with underground utilities should be avoided whenever possible, particularly water, sewer, and gas lines. Conflicts with water and sewer lateral pipes (e.g., house connections) might be unavoidable, in which case excavation should be done very carefully to avoid damaging those pipes. Additionally, designers should ensure that future tree canopy growth in the Rain Garden will not interfere with existing overhead utility lines. Call Miss Utility to check the proposed site for existing utilities prior to finalizing the Rain Garden location. Also, be aware that Miss Utility may not always mark private cable, propane, electric, and similar lines, so some additional site work may be necessary to locate these.

Water Table Rain Gardens should not be installed in areas that stay wet more than a few days after a rain event or in any area that appears to be a wetland.

Treatment Train A treatment train is a series of stormwater management features with the uphill practices draining to the subsequent practices in the series. The treatment train provides multiple opportunities for stormwater to be retained, filtered, and/or infiltrated, reducing stormwater impacts from a site. At the residential scale, various practices could be combined into a treatment train. For example, a Rain Barrel or cistern could collect roof runoff and drain it slowly to a Conservation Landscape or Rain Garden. A Green Roof could drain to a Permeable Hardscape or Conservation Landscape. Many combinations are possible! Consider including other practices before or after water flows into the Rain Garden.

Get A Rain Garden and Not a Pond

Based on the existing soils, some Rain Gardens will naturally drain better than others. Water is not supposed to sit in a Rain Garden any more than two days after a storm, and the design should reflect the existing site conditions.

As existing soils range from good infiltration rates to poor, there are three basic options for the design:

1. If existing soils percolate/infiltrate well (greater than 1 inch per hour) and have a sandy or sandy-loam texture, based on the analysis presented in **Appendix B,** the existing soils can be used as the filter bed, although it is recommended that soil amendments be added.
2. If the existing soils do not percolate/infiltrate as well (less than 1 inch per hour but greater than ½ inch per hour, using the procedure in **Appendix B**), it is advised that a pre-made Rain Garden soil mix -- usually purchased from a local vendor -- be used to replace the existing soil for the filter bed.
3. If the existing soils percolate poorly (less than ½ inch per hour based on **Appendix B**) and/or the soil has high clay content, the recommendation is to use the pre-made mix AND an underlying underdrain system to allow the filter bed to drain adequately. If this is the case, perhaps consider a Conservation Landscape or other practice in this manual that may be more affordable and functional for the site.

See the section on *Soil Texture and Infiltration* for more details on these options.

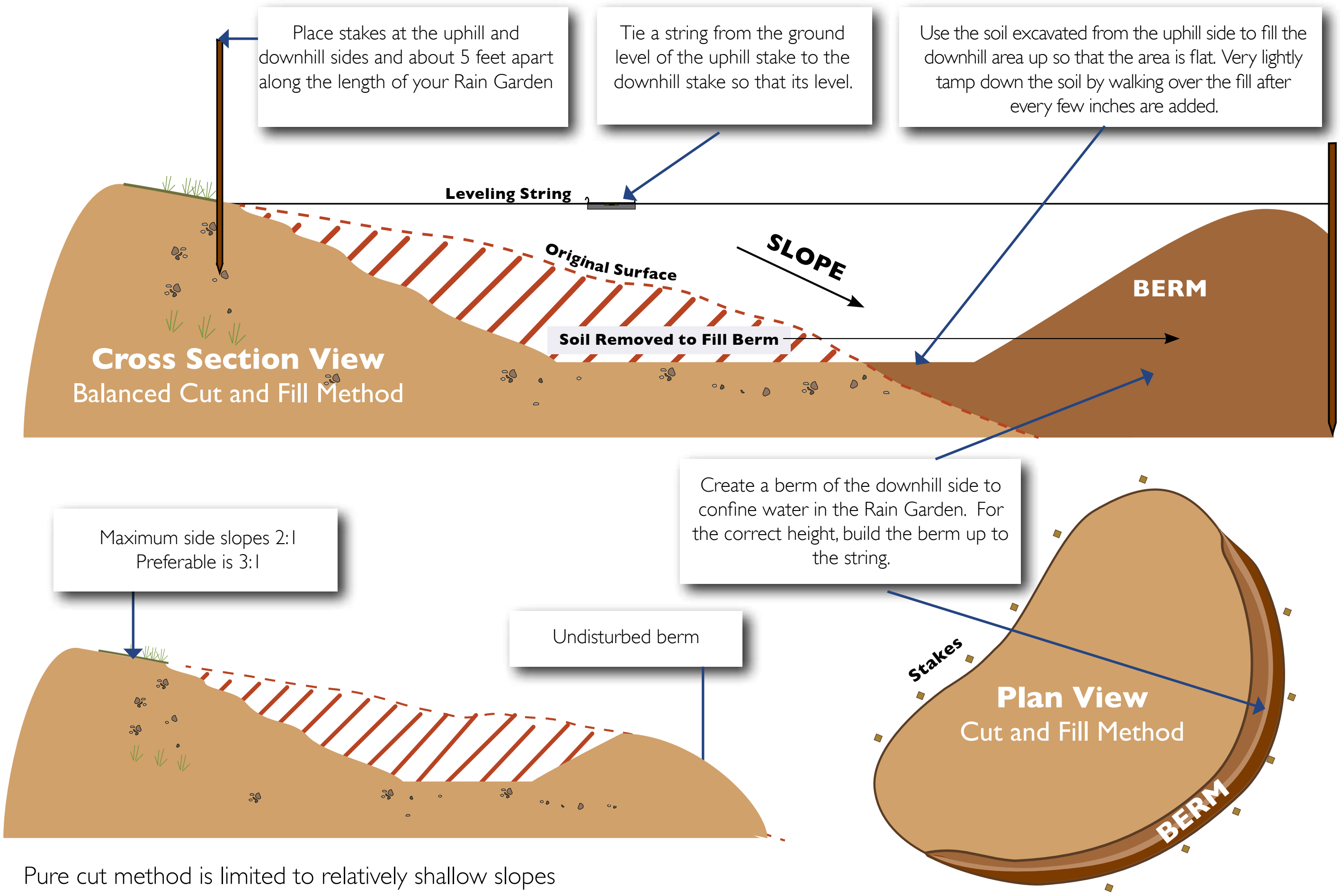


Figure 2.3. *Example of excavation and fill to create a downhill berm to contain the Rain Garden*
(Source: Washington State University Extension, 2013)

2.3. Design

The following section outlines important factors for Rain Garden design. It is important to have an accurate plan showing the various layers and their respective depths and dimensions.

Rain Garden Size A **Rain Garden Worksheet** accompanies this manual to help calculate the optimal size of the Rain Garden for capturing stormwater runoff from its respective drainage area. This worksheet can also help determine material quantities needed for a Rain Garden of a given size, estimate costs for those materials, and estimate the amount of material (i.e., existing soil) that may need to be removed from the site due to excavation and soil replacement. Finally, the worksheet estimates how much nutrient and sediment pollution the Rain Garden can reduce by absorbing and treating stormwater runoff from the drainage area that flows to it. The Rain Garden Worksheet *can be found here.*

As a very general rule, the Rain Garden surface area (not counting side slopes leading down to the flat basin) should be approximately 80 square feet for every 1,000 square feet of impervious area draining to the Rain Garden. This assumes a soil filter bed depth of 2 feet and 6 inches of ponding on the surface. This sizing allows the Rain Garden to capture the runoff generated by the first 1 inch of rainfall from the drainage area. Larger amounts of rain will fill the Rain Garden and some will bypass or overflow to a downhill area that is safe to convey the water.

Ponding Make sure the plan also includes side slopes and a downstream berm if needed so that water will pond (like in a bathtub) to the desired ponding depth without spilling out of the Rain Garden. This will be necessary if the Rain Garden is placed on a moderate slope (see **Figure 2.3**).

Soil Texture and Infiltration See **Appendix B** for detailed guidance on how to test soil texture and infiltration rates. The rate at which the existing soil at the proposed Rain Garden site percolates will have a significant impact on the design, as described in the box above. Soils that already have good infiltration rates can be used in the Rain Garden, with added soil amendments (see below). Whereas, soils that have very slow infiltration rates will need to be replaced with a sandy loam soil mix (see **Section 2.4** for mix recipe) and may also need an underdrain in order to properly drain down between rain storms. The minimum infiltration rate needed for a Rain Garden without an underdrain is ½ inch per hour. Many Rain Gardens do not have underdrains as they add complexity, cost, and labor to the project. However, if adding an underdrain is needed to make a Rain Garden site successful, see the section below about underdrains for guidance.

Soil Amendments For existing soils that have a sufficient infiltration rate, soil replacement is not needed but soil amendments are recommended. Till in 2 inches of compost or leaf humus into the existing soil in order to improve plant growth and water absorption.

> **A Good Soil Mix Will Help Ensure the Success of the Rain Garden**
>
> The corollary is also true: if the soil mix has too much clay or gets compacted during installation, the Rain Garden may not drain properly or as anticipated.

Filter Bed Soil Where the existing soil does need to be replaced due to low infiltration rates, make sure to use a suitable filter bed soil mix at an appropriate depth. The soil should be a uniform mix, free of stones, stumps, roots, or other similar objects larger than two inches. The soil mix should also be free of invasive plants and noxious weeds. If Rain Garden or Bioretention soil mix is purchased, check with the vendor to see that the mix meets specifications outlined in the appropriate state stormwater manual. If trees are included in the Rain Garden planting plan, tree planting holes in the filter bed should be around 4 feet deep to provide enough soil volume for the root structure of mature trees. Use grasses and perennial flowers instead of trees to landscape shallower filter beds. See **Section 2.5** for plant suggestions.

Excess Soil Plan for a place to dispose of or use excess dirt when the Rain Garden is excavated. Some of the soil may be used to make a berm on the lower edge of the Rain Garden, but there will likely still be leftover soil. If some of the excavated soil is used on the lot, make sure to add some topsoil, as that will help grass or other vegetation to establish.

In addition -- depending on the size of the installation, anticipated weather, and number of days needed for installation -- it may be advisable to place silt fence downhill from the Rain Garden excavation and/or stockpiles of excavated material. Stockpiles can also be covered temporarily with a tarp. Take all precautions necessary to not contribute sediment to downhill storm drainage systems and waterways.

> **Terminology**
>
> Commonly, "Rain Garden" is used to describe a practice that has no underdrain. Once the additional layers are added, a Rain Garden becomes a "bioretention" or "biofilter," though terminology for stormwater best management practices has not truly been standardized.

Considering an Underdrain? Underdrains are perforated pipes in a bed of gravel. An underdrain allows more water to flow through a Rain Garden by draining some water from the bottom of the practice. An underdrain also prevents a Rain Garden from staying soggy for too long.

The underdrain pipe is placed in the bottom-most layer of the Rain Garden, surrounded by washed gravel. Two sizes of gravel should be used: a 9 – 12 inch layer that encases the perforated pipe with ⅜ - ¾ inch gravel (commonly available #57 rounded gravel – avoid angular, crushed stone) and a 3 – 4 inch layer on top of this of smaller pea gravel. The pea gravel keeps the soil mix from filtering down into the underdrain (see Materials listed in **Table 2.2**).

The underdrain pipe should be a 3- or 4-inch perforated smooth-walled pipe, either black landscape pipe or PVC. The Maryland Department of the Environment specifies that perforated underdrain pipes be wrapped in two layers of ¼ inch stainless steel wire mesh (often called hardware cloth) to help prevent clogging. Do not wrap the underdrain pipe in geotextile filter fabric, as this will clog. The pipe should be installed with a slight slope of about 1%. Where the perforated underdrain pipe exits the Rain Garden area, it should be connected to a solid pipe that runs to a downhill point where it opens to daylight and can release the water. An apron of stone (at least 3 inches deep) should be placed at the pipe outlet to prevent erosion at that spot.

Best practice would include a cleanout and observation well when using an underdrain. This is a capped, vertical, non-perforated pipe that connects to the underdrain, usually with a 45-degree elbow. It extends up through the Rain Garden layers so that if the underdrain gets clogged, there is easy access to clear it with a plumbing snake or water jet. Finally, adding an underdrain will increase the excavation depth of the Rain Garden by a minimum of 12 inches, at least for a narrow trench area to house the underdrain pipe. See **Figure 2.4** for a cross-section of a typical Rain Garden with an underdrain layer and cleanout.

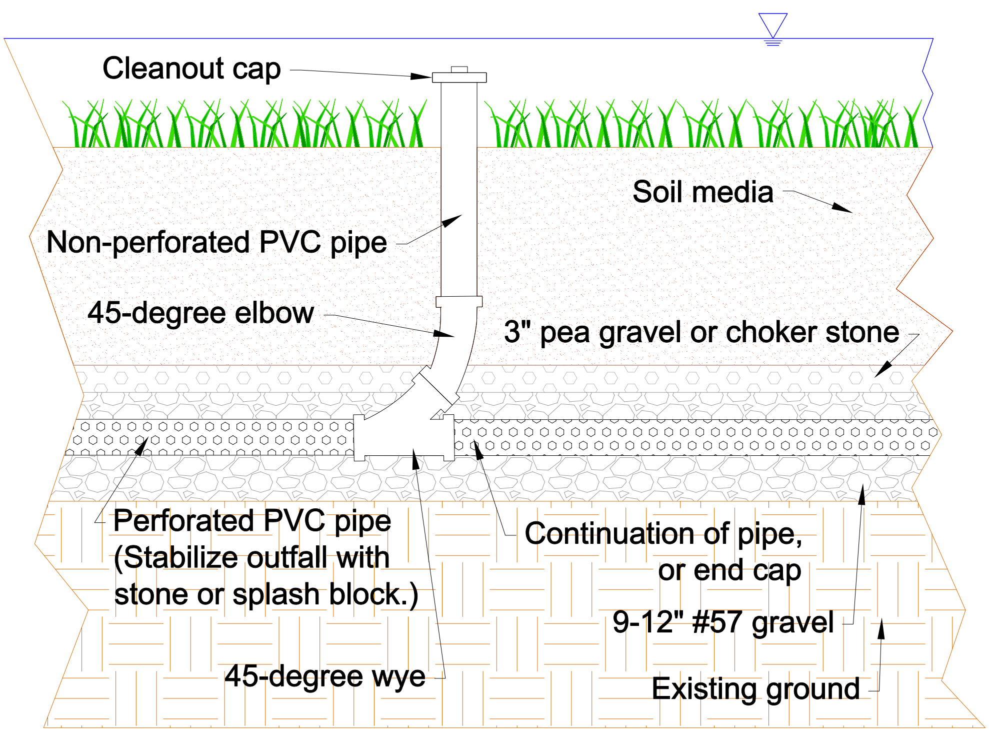


Figure 2.4. *Cross-section of Bioretention With Underdrain*

Pre-Treatment Pre-treatment refers to something that will remove leaves, grit from the roof, and larger particles of dirt from the runoff before it enters the Rain Garden, helping to keep the Rain Garden from clogging. Pre-treatment can consist of gutter leaf screens (for Rain Gardens that treat roof runoff), a strip of grass about 5 feet wide around the Rain Garden, or a stone and/or a shallow grass channel that leads into the Rain Garden. This width should be increased for Rain Gardens that are expected to receive higher levels of sediment than would be generated by a typical yard or roof.

Inlets As much as possible, runoff water should enter the Rain Garden as diffused flow. However, there will likely be at least one inlet or area of concentrated flow (e.g., from a pipe or uphill area where water becomes more concentrated). If the Rain Garden receives stormwater from gutter downspouts, for example, incorporate a pad of river cobble stone or some other means to reduce flow velocity at the mouth of the downspout. Add a strip of stone to other "transition" areas where concentrated water flowing into the Rain Garden may cause erosion. Where a Rain Garden is located next to a sidewalk, patio or driveway, consider including a similar treatment to prevent erosion and undercutting at the edge where the bed meets the hardscape. This stone strip should run the entire length of the Rain Garden edge where it meets the hard surface, be underlain with filter fabric, and be approximately 12 inches wide and 12 inches deep.

Overflow The Rain Garden will need to have a place to safely overflow when it fills up during large rain events without causing erosion, damage to building foundations, or problems with downhill sidewalks or walkways. The height of the overflow spillway will need to be set at the level of the maximum water ponding depth that is desired. The spillway can be made of compacted soil topped with filter fabric and river cobble stone, or similar material. See **Figure 2.5** for several examples. The recommended ponding depth is 6 inches, and calculations in the *Rain Garden Worksheet* assume 6 inches of ponding. The maximum ponding depth should be 12 inches. If children are likely to be playing near the practice, shallower ponding depth is recommended. Also, extra care should be taken to limit the slopes on the sides, and/or limit access to the practice.

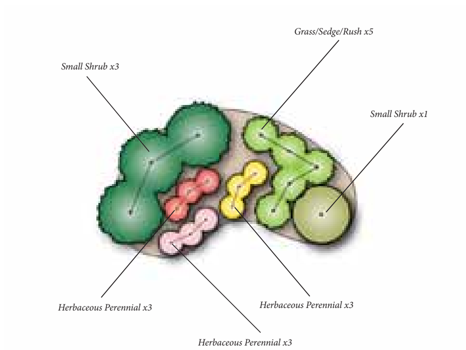
Ponding depth set by stone weir (middle of photo below mulch).

Ponding depth set with timber weir in berm

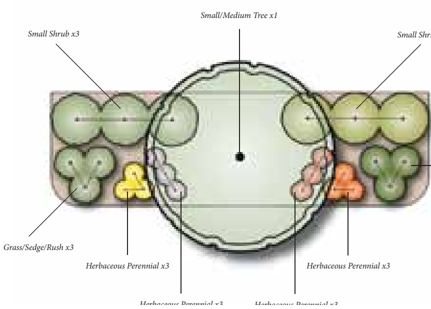
Ponding depth set with earth and timber weir

Figure 2.5. *Examples of How to Set the Ponding Depth*

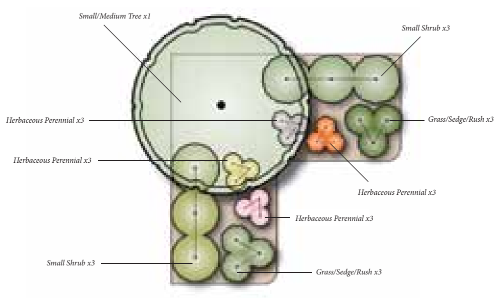
Shape A Rain Garden can be any shape as long as the basin surface is flat, the side slopes are not steep, and the water flowing into the garden spreads out evenly over the surface and does not concentrate at one end or corner of the Rain Garden area, especially close to the overflow. **Figure 2.6** illustrates several typical Rain Garden shapes. **Figure 2.7** portrays a different concept where the Rain Garden (or stormwater planter) is associated with the building design and incorporated in a concrete or other type of planter box. These usually treat rooftop water.



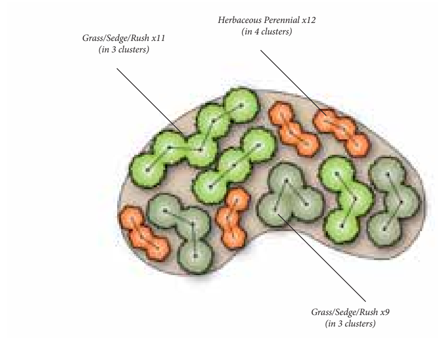
Kidney shape, in yard



Edge shape, often along property line



Corner layout



Alternate Kidney shape

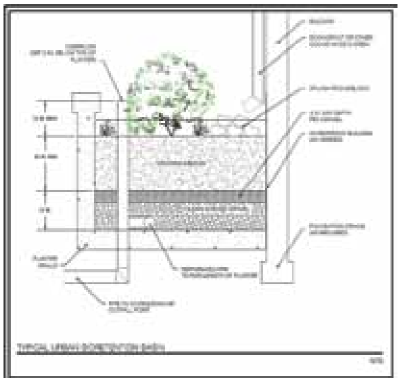
Figure 2.6. *Templates for Various Rain Garden Shapes, from WSA Conservation Landscape Design Tool*

Layouts or templates can be very similar between Conservation Landscapes and Rain Gardens, with the primary differences being Rain Garden ponding storage, and plant selection.

Rain Garden in a Box:

Some Rain Garden applications can be incorporated into planter boxes associated with a building, usually designed to treat runoff from the roof. These are sometimes referred to as stormwater planters or urban Bioretention. These generally qualify as **moderate** complexity practices, as presented in **Table 2.1**, and thus may require design support from a stormwater professional, perhaps working with the project architect**.** These designs make the Rain Garden concept applicable in a densely developed setting. As shown below, most of these will include an underdrain.

Rain Garden in a Box (Stormwater Planter)



Typical Design for Stormwater Planter

Figure 2.7. *Stormwater Planter / Rain Garden in a Box (option)*



2.4. Materials

Table 2.2. Material Specifications for Rain Gardens

(listed in order of location in a Rain Garden cross-section, top to bottom)

Material	Specifications	Size	Depth	Notes
Mulch	Double-shredded hardwood or approved pine straw substitute	N/A	2 – 3 inches	Aged minimum of 6 months; do not let mulch touch base of plants
Cobble/Stone	Washed river rock, large gravel, or small rip-rap	3 - 5 inch diameter stone	1 or 2 layers deep	Use at downspouts, inlets, outlets, and along hardscape edges as needed to dissipate flow and prevent soil erosion Use filter fabric under stone
Compost *(if not replacing the soil)*	The material should be well composted and free of viable weed seeds Fresh manure should not be used because of its high bacteria and nutrient levels	N/A	Add 2 inches of compost across Rain Garden surface area and incorporate into top 6 inches of soil	Follow recommendations from soil test if compost amendments are suggested
Filter bed soil mix *(if replacing the soil)*	Bioretention soil mix from a local vendor OR mixture of about 80% sand, 10% topsoil, and 10% well-composted leaf mulch, mixed well together	N/A	Typically 18 – 24 inches for a residential Rain Garden If planting trees, use more soil volume around the tree	USDA soil type loamy sand or sandy loam, with high sand content. Topsoil no more than 5 to 10% of mix
Underdrain pipe *(if using an underdrain)*	Perforated, corrugated (with smooth-wall interior) HDPE landscape pipe or equivalent	3 - 4 inches		Clean-out, observation well recommended
Underdrain gravel *(if using an underdrain)*	#57 rounded gravel	½ - 1 ½ inch stone	9 - 12 inches	Must be washed clean at quarry; avoid crushed stone, angular type stone
Pea gravel *(if using an underdrain)*	#8 or #78 stone	¼ - ½ inch stone	3 – 4 inches	Must be washed clean at quarry

2.5. Plants

Native plant species are preferred over non-native species, but some ornamental species may be used for landscaping effect if they are not aggressive or invasive. Plants should be specified for different areas of the Rain Garden, as the bottom of the Rain Garden will be wetter than the side slopes or upper edges. Plants in the bottom of a Rain Garden must tolerate both periodic inundation and very dry conditions. Thus, these plants must be very adaptable. The slopes and especially the upper edges of a Rain Garden are inundated rarely, so plants that can tolerate drier conditions are specified for this zone.

The plants recommended in the *WSA Conservation Landscape Design Tool* should be suitable for different areas within Rain Gardens. There are many other resources for Rain Garden/Bioretention plant recommendations. To get started, consult those resources listed in **Section 2.8.**

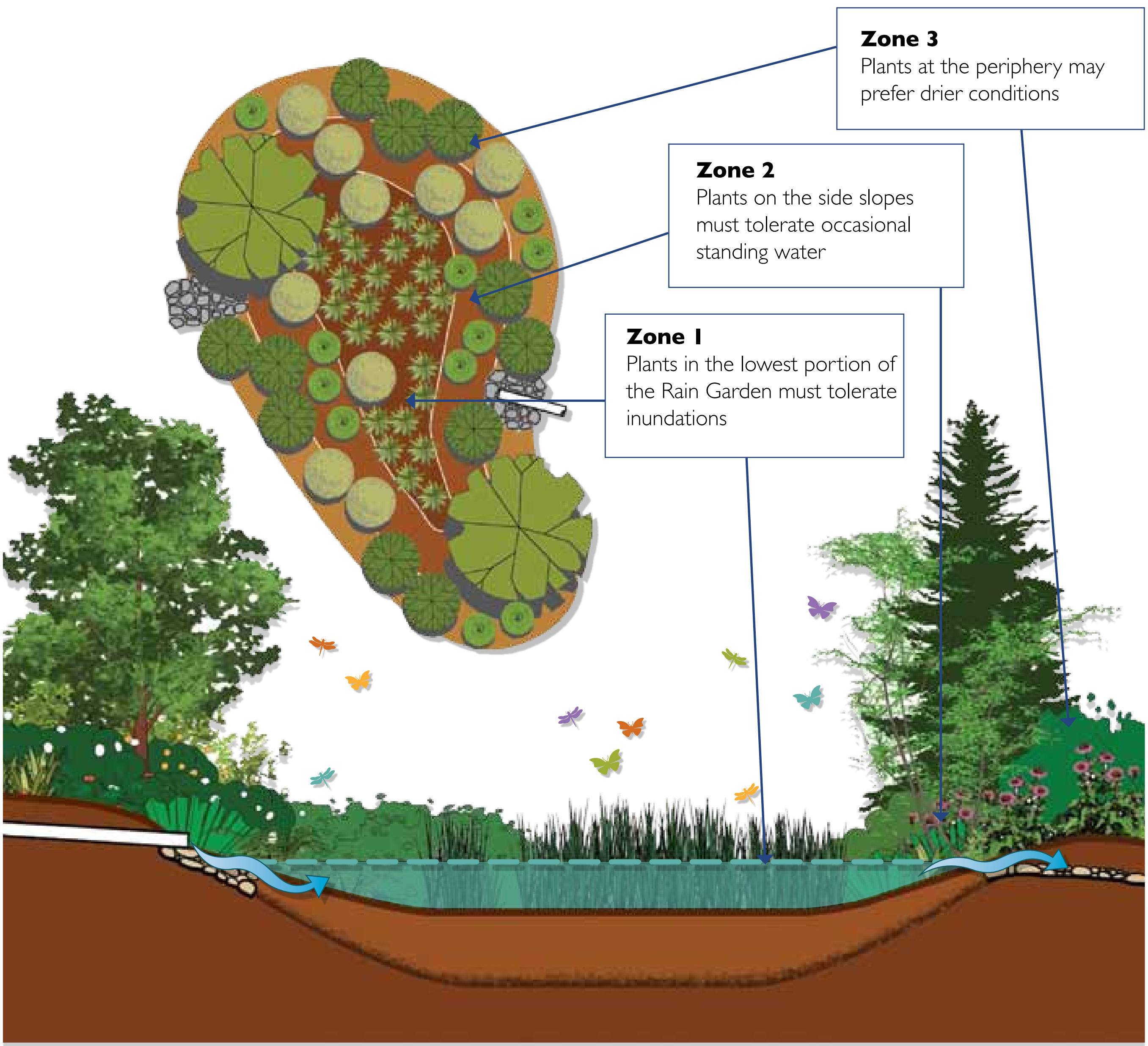


Figure 2.8. *Planting zones within a Rain Garden based on moisture*
(Source: Washington State University Extension, 2013)

Beware: Rain Gardens Can Become Very Dry

Some people make the mistake of selecting plants more adapted to a wetland. If the soil at the site drains moderately well, expect very dry conditions on occasion in the summer. Plants must be selected that are adaptable to the extremes of periodic inundation as well as periodic drought .

Match The Rain Garden to the Owner

Like all other gardens, Rain Gardens are successful if they are maintained. In addition to weeding as in traditional landscapes, Rain Garden inlets and overflows must remain clear to ensure that water enters and exits the Rain Garden. Leaves and excess perennial vegetation should be removed in the spring. Some owners are willing and able to regularly weed, prune, and mulch their Rain Gardens, while others may want a simpler approach that involves periodic cutting and some occasional weeding. Make sure the selection of plant types and layout is a good match for the owner's capabilities.

2.6. Construction

Step 1 - Outline the Garden & Mark Utilities Clearly mark both the boundaries of the Rain Garden and any nearby underground utilities (call Miss Utility at least two business days before digging). Also try to identify private propane, cable, electric, and other small lines. Make sure to have a plan and phone numbers of who to call in case there is any damage to utilities. Confirm the flow of water into the Rain Garden, checking the areas that are to contribute runoff to the practice. This may require using a survey level or hand level and a survey rod to check spot elevations and confirm flow paths.

Figure 2.9. *Have all underground utilities in the vicinity marked by Miss Utility before doing any digging.*

Step 2 - Erosion Control It is best to dig the Rain Garden when the weather is expected to be dry for several days. Install a row of silt fence below the construction site in case of rain. Cover stockpiles of soil temporarily with a tarp to prevent the material washing away.

Figure 2.10. *Install silt fence below the Rain Garden construction site for erosion and sediment control.*

Step 3 - Dig Basin
Elevations are Key:
Excavate the Rain Garden area and side slopes. The Rain Garden surface area should be as flat as possible. Adjacent side slopes should be no steeper than 1 foot of vertical drop for every 3 horizontal feet, referred to as a 3:1 slope. In order to not compact the soil, ensure that heavy equipment works from the sides to excavate the Rain Garden to the depth and dimensions specified in the design.

The outlet or overflow should be set at the maximum ponding elevation and slope downward away from the basin, with the flow path unobstructed. If the Rain Garden is going to be installed on a slope, see **Figure 2.3** to help guide the balance of excavation and fill for building a berm on the downhill side: the soil removed from the upper portion will build up the containment berm on the lower portion to create the basin. The berm should be thoroughly compacted so it does not fail when it gets saturated. If the site soils are very loose or sandy, this may require some clay to be added.

Figure 2.11. *Excavate from the side in order to prevent compaction within the Rain Garden.*

The bottom of the excavation should be as deep as necessary to account for the component layers included in the design. Working downward from the top, these include ponding depth, mulch, soil filter bed, pea gravel, and underdrain gravel, as necessary. For example:

6 inches ponding +
3 inches mulch +
24 inches soil =
33 inches deep, below the surface elevation.
If using an underdrain, also excavate the trench where the pipe will exit the Rain Garden to daylight. For underdrains, ensure that excavation depth accounts for the underdrain gravel approximately an additional 12 inches.

Step 4 - Rake or Till Bottom of Basin Rake or till the bottom soils as deep as possible to promote greater infiltration. Ensure that the bottom is as level as possible.

Step 5 - Install the Underdrain If an underdrain will be used, place about 3 inches of clean #57 rounded gravel evenly across the bottom of the pit. Place the perforated underdrain pipe at a slight slope (e.g., 1%) on top of the initial layer of gravel (see **Figure 2.12**). Add a non-perforated vertical clean-out pipe that extends above the top elevation of the Rain Garden; connect to the underdrain pipe with a 45-degree elbow and add a screw cap to the top of the clean-out pipe. Pack the remaining #57 stone around the underdrain pipe so that the pipe is covered by about 3 inches of gravel. Add about 3 inches of pea gravel so that it completely covers the #57 gravel layer.

Figure 2.12. *Install underdrain on top of initial layer of gravel.*

Step 6 - Install Inlet, Overflow and Berm Install any pre-treatment features associated with the plan, such as a stone pad at the mouth of downspouts. Seed and straw all side slopes, berms, and disturbed areas, unless these areas will be landscaped with other vegetation and mulch. Refer to Step 5 in **Section 1.6** – Construction of the Conservation Landscape chapter for detailed instructions for the stone inlet channel..

Step 7 - Spread Soil Replacement Mix or Compost Amendment
If there is no underdrain, place the soil mix directly into the bottom of the excavation. If an underdrain is used, place the soil mix on top of the pea gravel layer. Place the soil mix until the desired top elevation of the Rain Garden is achieved. Water the soil mix well with a hose to allow it to settle. Wait a few days to check for more settling, and add additional soil as needed.

Do:

- Call Miss Utility before digging
- Use appropriate soil mix
- Direct runoff to Rain Garden
- Water plants during 1st month
- Inspect finished Rain Garden after several storms

Don't:

- Compact the soil
- Place Rain Garden within 10 feet of building foundation
- Install Rain Gardens under trees

Figure 2.13. *Double-check elevations throughout the construction process to ensure each layer is at the correct height according to the Rain Garden design.*

Figure 2.14. *Add soil mix into excavated area until it reaches desired elevation for Rain Garden surface.*

Step 8 - Install Plants Prepare holes for trees and shrubs on Rain Garden basin surface (if used), install vegetation, and water accordingly. Plant trees and shrubs after they go dormant in the late fall, if possible. Avoid trees and shrubs on the berm, if it is present. Install any temporary irrigation. Place the surface cover (mulch, river stone, and/or grasses) around the plants, as per the design. Do not let mulch touch the base of plants. Water plants during weeks of no rain for at least the first two to three months.

Step 9 - Inspect Inspect the Rain Garden after several rain events to look for any needed adjustments: ensure that runoff is entering the Rain Garden properly, the garden is draining properly, there is no erosion at inlets and outlets, and plants are surviving. Remove silt fence once the site is sufficiently vegetated and stable.

2.7. Maintenance

Table 2.3. Recommended Maintenance for Rain Gardens

Maintenance Tasks	Frequency
• Water often during the first 2 months, and then as needed during first growing season (April-October), depending on rainfall • Expect up to 10% of the plant stock to fail in the first year, and plan accordingly for replacement plants	Upon establishment. Small herbaceous plants will require more watering
• Check and repair eroded areas • Check inlets and overflow areas for debris or leaves that are blocking flow	After heavy rains in first 6 months; periodically in subsequent years
• Remove weeds by hand	Monthly for first growing season; every 3 months in subsequent years
• For meadow type Rain Gardens consisting of grasses, mow the Rain Garden in early spring • For other types of plantings, check for winter damage and add mulch to bare spots as desired (2–3 inches). Do not let much touch base of plants. • Cut back perennials and remove dead growth • High winter wildlife value perennials/grasses can be left until they start sprouting in the spring	February or March
• Add reinforcement planting to maintain the desired vegetation density • Prune trees and shrubs • Thin herbaceous plants as desired • Remove excess leaf matter after all leaves have fallen in the fall	Fall
• Remove invasive plants using recommended control methods • Remove any dead or diseased plants • Stabilize bare areas draining to the Rain Garden, especially is there is erosion • Remove trash	As needed
• Remove accumulated sediment at inflow points	Annually

2.8. Resources & References

Albemarle County, VA, *Piedmont Native Plant Data Base*
http://www.albemarle.org/nativeplants/

Anne Arundel County Rain Garden webpage
http://www.aacounty.org/DPW/Highways/RainGarden.cfm

Ladybird Johnson Plant Database
http://www.wildflower.org/plants/

Maryland Department of the Environment (revised 2009). Maryland Stormwater Design Manual, Vols. 1 & 2
Chesapeake Conservation Network, Homeowner Guide for a More Bay-Friendly Property, Appendix C, List of Plant Resources (2013)
http://chesapeakestormwater.net/download/3859/

North American Native Plant Society
http://www.nanps.org/

StormwaterPA website, *Rain Gardens: Saving Streams One Yard at a Time* video
http://www.stormwaterpa.org/raingarden.html

USDA, *Plants Database*,
http://plants.usda.gov/java/

Virginia Department of Environmental Quality. 2013. *Virginia Stormwater BMP Specifications – Rev. 2013 (DRAFT).* Richmond, VA. Available at:
http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications.aspx

Washington State University Extension, *Rain Garden Handbook for Western Washington: A Guide for Design, Installation, and Maintenance*, 2013
https://fortress.wa.gov/ecy/publications/documents/1310027.pdf

Another possible native plant resource:
http://www.iconservepa.org/plantsmart/nativeplants/index.htm

Low Impact Development Center – Bioretention – Rain Gardens Design – Infiltration Model
http://www.lid-stormwater.net/index.html

Schott Nurseries – Native Trees/Shrubs
http://www.schottnurseries.com/

Native Plants – Super Plugs
http://www.northcreeknurseries.com/

Pine Straw Store – pine straw mulch
http://pinestraw.com/pine-mulch-facts/

Rain Gardens Across Maryland
https://extension.umd.edu/sites/default/files/_docs/articles/Rain_Gardens_Across_MD.pdf

Permeable Hardscapes

(Source: aaees.org)

(Source: Center for Neighborhood Technology)

Purpose & Benefits

- Stormwater runoff reduction
- High pollutant removal
- Control localized drainage problems
- Attractive alternative for walkways and driveways

Description

Permeable Hardscape are alternatives to traditional paving materials that allow water to seep into the ground. They can be used in a wide range of settings, from a simple pathway or small patio up to a large commercial parking lot. Over the last few years, the market for these materials has grown. Currently, some very attractive and cost-effective options are available for small projects. The chapter focuses on small-scale, residential applications (e.g., patios, walkways), largely using permeable pavers. Larger applications – including driveways, travelways, and parking – can use a variety of materials, including pervious concrete or porous asphalt, and specifications are commonly included in state stormwater manuals.

What to Expect

Permeable Hardscape are quite similar to and replace traditional paving or hardscaped areas, except the water is intended to move through the surface and percolate into the ground, instead of running off as quickly as possible. The gravel bed underneath the pavement surface is designed to hold water temporarily, so it will be deeper than that of traditional paving. Finally, the paved surface itself is different, and the contractor needs to ensure that the surface is installed correctly and does not become clogged during construction. Routine maintenance of Permeable Hardscaping includes sweeping or using a leaf blower to remove fine particles from between the paver stones. Larger applications may involve using a vacuum sweeper to keep the pavement surface from clogging.

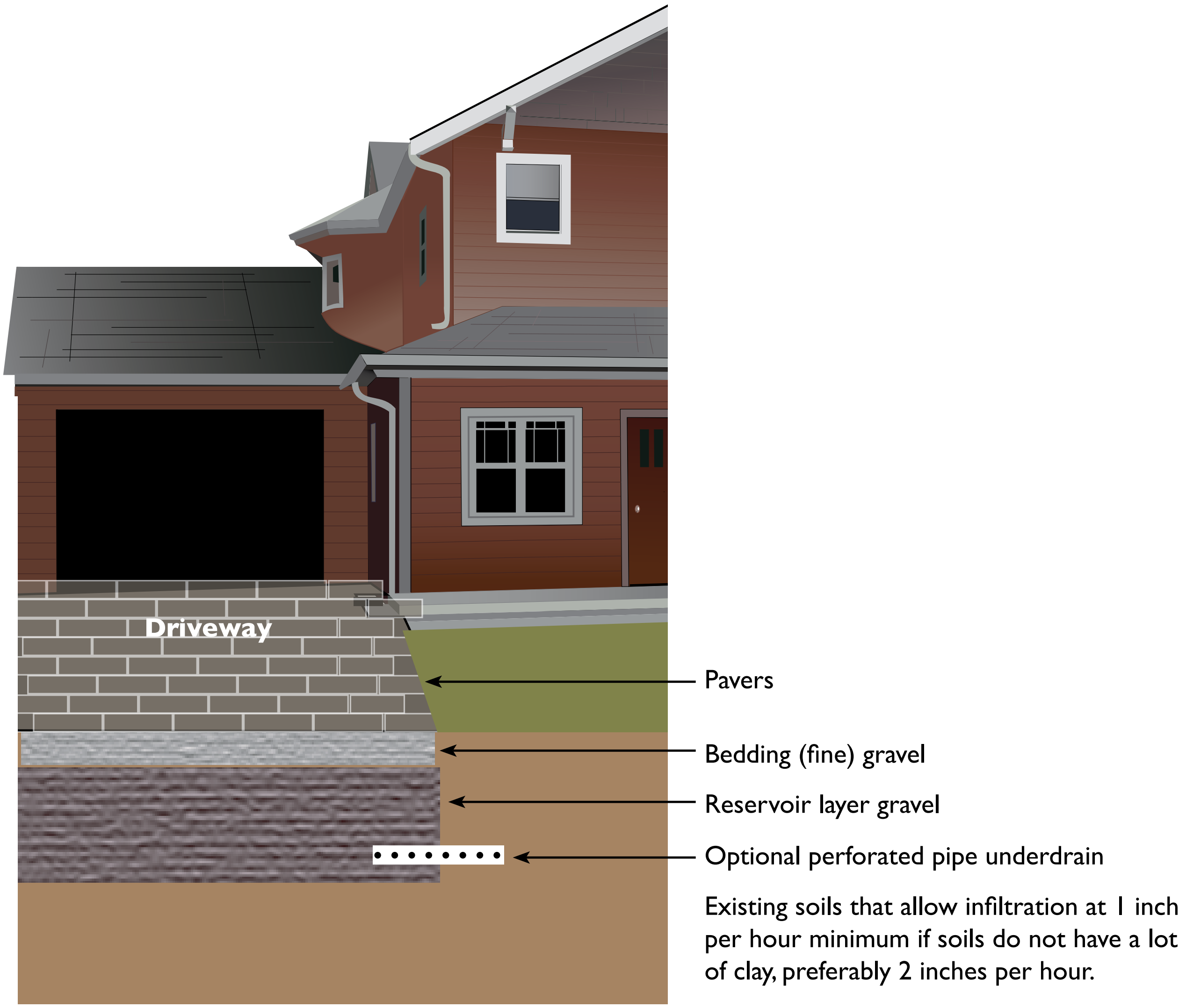


Figure 3.1. *Overview of a typical Permeable Hardscape*

3.1. Complexity

Permeable Hardscaping is similar to traditional paving or hardscaping, but special considerations are needed to ensure functionality for stormwater management. The actual installation is slightly different. The excavation is deeper and extra precaution should be taken to prevent clogging during construction. As the scale of the application increases, the design becomes more complex, and the services of a design professional are advisable, as outlined in **Table 3.1.**

Permeable Hardscapes should be designed and constructed by a contractor with experience and knowledge about this practice. The design and construction details provided in this chapter may allow Stewards and homeowners to better understand the practice, but not to construct this practice without the help of an experienced contractor.

Table 3.1. Design Complexity for Permeable Hardscapes

Design Complexity	Description	Guidance
Simple	• Very small scale pedestrian surfaces, including walkways and small patios	• Design can be completed using simple design tools included in this chapter • Make sure the soil will allow for stormwater to infiltrate • **Appendix B** includes some guidance for simple soils testing • Confirm the practice is separated from any building foundation • Take care during construction to make sure that the pavers do not become clogged
Moderate	• Larger pedestrian surfaces and small driving surfaces • Examples include larger patio surfaces or driveways (>1,000 square feet)	• Consult with a civil engineer, landscape architect, or experienced specialist to ensure that a driveway meets safety and structural standards • Paving surface can include permeable concrete, porous asphalt, reinforced grid pavers, and other proprietary products • If this practice will be installed close to a basement, ensure that proper precautions are taken to prevent leaking or compromising the foundation
Complex	• Parking lots, travelways, or other large impervious areas • Any surface that needs to be designed to support truck traffic • Typically in a commercial or institutional setting	• Design requires a professional engineer, landscape architect, or equivalent, with adherence to appropriate state standards. (MDE, 2009 or VA DEQ, 2013, for example) • Pretreatment often includes a formal forebay cell • May require more maintenance than other permeable surfaces • Depth depends on the structural requirements of the design

Figures 3.2 and 3.3 exemplify residential to light commercial scale projects that fall somewhere between the simple and moderate levels of complexity. They are small, but intended for parking, which makes structural considerations more complex. They do not connect to municipal stormwater infrastructure, therefore eliminating the need to tie an underdrain to an existing storm structure. **Figure 3.1** above shows a typical cross section for a moderate to complex system.

Figure 3.2. *Permeable paver installation for off-street parking, prior to applying grass seed. In this situation, the downspout could be directed to the pavers since the roof is small and the runoff should be relatively clean.*

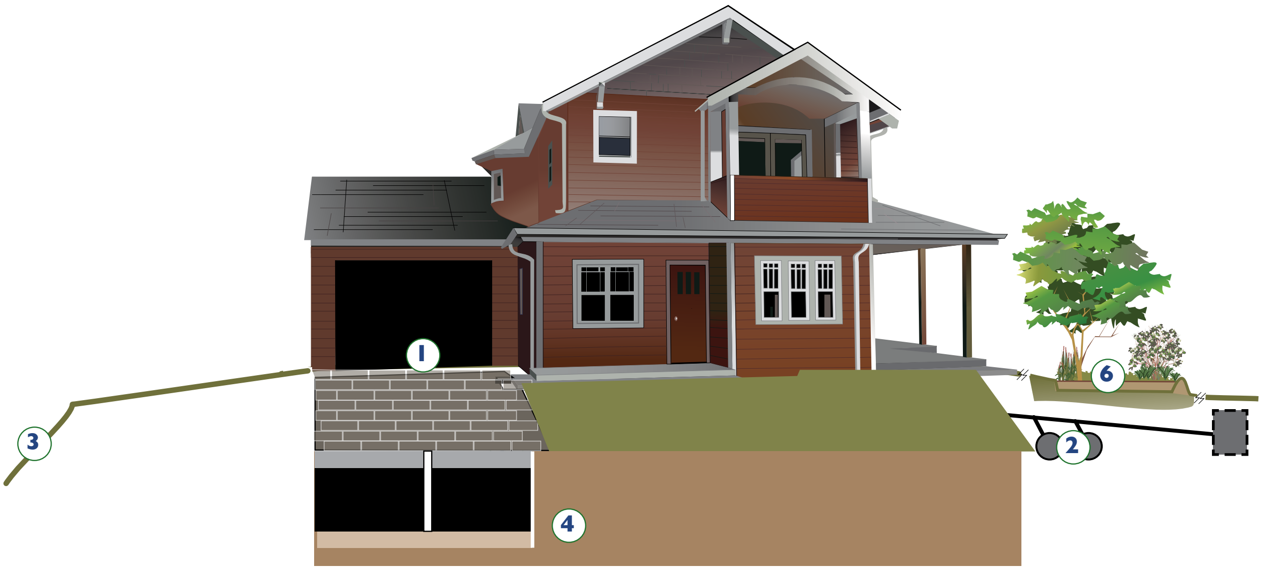
Figure 3.3. *Permeable paver parking installation, light commercial scale.*
(Source: New York State Stormwater Green Infrastructure)

Understand the Complexity of the Hardscaping Project

The intent of this guide is for practices in the SIMPLE to MODERATE categories. Larger paved areas, such as parking lots, or paved areas designed to support vehicular traffic need to be designed by an engineer or landscape architect. For driveways and other projects that are very close to a house or foundation, have a professional designer take a look at the design to ensure that it will not create structural problems or leakage into a basement.

3.2. Location & Feasibility

Where NOT to Locate Permeable Hardscapes



1. Close to building foundation 5 feet downhill, 25 feet uphill (for projects less than 1,000 square feet)*
2. Over utilities or septic systems
3. Near the edge of loose or steep slopes or bluffs
4. Over impermeable soils
5. Where a lot of water runs onto the Permeable Hardscape from upstream.
6. Under trees or over tree roots

*For projects closer than these setbacks, impermeable liners and/or custom drainage systems may be used, with experienced professional guidance and installation.

Figure 3.4. *Examples of site constraints for locating a Permeable Hardscape*
(Original graphic source: Washington State University Extension, 2013)

When deciding where to build a Permeable Hardscape, consider the siting constraints illustrated in **Figure 3.4**, and also the following considerations:

Soils Permeable Hardscape work best when they are installed over soils that allow water to infiltrate. **Appendix B** includes some simple tests and reference tools to determine whether or not the soils are able to infiltrate stormwater. It is strongly advised to conduct an on-site test in accordance with **Appendix B,** with a result of at least 1 inch per hour. If the native soils are too soft and sandy, they may need to be fortified with more stable, construction-worthy soils to support the loads associated with the intended uses.

Groundwater Depth Permeable Hardscapes filter pollutants as runoff flows through the natural soils. If the groundwater comes too close to the bottom of of the stone reservoir layer, pollutants can potentially flow through to the groundwater. In addition, these surfaces will likely have problems over the long term. As a rule, the grounwater should be at least 2 feet below the bottom of the reservoir layer. **Appendix B** has some tips for determining groundwater levels throughout the year.

Be Careful About Setbacks

Make sure the Permeable Hardscape is either far away from building foundations or (preferably) downhill (see Setbacks section below). If these conditions can't be met, a Permeable Hardscape is still an option, but an experienced installer, civil engineer, or landscape architect should be involved to ensure the design won't threaten the foundation or basement of the adjacent building.

Make Sure the Soils are Right for Infiltration

If the soils on the site are clay or don't allow water to infiltrate at an adequate rate of at least 1 inch per hour, consider the following modifications:

- Add a perforated underdrain system in the stone reservoir layer. The underdrain should allow water to flow to an outlet in the yard or a place that can receive the water (see design section of this chapter).
- For driveways, consider a two-track design that reduces the paved area by only placing asphalt or concrete strips under the path of tires.
- For patios and walkways, allow water to drain to a grassed or vegetated area that will absorb the water.

Setbacks The recommended setbacks, depending on the size of the hardscaped area are:

- For small projects (<1,000 square feet)
  - 5 feet if downhill from building (preferred).
  - 25 feet if uphill
- For larger projects
  - 10 feet if downhill from building
  - 50 feet if uphill

For lots with individual wells, try to locate the Permeable Hardscape at least 50 feet away from the well if it is cased down to bedrock, or 100 feet if it is an unconfined well, and at least 25 feet from a septic system.

Be aware of Critical Areas, as defined by the Maryland Department of Natural Resources. In Maryland, a 100-foot buffer zone from average high tide water level, wetlands, and streams is a particularly sensitive area. Generally, it is best to avoid installing practices in these areas, but if a practice will be installed in Critical Areas, they *must* adhere staunchly to the State specifications, including soil permeability. Consultation with a professional engineer is advised in these cases.

Proximity to Utilities Always call Miss Utility before digging. Interference with underground utilities should be avoided whenever possible, particularly water, sewer, electric and gas lines. Conflicts with water and sewer lateral pipes (e.g., house connections) might be unavoidable, in which case excavation should be done very carefully to avoid damaging those pipes. Also, be aware that Miss Utility may not always mark private cable, propane, electric, and similar lines, so some additional site work may be necessary to locate these.

Do:

- Test soil to determine suitability for permeable pavement (types A/B/C – infiltration rate 1 inch/hour or faster)
- Add underdrain if soils infiltrate slowly, or if the drainage area is large
- Add a grass filter strip or other pre-treatment of incoming water to minimize maintenance and chances of failure

Don't:

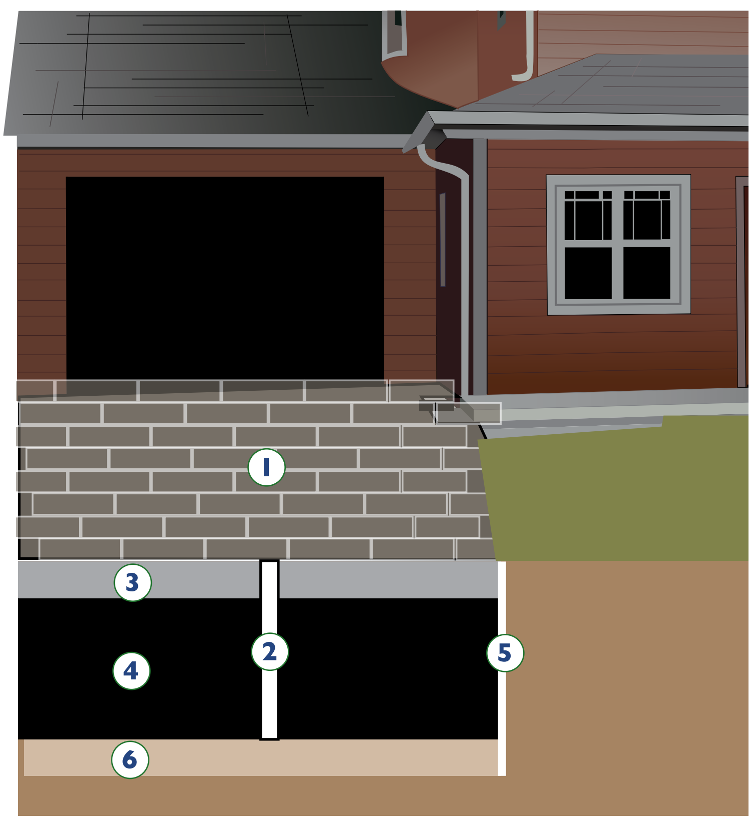
- Locate next to a building foundation, water well, septic field, or beneath trees
- Direct runoff toward a building foundation
- Send too much water to a Permeable Hardscape, especially from pervious surfaces – too much fine sediment = clogging

Shape of the Land Permeable Hardscaping is the most effective when it is used on flat or nearly flat areas (less than or equal to 5% slope). If permeable pavers are used along a path or other surface that has steeper sections, consider using steps to create a flat surface. To prevent clogging, make sure that the permeable area does not receive too much runoff from upslope, non-paved areas, such as mulched or landscape beds and especially areas of exposed soil. Also, Permeable Hardscape shouldn't take too much runoff from roof downspouts.

As a rule, the total area of rooftop or other impervious surface directed to the hardscape should not be more than two times the area of the hardscape itself. If the Permeable Hardscape is replacing an existing impervious surface, check to see how dirty the existing surface is after a rain storm. This is a good indication of how much dirt and sediment will wash onto the permeable replacement. If the proposed Permeable Hardscape area seems to receive too much water and/or sediment from upslope areas, consider using simple swales or French drains to divert a portion of the runoff around the practice, or, preferably, stabilize upslope areas with denser vegetation.

3.3. Design

The materials used to design Permeable Hardscape are readily available from various suppliers and manufacturers. The design is fairly simple when the practice is designed to treat small areas. **Figure 3.5** shows a typical cross-section of this practice. It is important to have an accurate plan showing the various layers and their respective depths and dimensions.



1. Permeable Pavement Surface Material
2. Observation Well, Solid (No Perforations) 4"-6" PVC (Optional, not typical)
3. Bedding Layer (as directed by manufacturer)
4. Reservoir Layer
5. Non-Woven Geotextile (sides only)
6. 2"-4" Sand Filter Layer or No. 8 choker stone (Optional, not typical)

Figure 3.5. *Typical Permeable Hardscape Cross-Section*
(Source: Washington State University Extension, 2013)

Sizing At a minimum, the stone reservoir layer below the permeable surface should be 6 inches deep. For parking areas or driveways, the reservoir should be at least 12 inches deep, or an adequate depth to support structural and vehicular loads. In addition, read the pavement system manufacturers' guidance to ensure that the paved areas are structurally sound. If the Permeable Hardscape receives runoff from conventionally-paved areas, a good rule of thumb is the area of the impervious surface draining to the pavers should be roughly the same area as the paver system itself. If the stone reservoir is deeper than 6 inches, this ratio can be pushed up to 2:1, as long as some form of pre-treatment is provided (see below).

Note that heavy rains may overwhelm a Permeable Hardscape, regardless of soil quality below the reservoir. It is important to point out to the client that sometimes the water will not be able to infiltrate fast enough, and water will run off the Permeable Hardscape.

Pre-Treatment As stated above, Permeable Hardscape should not receive too much runoff from other surfaces. Runoff that is directed to these areas should have some kind of pre-treatment or pre-filtering before it flows onto the permeable surface. Leaf screens should be installed in gutters or downspouts. Other areas can flow over a shallow-sloped grassed or vegetated area (filter strip) or through a gravel or stone-filled trench adjacent to the permeable surface. This is to prevent small particles from clogging the spaces between the pavers, and therefore to minimize maintenance. **Figure 3.6** shows a permeable paver installation that has significant clogging from sand and fine soil particles. The area draining to this installation is large, and there is no filtering between the asphalt parking area and the permeable pavement. **Figure 3.7** shows examples of pretreatment options

Figure 3.6. *Permeable paver installation without pretreatment or filtering. Clogging evident from sediment and grit from adjacent surfaces.*

Figure 3.7. *Gravel diaphragm and grass filter strips to catch sediment before runoff reaches permeable pavement*

Excess Soil Plan for the disposal or use excess dirt that will come from excavation. Add some topsoil to excavated dirt if it will be reused onsite for grass or vegetation.

Site Drainage Although Permeable Hardscape are designed to infiltrate stormwater, they will not work long if they are flooded with runoff from large storms. When laying out the site, make sure that ponded water has somewhere to go during larger storms. This is no different than traditional hardscapes. The water flowing to and away from the hardscapes should be conveyed in a stable manner, and should not cause erosion issues.

3.4. Materials

Table 3.2 includes a list of materials needed to construct Permeable Hardscaping. Note that the actual permeable pavers include many different options. In addition, some manufacturers may specify a different subgrade material. For example grassed pavers require a soil medium below the paver to support grass growth.

Table 3.2. Material Specifications for Permeable Hardscapes

(Listed in order of location in a Permeable Hardscape cross-section, from TOP to BOTTOM)

Material	Specifications	Size	Depth	Notes
Permeable surface	Varies	Varies	Varies	Per manufacturer
Bedding layer	#8 or #78 stone, clean, washed	⅜ - ½ inch	Per manufacturer	Manufacturer may indicate different bedding material
Reservoir	#57 clean, washed rounded gravel	½ - to 1 ½ inch gravel	6 inches minimum for patios and walkways 12 inches or minimum needed for structural/vehicular load (e.g., driveways)	Depth may also be dictated by structural considerations Consult with supplier or manufacturer Avoid angular, crushed stone; prefer rounded gravel
Filter fabric	Standard filter fabric or non-woven geotextile	N/A	Sides ONLY	This is also considered optional, and is more applicable to moderate or larger-scale applications
Underdrain pipe (if used)	Perforated, corrugated (with smooth-wall interior) HDPE landscape pipe or equivalent	3 – 4 inches	Placed in stone reservoir layer at 0.5 to 1% slope Once the pipe leaves the Permeable Hardscape area itself, it should continue until the pipe meets the ground surface somewhere in the yard via a non-perforated section	Optional (typically not included)

3.5. Construction

Permeable Hardscape can require more precision in construction than some of the other BMPs. Surfaces should align and be flat, the base layers should be evenly applied and uniformly compacted to an appropriate degree. Pay particular attention to critical areas, such as where Permeable Hardscape edges meet other surfaces (e.g., asphalt, grass areas). It is best to work from a thorough plan, including plan view, profile or cross-section views, with depths and dimensions labeled. Measure carefully and frequently to ensure the installation is staying on plan.

Step 1 - Outline the Project & Mark Utilities Mark the excavation area for the hardscape. Call Miss Utility before excavating, and also check for private cable, propane, electric, and other lines. Also try to identify private propane, cable, electric, and other small lines. Make sure to have a plan and phone numbers of who to call in case there is any damage to utilities. Ensure only very small areas of landscaped surfaces are directed to the pavement and there is a pathway for water to flow during large rain events. In some cases, this may require using a survey level or hand level and a survey rod to check spot elevations and confirm flow paths.

Do:

- Check levels and elevations carefully and frequently during installation
- Rake, till, or otherwise scarify the bottom surface of the excavation to improve infiltration
- Make sure the edges around the installation are solid – if the surroundings slump or get washed away, so will the hardscape!

Don't:

- Ignore manufacturer specifications and recommendations – each product may have different requirements
- Pressure wash the spaces between pavers to clean sediment – light vacuuming is recommended instead

Figure 3.8. *Excavation of permeable paver installation in small parking lot*

Figure 3.9. *Installation of gravel reservoir layer*

Step 2 - Excavate It is best to excavate when the weather is expected to be dry for several days. Excavate to dimensions and depths, as per the plan. Account for all the layers and be aware of variation that can occur based on the materials. For example, for ½-inch diameter gravel that is angular, it will be difficult to get the surface to be completely flat; expect ¼ inch dips and protrusions.

Step 3 - Rake or Till Rake or till the bottom soils to promote greater infiltration.

Figure 3.10. *Installation of pavers (top left), compaction (top right), and filling spaces with pea gravel (bottom).*

Step 4 - Filter Fabric Line the sides ONLY (never between the stone reservoir and underlying soil) of the excavated area with filter fabric (optional). This can be held in place with landscape staples.

Step 5 - Install Gravel Install the amount of gravel called for in the plans, followed by a 2-4 inch layer of bedding material, specified by the supplier or manufacturer. Place gravel and other base materials in layers of no more than 4-6 inches. Compact layers of gravel and base materials lightly by tamping manually. For heavier load applications, like driveways or parking spaces, compaction of base layers should follow manufacturer recommendations and municipal or state specifications, such as the Maryland Stormwater Design Manual (MDE, 2000).

Step 6 - Install Paving Install permeable paving material at the surface. Ensure that the surface is even and flat, and level or with a very slight slope, based on the plans. It is best to limit the difference between the elevations of two adjacent blocks to no more than ¼ inch to avoid tripping hazards and additional disturbance to the pavers.

Step 7 - Stabilize If the design calls for grass seed to be planted, spread seed and stabilize with a temporary stabilization method, such as paper mulch or jute mat.

Step 8 - Inspect Inspect the area after several rain events to look for any needed adjustments. Ensure that the surface is draining properly and that the surface is not becoming clogged.

3.6. Maintenance

Table 3.3. Recommended Maintenance for Permeable Hardscapes

Maintenance Tasks	Schedule
• Sweep the surface if sand or debris accumulates • Leaf blowers can also be used, but make sure debris is removed from the pavement surface • Agitate with a rough brush and vacuum the surface with a wet/dry vac if the joints fill with sand • Remove and replace clogged blocks in segmented pavers • Hire a vacuum sweeper to restore the surface for moderate or larger applications • Repair any structural damage to the paver surface (e.g., cracking, broken pavers, sinkholes)	As needed, particularly at change of seasons when leaves, winter sanding, and other debris may accumulate
• Repair and stabilize any areas that are eroding or washing dirt or debris onto the surface • Check downspouts and channels leading to the Permeable Hardscape and remove any accumulated debris	Quarterly, if other areas drain to the hardscape

3.7. Resources

Maryland Department of the Environment. 2009. *2000 Maryland Stormwater Design Manual – Rev. 2009.* Baltimore, MD. Available at: http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Pages/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.aspx

Smith, D. 2006. Permeable Interlocking Concrete Pavement-selection design, construction and maintenance. Third Edition. Interlocking Concrete Pavement Institute. Herndon, VA

Virginia Department of Environmental Quality. 2013. *Virginia Stormwater BMP Specifications – Rev. 2013 (DRAFT).* Richmond, VA. Available at: http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications.aspx

Infiltration Trenches & Dry Wells

Purpose & Benefits

- Stormwater runoff reduction and treatment
- High pollutant removal
- Can help control localized drainage problems

Description

Infiltration Trenches and Dry Wells are gravel-filled trenches or pits that store runoff temporarily until it seeps into the ground through the bottom of the trench or pit. Unlike most of the other practices described in this manual, these practices do not necessarily incorporate vegetation into their design. Instead, they rely on natural soils to absorb runoff and filter pollutants.

What to Expect

Infiltration Trenches are installed by digging a trench which is then filled with a 1.5 to 4 foot layer of clean gravel, and a top layer of pea gravel or topsoil and grass. Small-scale, residential practices will likely use the shallower depth. With Dry Wells, roof drains are piped directly into the gravel layer of a gravel-filled pit. When designing Infiltration Trenches and Dry Wells, it is important to make sure that the native soils allow water to percolate, and that the practice is set back from buildings to avoid foundation damage or flooding. If the underlying soils are not suitable for the practice, it can lead to nuisance conditions, such as standing water. Karst topography may make these practices infeasible or even dangerous (see section 4.2). However, given the right conditions, these practices are simple, cost-effective, and relatively easy to maintain.

Roadside Infiltration Trench
(Source: Flickr Creative Commons, Wendy Cutler)

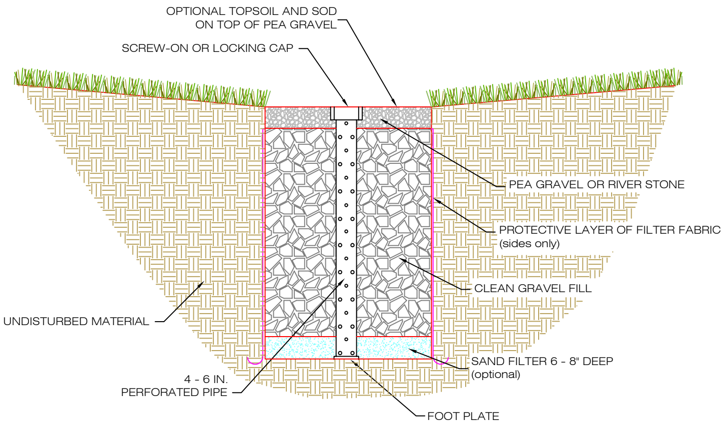


Figure 4.2. *Typical Infiltration Trench*
(Source: Virginia DEQ, Specification #8, 2013)

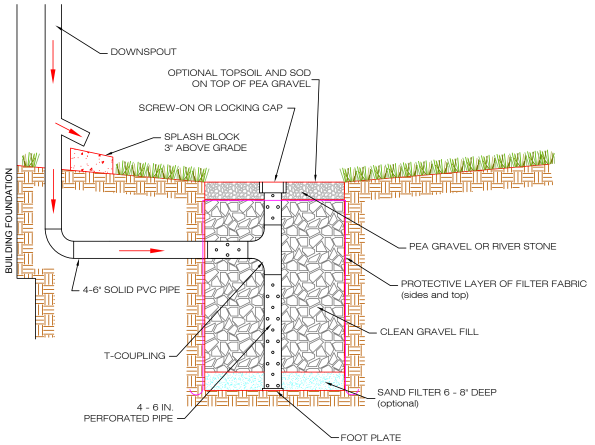


Figure 4.3. *Typical Dry Well with Optional Observation Well*

4.1. Complexity

Infiltration Trenches and Dry Wells are relatively small and simple practices that capture runoff from rooftops or very small paved areas. As the practices get larger and are designed to capture more area, the design can become more complex. Additional guidance is provided in **Table 4.1.**

Table 4.1. Design Complexity for Infiltration Trenches and Dry Wells

Design Complexity	Description	Guidance
Simple	• Small-scale, typically designed to treat water from one or two roof downspouts	• Design can be completed using simple design tools included in this manual • Ensure the soil will allow for stormwater infiltration (see **Appendix B**) • Ensure the practice is separated from any building foundation • Up to 3 feet deep
Moderate	• A bit larger in scale, treating impervious areas over 2,000 square feet • Typical design would be an Infiltration Trench that treats water from rooftops, driveway, and maybe small parking lots or other impervious areas	• Design should be provided by a professional, such as an experienced landscape contractor, licensed landscape architect, engineer, or design/installation specialist • May include vegetation and more sophisticated ways to convey and slow down runoff as it enters the practice and to manage overflow from larger rain events • A formal soil test should be completed by an engineer, landscape architect, or soils specialist • Up to 5 feet deep
Complex	• Infiltration Trench or basin treating commercial or institutional site; up to about ½ acre of drainage area	• Design requires a professional engineer or landscape architect and adherence to detailed stormwater design manual specifications • Pretreatment often includes a formal forebay cell • May require more maintenance than other Infiltration Trenches

Understand the Complexity of the Infiltration Project

The intent of this guide is for practices in the SIMPLE (or low end of MODERATE) categories. In general, Infiltration Practices that capture larger areas become more complex. Larger drainage areas need channels and pipes to get stormwater to and from the practice safely. These higher-volume practices require more features to filter grit and sediment to prevent clogging or groundwater pollution.

Infiltration Practices should be designed and constructed by a contractor with experience and knowledge about this practice. The design and construction details provided in this chapter may allow Stewards and homeowners to better understand the practice, but not to construct this practice without the help of an experienced contractor.

4.2. Location & Feasibility

Where NOT to Locate Permeable Hardscapes

1. Within 10 feet of a building foundation
2. Over Utilities
3. Near the edge of steep slopes or bluffs
4. Near an existing or reserve septic drainfield or tank
5. In low spots that do not drain well
6. Within 2 feet of high ground water level
7. In areas that would require disturbing healthy native soils and vegetation like under existing tree canopy
8. Where there is high groundwatrer during the winter
9. Near Wells- Stay back 50 feet from confined wells, or 100 feet from unconfined wells

Figure 4.4. *Examples of site constraints for locating an Infiltration Practice*
(Original graphic source: Washington State University Extension, 2013)

When deciding where to build an Infiltration Practice, consider the siting constraints illustrated in **Figure 4.4,** as well as the following:

Soils When installing an Infiltration Practice, it is important to ensure soils can infiltrate the water directed to them. For small-scale practices, this testing can be based on observations described in **Appendix B,** with a result of at least 1 inch per hour, and preferably a sandy or sandy-loam texture. Since the performance and longevity of these practices depend on adequate infiltration, the 1 inch per hour threshold should be considered a bare minimum, with recommended levels exceeding 2 inches per hour. For larger practices, the designer should perform a soil infiltration test in accordance with the applicable state stormwater management manual. When testing the soils, make sure to test the soils below the surface, at the depth of the bottom of the trench.

Make Sure the Soils are Right for Infiltration

If the soils on the site are clay and/or do not allow water to infiltrate at an adequate rate of 1 inch per hour, consider using a Conservation Landscape (**Chapter 1**) or Rain Garden (**Chapter 2**).

These practices have similar applications as Infiltration Practices, but use plants and a filtering soil medium to remove pollutants. They are generally more adaptable to a site with soils that will not support a full infiltration design.

Groundwater Depth Infiltration Trenches filter pollutants as runoff flows through the natural soils. If the groundwater comes too close to the bottom of the trench, pollutants can flow through to the groundwater. In addition, Infiltration Trenches that come too close to groundwater may drain slowly, creating a drainage or standing water problem. The grounwater should be at least 2 feet below the bottom of the trench in most areas. **Appendix B** has some tips for determining groundwater levels throughout the year.

Setbacks To avoid the risk of seepage into basements, do not install Infiltration Practices directly adjacent to building foundations. Recommended setbacks from foundations are:

- 10 feet if Infiltration Trench is downhill from building (preferred).
- At least 25 feet if the Infiltration Trench is uphill from the building. This option is discouraged, but can be used if an overflow channel directs water away from the building to a downhill channel, driveway, or street.
- 100 feet away from a drinking water well
- 50 feet away from the edge of a septic drain field
- Also, keep Infiltration Practices outside the drip line of existing trees to avoid damaging tree roots during excavation.

Karst Topography – Do Not Create a Problem While Trying to Solve Another

Karst topography (or Karst terrain) is geology that is characterized by soluble rocks that can dissolve to form sinkholes and caves. Water and associated pollutants can travel very quickly in Karst, and Infiltration Practices are potentially problematic. If the site is in a confirmed Karst area, practices such as bioretention cells *with underdrains* are recommended. Check local and/or state design standards to determine what practices are restricted in Karst.

Be Careful About Setbacks

If you are near a finished basement, make sure you understand if and how the building is waterproofed.

Proximity to Utilities Always call Miss Utility before digging the Infiltration Trench. Interference with underground utilities should be avoided whenever possible, particularly water, sewer, and gas lines. Conflicts with water and sewer lateral pipes (e.g., house connections) might be unavoidable, in which case excavation should be done very carefully to avoid damaging the pipes. Check the proposed site for existing utilities prior to finalizing the Infiltration Trench location.

Shape of the Land Infiltration Practices should never be located near slopes greater than 15% and the practice itself should be nearly or completely flat.

Land Area Being Treated Stabilize the area being treated before the practice is used, since soil particles carried by runoff from bare soils will clog the practice. Do not use Infiltration Practices to treat areas that will remain as bare soil for a long period of time, or to treat runoff from any areas where vehicles are maintained (except the roof of a covered garage).

Consider a Dry Well for a Small Roof

Dry Wells (sometimes called "soak-away pits") are very similar to Infiltration Trenches, but are configured as a stone-filled pit rather than a trench (see **Figure 4.3**). With most Dry Wells, the roof downspout is piped directly into the underground gravel/stone layer. This practice typically includes a leaf screen or debris filter in the gutter or downspout, and a surface overflow pipe for larger rain events.

4.3. Design

The materials used to design Infiltration Trenches are readily available, and the design is fairly simple when the practice is designed to treat small areas.

Practice Size Infiltration Trenches are sized to hold the runoff from 1 inch of rain. Since the practices are usually filled with sand, rounded stone, and gravel, this runoff is stored in the porous spaces between the stones in the reservoir. The surface area needed will depend on the depth of the stone reservoir and the area of impervious cover treated, using the following rule:

Surface Area (square feet) = 0.20 x Impervious Area Treated (square feet) / Stone Depth (feet)

Surface Area (square feet) = 0.20 x Impervious Area Treated (square feet) / Stone Depth (feet)
– 1.5 x Chamber Volume (cubic feet) / Stone Depth (feet)

Click here to download the Dry Well Worksheet. This spreadsheet can calculate and recommend certain areas and volumes for an infiltration BMP, provide material quantities, approximate material costs, and pollutant removal effectiveness.

Pre-Treatment Pre-treatment refers to something that will remove leaves and grit from the roof, and larger particles of dirt from the runoff before it enters the practice, helping to keep the infiltration area from clogging and not draining properly. The type of pretreatment depends on the scale of infiltration. For practices that treat rooftop only, the biggest concern is leaf litter that can clog the practice. For this scale, the only pretreatment needed is leaf screens installed at the roof gutter. For practices that treat somewhat larger areas (including from small areas of pavement), runoff must first flow through a simple grass strip or channel before it reaches the infiltration area.

Excess Soil Plan for a place to dispose of or use excess dirt that will come out of the ground when the Infiltration Practice is excavated. If some of the excavated soil is used on the lot, add some topsoil, as that will help grass or other vegetation to establish.

Inflow If the Infiltration Trench receives stormwater from roof downspouts, incorporate a pad of river cobble stone or some other means to reduce flow velocity at the mouth of the downspout. For other areas that drain to the Infiltration Practice, it is best if the flow is spread out and diffuse (referred to as "sheetflow"), and not concentrated in a pipe or channel. Where a sidewalk, patio driveway, or other impervious area is flowing into an Infiltration Trench, add a strip of river cobble or stone at the edge to prevent erosion and undercutting of the impervious surface. This stone strip should run the entire length of the Infiltration Trench where it meets the hard surface, be underlain with filter fabric that extends under the hard surface, and be approximately 12 inches wide and 12 inches deep.

Do:

- Locate any utilities present when planning location of Dry Wells
- Plan for removal, disposal or use of excess soil
- Size the Infiltration Trench or Dry Well properly, or plan carefully for overflows

Don't:

- Install close to building foundation, especially if uphill from building
- Locate near water wells or septic fields
- Use filter fabric on the bottom of the excavation.

Filter Fabric is Used Differently for Infiltration Trenches vs. Dry Wells

An important design consideration is whether incoming water will flow to the practice over the surface of the ground (typical for Infiltration Trenches) OR be piped directly into the underground gravel/stone layer (typical of Dry Wells).

When water enters from the surface, highly porous filter fabric can be used on the sides of the excavation, but not on any horizontal surface, including at the bottom of the excavation or between the gravel and pea gravel layers. Use of filter fabric on these horizontal planes can lead to clogging.

Alternately, if water is piped directly into the gravel/stone layer underground, it is recommended that the filter fabric layer be used on the sides and wrapped around the top of the gravel layer to serve as a separation barrier, especially if covered with topsoil and turf. However, do not use filter fabric at the bottom of the excavation, as this can interfere with proper infiltration.

Filter Fabric is often referred to as geotextile and comes in many forms, depending on the application. Select the right geotextile for the job. While most practices in this manual employ non-woven, Class C geotextile, some situations call for different products. Check with an engineer or geotextile vendor to select the right material.

See **Figures 4.2 and 4.3** for details.

Overflow During large storm events, the Infiltration Practice will fill with water. The remaining runoff needs to flow safely from the site and not towards building foundations or other structures that can be damaged. Ideally, this is a gently-sloping, vegetated, and stable area in the yard that slopes away from the house or neighboring houses.

Incorporating Into the Site Infiltration Trenches are typically long, rectangular-shaped practices. As a result, they can be incorporated into the site without changing the appearance of the existing land. They work well when aligned with edges, such as rooftops or pathways. Dry Wells are usually square or circular in shape and placed close to each downspout.

4.4. Materials

Table 4.2. Material Specifications for Infiltration Trenches: From Bottom to Top

Material	Specifications	Size	Depth	Notes
Filter fabric	Non-woven, Class C geotextile or standard filter fabric	N/A		See notes above – use on sides of excavation; wrap around top of gravel ONLY IF water is piped directly into gravel layer (Dry Well)
Gravel	Washed gravel or stone, preferably rounded, "bank run"	1 ½ - 3 ½ inch diameter #1, #2, or #3 stone	18-48 inches (1.5-4 feet)	Can also be used as erosion prevention at inlets and outlets Use filter fabric or weed-block under the stone
Pea gravel	#8 or #78 stone	⅜ - ½ inch	2-4 inches	Must be washed clean at quarry
Observation well (optional)	4 to 6 inch Schedule 40 PVC pipe, with ⅜" perforations (see notes)	4-6 inches	Deep enough to extend from the bottom of the gravel layer to extend about 6 inches above the surface.	Also includes a cap and footplate. Pipe above gravel layer should *not* be perforated.
Cobble/Stone	Washed river rock, large gravel, or small rip-rap	3 - 5 inch diameter stone	1 or 2 layers deep	Use at downspouts, inlets, outlets, and along hardscape edges as needed to dissipate flow and prevent soil erosion Use filter fabric under stone

4.5. Construction

Step 1 - Outline the Project & Mark Utilities Mark the excavation area for the Infiltration Trench. Call Miss Utility before excavating. Confirm the flow of water into the Infiltration Trench, checking the areas that will contribute runoff to the practice. In some cases, this may require using a survey level or hand level and a survey rod to check spot elevations and confirm flow paths. The best method is direct observation during a rain event.

Step 2 - Erosion Control & Excavation It is best to dig the trench when the weather is expected to be dry for several days. It is recommended to put a row of silt fence below the area that will be excavated. Excavate the trench at least 18 inches wide. Use only light weight (i.e., walk-behind) machinery and hand tools, or work from the side of the trench.

Step 3 - Rake or Till Rake, till, or otherwise scarify the bottom soils to promote greater infiltration.

Step 4 - Filter Fabric Line the SIDES ONLY of an Infiltration Trench with non-woven geotextile. Do not put geotextile horizontally across the bottom of the excavation. For Dry Wells where water is piped into the gravel layer, leave enough extra fabric at the edges to fold over the top of the gravel layer (for Step 7).

Step 5 - Install Well If using an observation well, install with the footplate at the bottom of the trench.

Step 6 - Install Stone Install the amount of cobble or gravel stone called for in the plans to within 2-4 inches of the ground surface. **Figure 4.5** shows a Dry Well installation at the stage between Step 6 and Step 7.

Figure 4.5. *Dry Well installation with an observation well, shown after gravel is placed, before pea gravel*
(Source: Lancaster Counter Conservancy - Urban Greening Program)

Do:

- Call Miss Utility to locate any utility lines before digging
- Scarify (roughen) the bottom of the trench or basin
- Place gravel in 4-12 inch layers

Don't:

- Line the bottom of the trench or well
- Compact the soils in the trench
- Rush if the excavation is near utilities – a little extra time could save a lot

Step 7 - Fold Fabric Fold the top edges of the filter fabric from the sides over the top of the stone, only if the design calls for water to be piped directly into the gravel layer (typical of Dry Wells). If water will enter the practice by flowing over the ground surface, do not wrap filter fabric over the top.

Step 8 - Add Pea Gravel Install a 2-4 inch layer of pea gravel. It is also acceptable to top the stone layer with soil and sod as an alternative. Do not compact the top layer.

Step 9 - Add Pre-Treatment Install any pre-treatment features associated with the plan, such as a stone pad at the mouth of downspouts. A stone pad, sometimes called an apron, should be installed lower than the surrounding grade. Dig a 1-2 foot wide channel, approximately 4-6 inches deep at the edges, and 6-8 inches deep through the center. Line this with filter fabric or "weed block" (secured with landscape staples), and backfill with one or two layers of 3-5 inch diameter cobble. See Chapter 1, Conservation Landscapes, Section 1.3, for more information on the cobble apron. Seed and straw or landscape all side slopes, berms, and disturbed areas.

Step 10 - Inspect Inspect the trench after several rain events to look for any needed adjustments. Ensure runoff is entering the practice properly and draining properly. Ensure inlets and outlets have no erosion.

Be Careful When Digging

This practice relies on soils at the site to work properly. When digging the trench, ensure the soils at the bottom of the trench are not smeared, which will seal the soils and limit infiltration. Do not allow muddy water to flow to the trench during construction, and do not compact the soil by running equipment back and forth across

4.6. Maintenance

Clogging is the Biggest Maintenance Concern

The most important part of maintaining Infiltration Trenches is to make sure that debris and grit do not enter the trench or Dry Well, causing it to clog. If using an observation well, the well can be checked after a rain event to ensure that all the water is percolating into the soil. Ideally, all the water would be gone within 48 hours after the end of a rain event. It should take no more than 72 hours after the end of a rain event to drain the practice.

Table 4.3. Recommended Maintenance for Infiltration Trenches

Maintenance Tasks	Schedule
• Ensure the contributing drainage area is stabilized, and repair any areas that are eroding • Check downspouts and channels leading to the trenches, and remove any accumulated debris	Quarterly
• Check observation wells (if any) 3 days after a rain event with ½ inch of rainfall or greater. • Treat the practice for clogging if standing water is still present after 3 days • If no observation wells are included, but the practice is very shallow, observe ponding by removing some pea gravel at the surface of the trench	Twice/year
(Clogging troubleshooting) • If the Infiltration Trench starts to drain slowly, remove the top pea gravel or topsoil/turf layer. If filter fabric is present, this may be the source of the clogging. Remove this layer of filter fabric. Check to see if the trench will draw down and replace the overlying material with clean pea gravel or topsoil. • If a Dry Well does not drain properly, dig down to check inflow points for excessive leaves or debris.	Once/year or as needed
(Overhaul) • If the Infiltration Trench or Dry Well is clogged from the bottom, and water stands on the surface, then the practice will need to be reconstructed. If the issue is the underlying soils, the practice should be replaced with a Rain Garden or Conservation Landscape.	Once/year or as needed

4.7. Resources

Maryland Department of the Environment. 2009. *2000 Maryland Stormwater Design Manual – Rev. 2009.* Baltimore, MD. Available at: http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Pages/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.aspx

Virginia Department of Environmental Quality. 2013. *Virginia Stormwater BMP Specifications – Rev. 2013 (DRAFT).* Richmond, VA. Available at: http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications.aspx

West Virginia Department of Environmental Protection (WVDEP). 2012. *West Virginia Stormwater Management and Design Guidance Manual.* Prepared by: Center for Watershed Protection.

Rainwater Harvesting

Rain Barrel set up for watering planters
(Source: Flickr Creative Commons)

Small, low-profile cisterns

Purpose & Benefits

- Reduce runoff from the property
- Provide non-potable water source for reuse
- Provide additional water storage for slow release to Conservation Landscapes and Rain Gardens

Description

Rainwater Harvesting is a term for the age-old concept of capturing runoff and storing it in a Rain Barrel, cistern or other container for future use. Rain Barrels and cisterns are similar in function and design, but the cistern is a larger tank than a Rain Barrel. Rainwater that falls on a rooftop is collected and conveyed into an above- or below-ground storage tank for non-potable water uses such as irrigation, exterior washing (e.g., washing cars, building exteriors, etc.), operating water features (ponds and fountains), and possibly some interior reuse options like flushing toilets or laundry (indoor uses may require additional treatment of the water as per local health codes). In many instances, Rainwater Harvesting is combined with Conservation Landscapes (**Chapter 1**), Rain Gardens (**Chapter 2**), or landscaped areas to allow stormwater stored temporarily in the tank to be used to water these practices and infiltrate into the ground.

What to Expect

Normally, the tank cannot hold the entire runoff volume from a rain event. An overflow should be designed to send any extra water to a stable place, like a stone or concrete pad, to prevent erosion. If the rain water is not used for irrigation, a recommended approach for stormwater management is to leave the spigot slightly open at the bottom of the tank so that it slowly releases any water that is stored in the tank, and empties the tank for the next rainfall event. This is especially effective when the Rainwater Harvesting system is used in conjunction with a Conservation Landscape or Rain Garden. However, homeowners or businesses may have other uses in mind that suggest other methods to operate the system.

Other important considerations include: (1) creating a plan for the winter when the water may not be used, and (2) preventing mosquitoes from breeding in the summer.

Figure 5.1. *Examples of residential Rainwater Harvesting cisterns*

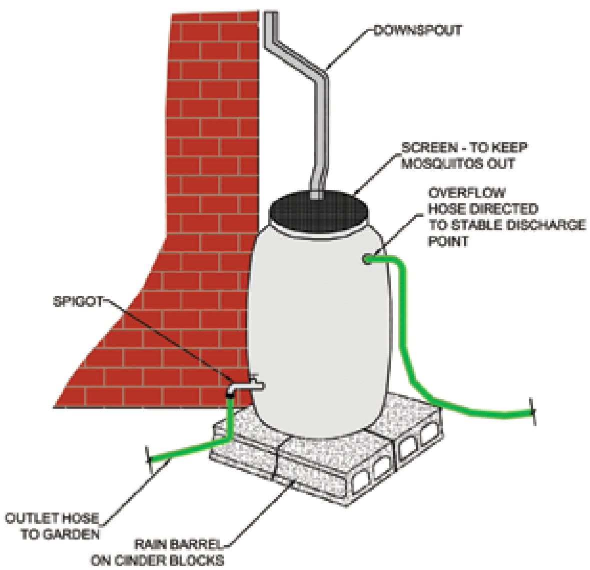


Figure 5.2. *Single Rain Barrel system, with overflow*
(Source: MDE, 2000)

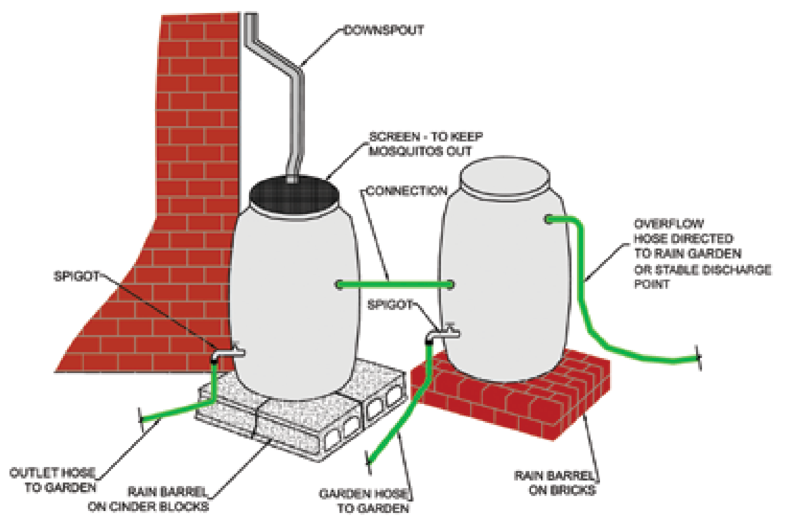


Figure 5.3. *Interconnected Rain Barrel system, with overflow*
(Source: MDE, 2000)

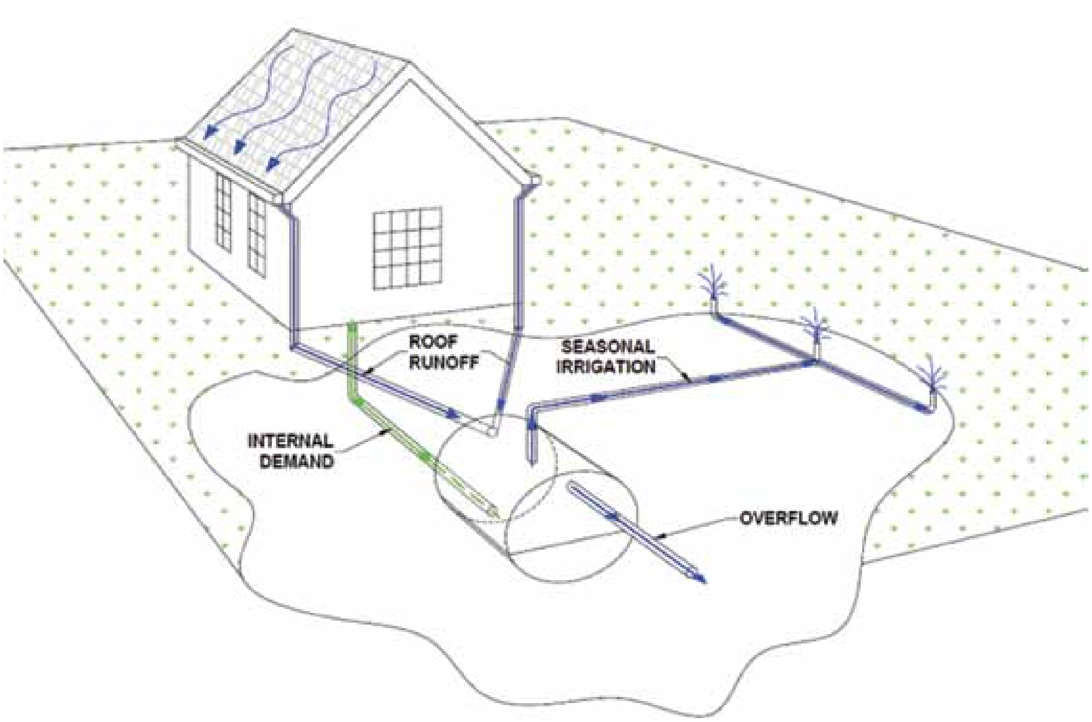


Figure 5.4. *Underground cistern for year-round indoor use and seasonal outdoor use*
(Source: VADEQ 2013, original graphic by Alex Forasté)

5.1. Complexity

A simple Rain Barrel or single above-ground tank system is quite simple, and with a few commonly available tools, most people can assemble and install a perfectly usable system. Larger systems are inherently more complicated. Design features that add complexity include multiple, separate vessels that must be connected together, a more extensive system of gutters and collection pipes, and some type of pre-treatment system to keep leaves and debris out of the vessel. More complex designs will likely require some assistance from a professional, or at least an experienced installer (see **Table 5.1**). For underground cisterns or storage tanks, a backhoe or excavator will be needed. For underground work, utilities and groundwater depth become considerations, raising the complexity and likely necessitating additional professional assistance.

Understand the Complexity of the Rainwater Harvesting Project

The intent of this guide is for practices in the SIMPLE, or low end of MODERATE categories. If the practice is in the moderate or complex category, consider consulting with an appropriate design professional or experienced installer.

A Steward or homeowner can usually install a simple Rain Barrel. Consult a landscape contractor for cistern installations, or where Rain Barrel installations are complex or uncertain.

Table 5.1. Design Complexity for Rainwater Harvesting Systems

Design Complexity	Description	Guidance
Simple	• Rain Barrels or simple above-ground tank • 50-300 gallons in size • Each tank collects from one downspout • Gravity-fed outflow • Has basic screening or filtration (e.g., leaf screens on gutters), but not greater treatment system at the tank • See **Figures 5.2 & 5.3**	• Design and construction is simple and can be done by handy homeowners, volunteers, or contractors with a little guidance • Most difficult part of assembly may be cutting and re-routing downspouts and installing hardware at bottom end of Rain Barrel
Moderate	• Larger home-scale storage systems • see **Figures 5.4 & 5.5** • 300-1000 gallons, above or below ground • Collect from multiple downspouts • May include pump distribution, and pre-screening, first-flush diverters (**Figure 5.6**), which add complexity	• Elevation of tank(s) with respect to downspouts, inlets, and outlets are the primary complicating factors • Many tank materials available to best meet desired application • Design should include basic drawings with elevations to ensure flow and storage are aligned • Construction likely requires professional assistance, such as an experienced plumbing contractor
Complex	• Larger commercial or institutional applications • Large above-ground or underground systems • Will likely include large collection pipes, filters, pumps, sensors, and valves	• Will usually require a professional architect, engineer, or landscape architect, and adherence to stormwater manual design specifications (MDE, 2000, Ch. 5; VDEQ, 2013, Specification #6) • Requires contractor with capabilities for general site development and plumbing contractor with specific experience in Rainwater Harvesting

Figure 5.5. *A residential system with a large underground tank adds complexity*
(Source: Rainwater Management Solutions, Inc.)

5.2. Location & Feasibility

At the simpler end of Rainwater Harvesting, above-ground storage (Rain Barrels or small cisterns) are typically located in close proximity to the house, garage, or shed where the runoff is coming from. The downspout is then directed to the storage vessel. For an underground storage and distribution system, selecting the location is more complicated. Here are some factors to consider:

Location of Downspouts To avoid unnecessary piping, plumbing, or other conveyance, the storage tank or reservoir is typically located where the downspouts come down from the roof. However, aesthetics or the location of the intended water use may be considerations. If the house has several downspouts, consider whether the project will interconnect the downspouts or interconnect storage vessels. The simplest option is to have each tank only collect water from a single downspout.

Location of Water Use and/or Drawdown It is important to consider the pathways by which water enters and exits the system. For example, it may not be the best option to put a Rain Barrel right under an existing downspout on one side of a house, where the homeowner will need to run a large amount of hose to reach a garden or Rain Garden on the other side of the house. Sometimes it will make more sense to put the container away from the structure entirely and to convey the water farther from the downspouts to the container via gravity flow.

The relative elevations of downspouts and storage tanks will also affect pumping requirements. Locating storage tanks in low areas will make it easier to route roof drains from buildings to cisterns. However, it

Do:

- Have a use or uses of the water in mind before installing the system
- Empty Rain Barrel between rain events, ideally into another practice

Don't:

- Underestimate the weight of a barrel or cistern full of water
- Allow water to overflow that will sit against the house foundation or structure

can make gravity flow out of the tank more difficult and increase the likelihood that pumping will be necessary to distribute the water to areas situated on higher ground. Conversely, placing storage tanks at higher elevations may require building a pedestal or foundation and securing the tanks, but will reduce or eliminate the amount of pumping needed for distribution.

Setbacks from Buildings The overflow from a storage tank should not cause standing water or saturated soil within 10 feet of any building foundation. Tanks must be watertight to prevent water damage near a building, and in general, underground tanks should be at least 10 feet from any building. Both the overflow outlet pipe and the drawdown outlet pipe should steer water well away from the foundation, with the ground sloping gently away from the building.

Rooftop Material The quality of the harvested rainwater will vary according to not only how much debris gets into the tank, but also based on the roofing material over which it flows (see box below).

Water Table The water table depth is only a concern for a buried cistern. Underground storage tanks are only appropriate where they can be placed entirely above the water table. Special considerations may allow a tank to be partially or entirely submerged in the groundwater, but a professional engineer must design this system due to the necessary structural calculations and water quality concerns.

Consider the Rooftop Material and Water Quality

Water harvested from certain types of rooftops may pick up toxic compounds. Carefully consider the eventual use of water coming off roofs covered with asphalt sealcoats, tar and gravel, paint, treated wood, metal that contains lead, or any material that may contain asbestos. Due to possible toxicity concerns, avoid using water that is questionable for watering food gardens or for any purposes that involve significant body contact.

5.3. Design

There are six primary components of a Rainwater Harvesting system:

- Roof surface
- Collection and conveyance system (e.g., gutter and downspouts)
- Pre-screening/filter
- Storage tank
- Overflow
- Distribution system

Rooftop Surface The rooftop surface should be made of relatively smooth material with good drainage, either from a sloped roof or an efficient roof drain system. Slow drainage of the roof leads to poor rinsing and more accumulation of debris (leaves, sticks, etc.) in gutters, which can decrease the quality of water collected in the system. As mentioned before, some materials may leach toxic chemicals making the water less desirable for certain uses.

Collection and Conveyance System The collection and conveyance system consists of the gutters, downspouts and pipes that channel stormwater runoff into the storage tank. Gutters and downspouts should be designed as they would for a building without a Rainwater Harvesting system. Aluminum, round-bottom gutters and round downspouts are generally recommended for Rainwater Harvesting, although most retrofit systems simply utilize the existing gutters and downspouts. Gutters and downspouts should be kept clean and free of debris and rust.

Pre-Screening Pre-screening of water before it enters the tank is required to keep sediment, leaves, contaminants and other debris from the system. Leaf screens and gutter guards meet the minimal requirement for pre-screening of small systems. Larger or more complex systems may require a pre-fabricated first-flush diverter (see **Figure 5.6**). All pre-filtration devices should be designed to have relatively low maintenance requirements, such as cleaning the screening material several times per year or after significant storm events. The purpose of pre-screening is to significantly cut down on maintenance of the tank itself by preventing debris and organic buildup in the tank, thereby decreasing bacterial growth in the tank.

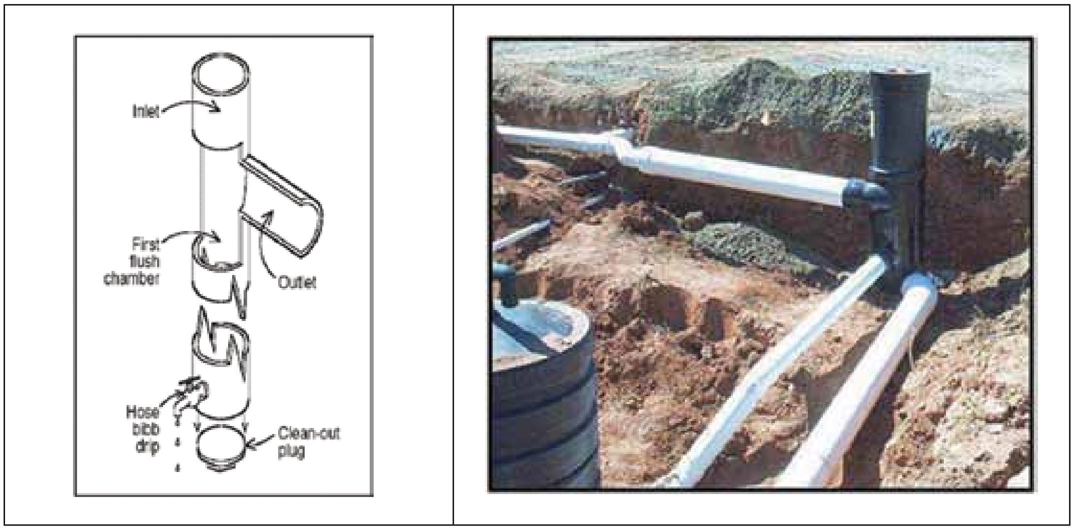


Figure 5.6. *Schematic & photo of pre-screening first-flush diverters designed to remove leaves, grit, and debris before water enters the cistern – applicable for moderate or complex Rainwater Harvesting projects.*
(Source: VADEQ 2011)

Tanks Will Be Heavy

Water weighs 8 pounds per gallon. A full 50-gallon Rain Barrel will weigh approximately 400 pounds. A full 275-gallon cistern will weigh over a ton, at approximately 2,200 pounds!

Storage Tanks The storage tank is the most important and typically the most expensive component of a Rainwater Harvesting system. Typical cistern capacities range from 50 to 250 gallons, although some commercial applications can be over 30,000 gallons. Multiple tanks or barrels can be placed together and connected with pipes to balance water levels and increase overall storage, as needed. The tanks can be made of many materials and configured in various shapes, depending on the type used and the site conditions where the tanks will be installed. For example, configurations can be rectangular, L-shaped, or cylindrical.

Storage tanks should be placed on a solid foundation of tight or compacted soil. The load-bearing capacity of the soil must be considered, since full cisterns can be very heavy. This is particularly important for above-ground cisterns, as significant settling could cause the cistern to lean or potentially topple. A gravel, cinderblock, or concrete base may be appropriate depending on the size of the tank and the existing soils. A strong base is especially important if the tank needs to be raised up to allow for more elevation change for gravity-fed distribution of the water.

Figure 5.7. *Larger above-ground tank made of opaque and durable material.*

Additional factors to consider when designing a Rainwater Harvesting system and tank include:

- Above-ground storage tanks should be UV-light and impact resistant.
- Underground storage tanks must be designed to support any anticipated loads (e.g., coverage soil, vehicles, pedestrian traffic, etc.).
- Underground Rainwater Harvesting systems should have an opening to allow access for cleaning, inspection, and maintenance purposes. This access point should be secured/locked to prevent unwanted access.
- Rainwater Harvesting systems may be ordered from a manufacturer or can be constructed on site from materials, such as ferro-cement.
- Storage tanks should be opaque or otherwise protected from direct sunlight to inhibit algae growth.
- Rain Barrels or cisterns that have an open top should utilize 2 layers of windows screen secured to the top to prevent mosquitoes from getting in and to keep leaves and debris out.

Sizing the Tank(s) For water quality improvement, a 1 inch rainfall event is a typical recommended amount to capture in a Rainwater Harvesting tank. This is the standard for most of Maryland, including Annapolis and the Eastern Shore. Use the following formula to determine how many gallons a roof area will produce in a 1-inch rain event:

Storage volume (gallons) = Area of the roof (square feet) that drains to the tank X 0.625

For a home with a 1200 square foot roof footprint divided equally between 4 downspouts, the area going to one downspout is:

1200 square feet ÷ 4 = 300 square feet

The minimum tank volume needed to capture 1 inch of runoff from that section of roof is:

300 square feet x 0.625 = 187.5 gallons

Given that most Rain Barrels hold approximately 50 - 75 gallons, capturing a full 1 inch of runoff at this downspout will require connecting multiple barrels together (**Figures 5.8 and 5.9**) or using a larger tank (for example, **Figure 5.7**). Most homeowner systems that use only one Rain Barrel are significantly undersized for the 1 inch storm. This is not a problem, but careful consideration of the overflow routing is in order.

Figure 5.8. *Two Rain Barrels connected together to capture more roof runoff*

Water storage below the outlet (e.g., spigot, with hose to garden), called dead storage, and an air gap at the top of the tank should be considered when factoring the total volume of the barrel or cistern. For gravity-fed systems, a minimum of 6 inches of dead storage should be provided. For systems using a pump, the dead storage depth will be based on the pump specifications. For example, in a typical gravity-fed 55-gallon Rain Barrel, 6 inches of storage at the bottom will be approximately 10 gallons and the air gap at the top will be approximately 5 gallons. The actual usable volume of the barrel will be around 40 gallons. Note that 6 inches of standing water at the bottom of the tank is a prime condition for mosquito breeding, so it is essential to make sure the tank system is mosquito proof.

Overflow As mentioned earlier, the overflow at the top of the tank must carry extra water away from the tank and about 10 feet away from any adjacent buildings once the tank fills up. The diameter of the overflow outlet and pipe should be adequate to carry overflow water without the tank overtopping, typically 1 to 3 inches for a small-scale system. Place a screen over the end of the overflow pipe to prevent rodents and insects from

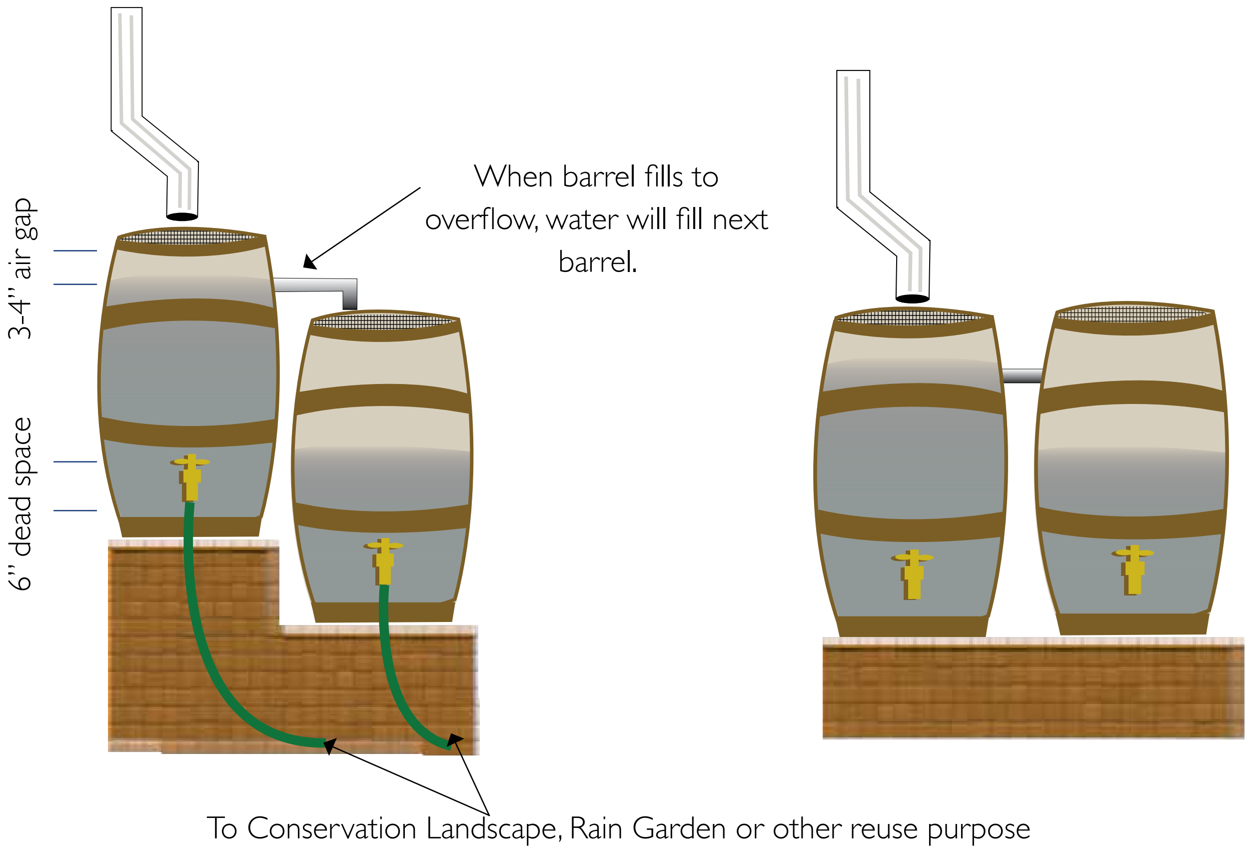


Figure 5.9. *Possible two-barrel configurations for Rainwater Harvesting. This allows more storage while still using small vessels. If more than two barrels are required, a larger tank or cistern is recommended.*

getting into the tank. If possible, lead the overflow pipe to a Conservation Landscape, Rain Garden, or other site that will allow water to infiltrate into the ground.

Outlet For simple gravity-fed Rainwater Harvesting systems, place an outlet spigot near the bottom of the tank (above the dead storage). A regular hose-bib spigot is the easiest type of outlet to use because a garden hose or soaker hose can be directly attached. Ideally, for stormwater management purposes, this outlet would be left open in order to draw down the tank so that it is empty for the next rain event. If the homeowner desires to have some water stored for later use for irrigation, for example, the tank should be emptied before the next storm or at least the spigot left open during non-irrigation months. As with the overflow pipe, drain the outlet/hose to a nearby Rain Garden, Conservation Landscape or other location where the water can soak into the ground.

Figure 5.10. *Rain Barrel with open top, 2 layers of screen, and downspout entering above. This allows for some pre-screening of leaves and debris as well as a strategy to prevent mosquitoes from entering.*

5.4. Materials

Materials for a basic, gravity-fed system are outlined in **Table 5.2.** Note that Rain Barrel kits are readily available from certain vendors, watershed groups, and soil and water conservation districts. These may contain most of the needed materials. See **Table 5.3** for typical components of a simple Rain Barrel.

Table 5.2. Materials Specifications for Rainwater Harvesting Systems

Material	Specifications	Notes/Comments
Downspout	• Match existing gutters and downspouts	• May need elbows or extensions to reach from existing downspouts into to the tank
Pre-screening for simple tank	• Typical leaf screens or gutter guards • Can also use basic, fine-mesh metal or plastic insect screen for top of tank	
Pre-screening first-flush diverter for more complex systems	• Vortex filters or first-flush diverters	• Some simple first-flush diverters for small-scale systems can be made from gutter/downspout materials • More complex vortex filters are pre-fabricated from various vendors
Base/foundation for tank	• When needed, gravel, block or pavers to stabilize the surface under a tank	• The base must be made level • Loose/soft soils must be compacted
Tank/barrel/cistern	• 50-65 gallon food grade plastic barrels • 250-275 cube-shaped plastic tanks in cages	• Variety of materials and configurations possible – should be impact resistant, UV resistant, and able to support any loads above or around it
Spigot and hose	• Typical garden hose, and readily available spigots and connectors from hardware store	• Installing a spigot in bottom of a Rain Barrel may require long reach or long-handled pliers
Overflow outlet/pipe	• Flexible pipe or PVC pipe sections • Connector to secure pipe to tank	• Reduce erosion by allowing water to release at ground level
Erosion control	• 3 inches of gravel, stone, or a splash block	• This will prevent erosion at the opening of the overflow and outlet pipes or hoses
Miscellaneous hard-ware	• *Possible:* downspout extension or adapter, screws, fasteners to hold components together • Non-toxic caulk to seal pipe connections	• This will depend on the specific components of the system, but a hardware store representative will likely be able to advise do-it-yourself efforts
Tools	• *Likely:* adjustable wrench, screwdriver • *Possible:* drill, hole saw bit for drill, hack saw, long-handled pliers, shovel, rake, tamper	• A kit may not require any tools • More tools will be necessary for custom systems

Table 5.3. Materials for a Rain Barrel

Item	Approximate Price	Notes
Screen – a few square feet	$2-7	• If the Rain Barrel has an open top, use a double layer in a crisscross pattern (e.g., the small square holes *not* aligned) secured to the top to prevent mosquito breeding • See **Figure 5.10**
Rain Barrel	$25-100	• The lower price is for the barrel only • Rain Barrel kits may come with spigots, connections, hardware, and/or diverters
Overflow outlet/pipe	$2-5	• Flexible pipe or PVC pipe sections
Hose bib/spigot, ¾ inch with ¾ inch nut, rubber gasket, and washer	$5-10	• Should be water tight, with gasket and washer on inside of barrel
Garden hose	$5-50	• Price depending on length and quality
Self-drilling sheet metal screws	$2-5	• To hold the screen to the lid of the barrel

Tools required:

- drill (hole for spigot, starter hole in lid for keyhole saw)
- keyhole saw or hole saw for drill attachment (to cut hole in lid)
- screwdriver (to secure screen)
- pliers (to hold nut in place to secure hose bib)
- adjustable wrench (to tighten hose onto spigot)

General notes: Total cost for this system can be as little as $40 and take only a couple hours to construct. As shown, it does not have a dedicated overflow, but assumes that the ground beneath the barrel is stable and will not erode, like concrete or gravel for example. Pre-assembled kits are readily available, as well.



5.5. Construction

The following are instructions for constructing a basic, gravity-fed system located close to a downspout:

Step 1 – Prepare the Ground Level the ground where the tank will be located, using rakes or shovels. Test soil compaction by stomping on it or chopping into it. If it is firm, the tank may possibly be placed directly on the ground. If the soil is loose or unstable, tamp it down and build a foundation using gravel and pavers or block. Foundations raise the elevations of the tanks, and clearance under the downspouts should be re-measured to know where to cut off the downspouts.

Step 2 – Check Final Height Measure the height of the tank and make sure there is enough clearance to get the tank under the downspout connection point. Don't forget to account for the height of the foundation below the tank, if applicable.

Step 3 – Assemble Tank Assemble the tank and any necessary connection hardware. Pre-built kits, may have this step partially or fully completed. Otherwise, cut a hole in the lid if necessary, and affix the screen to the lid. Alternatively, connect the downspouts to another screening device or first flush diverter. Install a hose bib 6 inches from the bottom of the tank, if there isn't one already. Attach additional hardware as necessary if the system will have multiple tanks or a dedicated overflow hose. An interconnecting hose between tanks will equalize the water level in the tanks if the water level is above this bridge. An overflow outlet point should be installed near the top, leaving at least 2-6 inches from the top of the tank for the air gap. See the diagram in **Figures 5.2 and 5.3** for examples of barrel-based systems.

Do:

- Make sure the ground beneath the barrel/cistern is solid, and level
- Make sure that wherever the water is directed is several inches below the spigot
- Ensure any overflow is directed away from the house, and to a stable surface like a splash block or gravel with the ground sloping gently away from the house

Don't:

- Use materials easily damaged by sunlight
- Leave the Rain Barrel full after it gets filled – it can only do its job in a storm if it is empty when the rain comes!

Step 4 – Install Tank & Route Downspouts Put the tank in place on the ground or on its foundation and confirm that it is stable and level. Route the downspout into the top of the tank. This will likely involve cutting off a section of the downspout with a hacksaw and attaching a curved downspout section to lead the downspout into the inlet. Connect any filtration or diversion devices to the downspout, if applicable.

Step 5 – Install Overflow Pipe Connect the overflow pipe to the overflow point of the tank and seal it properly. Lead the end of the pipe to where it can release water at ground-level away from the building. The ground at the outlet may need gravel, stone or a splash block to prevent erosion.

When Using Pumps

If the system involves a pump inside the tank, or an underground tank, install any in-tank components and an observation/access port if the tank does not already have one.

Step 6 – Connect Distribution Pipe Connect the hose to the outlet at the bottom of the tank. If the system is intended to have a constant slow-release from the tank, put the open end of the hose in place and make sure the spigot is slightly open. If the system is intended to have the hose ready for use, but with no particular destination in mind, connect a hose and leave it coiled next to the tank.

5.6. Maintenance

Table 5.4. Recommended Maintenance for Rainwater Harvesting Systems

Maintenance Task	Frequency
• Keep gutters and downspouts free of leaves and other debris • Inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots	At least once/year
• Inspect and clean pre-screening devices	At least four times/year
• Inspect condition of overflow pipes, overflow filter path and/or secondary runoff reduction practices • Inspect tank for sediment buildup • Inspect structural integrity of tank, pump, pipe and electrical system (as applicable based on the system)	Every third year
• Replace damaged or defective system components • Check mosquito screens and patch holes or gaps immediately	As needed
• Check Rain Barrel or tank regularly to see if mosquito larvae are present • Use mosquito dunks or similar for short-term control and repair any openings allowing mosquitoes to enter	Summer, as needed
• Drain tank after growing season if used for seasonal irrigation use only • Add empty plastic soda bottles (with tops affixed) to the water if some winter use is desired, so that if the tank freezes, it will not crack	Winter, as needed

5.7. Resources

American Rainwater Catchment Systems Association
http://www.arcsa.org/

Cabbell Brand Center. (2009). *Virginia Rainwater Harvesting Manual*, 2nd ed.

Hirschman, D., & Collins, K. (2008). Technical Memorandum : *The Runoff Reduction Method.*

Maryland Department of the Environment. (2009 update). Maryland Stormwater Design Manual. Vol. 1. Chapter 5.

Texas Water Development Board. (2005). *The Texas Manual on Rainwater Harvesting*, 3rd ed.

Virginia Department of Environmental Quality. 2013. *Virginia Stormwater BMP Specifications – Rev. 2013 (DRAFT).* Richmond, VA. Available at: http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications.aspx

Arlington Echo
http://www.arlingtonecho.org/restoration-projects/rain-barrels.html

Green (or Vegetated) Roofs

Vegetated Roof in Norway
(Source: Wikimedia)

Purpose & Benefits

- Reduce runoff from rooftops
- Lower utility bills
- Better roof longevity
- Aesthetic amenity

Description

Green Roofs (also known as Vegetated Roofs) capture and temporarily store stormwater runoff before it flows into the roof guttering system. Components of a Green Roof include low-growing, drought-tolerant plants (such as sedum species), an engineered growing medium that is designed to support plant growth, and an alternative roof surface that typically consists of waterproofing and drainage materials. Water drains vertically through the media and then horizontally along a waterproofing layer towards the roof drains/gutters. The Green Roof performs several critical stormwater runoff related functions; filters pollutants from the air and rain water, and reduces volume, force of flow, and water temperature.

What to Expect

The materials of a Green Roof are heavier than a typical roof, so buildings must meet certain structural standards in order to support the extra weight. Consult a building engineer or architect to determine if the structure will adequately handle the load. Some irrigation is likely necessary after installation to ensure the plants get established, but plant species are selected so that the roof does not need supplemental irrigation or fertilization after vegetation is initially established. Removing invasive plants, weeding, and overall vegetation management are the primary maintenance considerations, as well as structural repairs as needed.

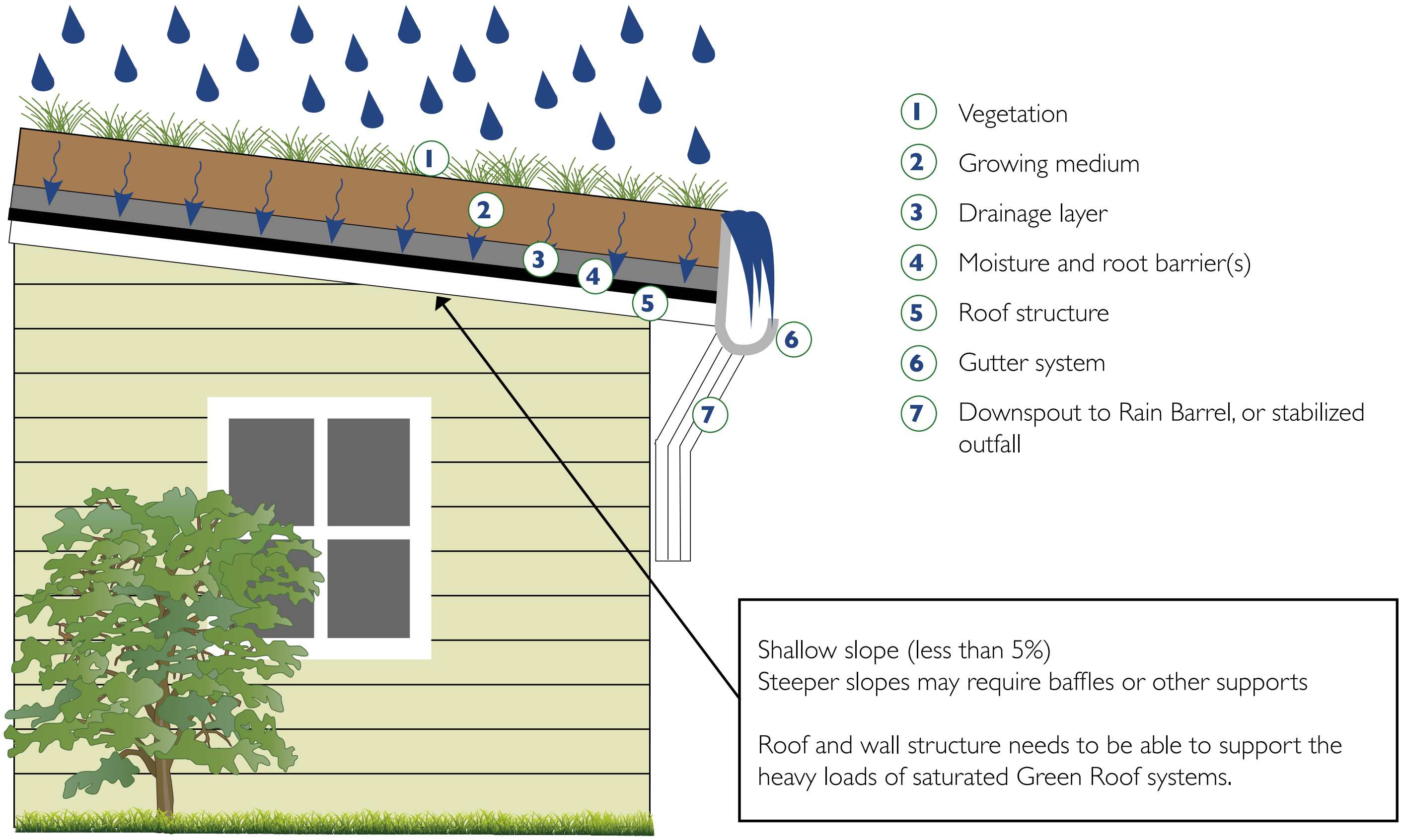


Figure 6.1. *The components of a typical Green Roof*

6.1. Complexity

A Green Roof is likely not something that can be installed by someone without some building experience. Green Roof systems contain multiple components and have many design considerations that are generally outside the expertise of those who do not design and build structures. Therefore, this practice will likely require at least a licensed contractor, and possibly an engineer or architect, to properly design and build (see guidance in **Table 6.1**).

"Extensive" Green Roofs typically have 2 to 8 inches of growing media, whereas "intensive" Green Roofs have thicker media that can capture and treat more water and support the growth of larger plants (e.g., shrubs and trees). Some homeowners and landscape contractors install basic extensive Green Roof systems themselves with good success, but typically these are installed on accessory buildings.

Understand the Complexity of the Green Roof Project

The intent of this guide is for practices in the SIMPLE or low end of MODERATE categories, and for modular and/or extensive systems. Even if the practice is in the simple category, consider consulting with an appropriate design professional, as Green Roofs must be integrated with the existing structure and involve inherent complications.

Green Roofs should be designed and constructed by a contractor with experience and knowledge about this practice. The design and construction details provided in this chapter may allow Stewards and homeowners to better understand the practice, but not to construct this practice without the help of an experienced contractor.

Table 6.1. Design Complexity for Green Roofs

Design Complexity	Description	Guidance
Simple	• Basic construction, fewer layers or components • Some kits available for homeowners with sturdy, shallow-sloped roofs • Sheds, garages, possibly main residence	• Waterproofing is important, especially if on a residence or other enclosed building • Structure must be strong and roof slope should be shallow, usually <3% • Techniques for steeper roofs are available, such as using a tray matrix, baffles or grids.
Moderate	• Extensive Green Roofs, shallower commercial systems or traditional designs • Special materials for waterproofing and root barrier should be used • *Can* weigh more than 50 pounds/square foot when saturated • Steeper slopes possible, but special installation is required	• Design should be provided by a professional, such as an architect, engineer, or Green Roof design/installation professional • Design should be made using accepted construction specifications • Construction will likely require specialized contractor
Complex	• Intensive Green Roofs, deeper, more comprehensive systems • Can handle fairly large rain events • Can weigh more than 100 pounds/square foot when saturated • Most likely only for commercial, institutional, or industrial buildings due to load-bearing requirements • Very expensive	• Requires a professional architect or engineer in addition to Green Roof specialist • Requires adherence to state or local stormwater or Green Roof manual design specifications • May require more maintenance than other Green Roof systems

6.2. Location & Feasibility

When deciding whether a Green Roof is an appropriate practice for a specific property, it is important to consider the following:

Structural Capacity of the Roof When designing a Green Roof, designers must not only consider the water storage capacity of the Green Roof, but also its structural capacity to support the weight of the additional water. An existing conventional rooftop typically must be modified to support an additional 15 to 30 pounds per square foot for an extensive Green Roof. As a result, a structural

Understand the Constraints

The roof and structure must be strong enough to hold the weight of the saturated Green Roof, plus the necessary other loads like snow and wind typical for the region.

Do:

- Consult a structural engineer or architect to verify that building can carry the weight of Green Roof
- Plan access to roof for construction and for long-term maintenance
- Look up local building codes and state design specifications for Green Roofs

Don't:

- Attempt to install Green Roof on slopes steeper than 25%

engineer, architect, or other qualified professional should be recruited to verify that the building has enough structural capacity to support a Green Roof. An intensive Green Roof is deeper and can have much heavier loads.

Roof Pitch Green Roof stormwater storage volume is maximized on relatively flat roofs (a slope of 1 to 2%). However, enough slope is needed to ensure good drainage and prevent ponding on top of the growing media. Green Roofs can be installed on rooftops with slopes up to 25% if baffles, grids, or strips are used to prevent slippage of the media. Most residential roofs are too steep for a Green Roof system that does not have baffles or other slip-stops.

Roof Access Adequate access to the roof must be available to deliver construction materials and perform routine maintenance. Consider if a forklift, crane, or other equipment is needed to get construction materials up to the roof. Also, have a plan for staging construction materials on the roof. Regular maintenance may be required depending on a number of factors, which will necessitate accessing the roof and possibly carrying some replacement materials up to and around the roof.

Figure 6.2. *Vegetated Roof on a home in Maryland.*
(Source: Chesapeake Conservation Landscaping Council)

Roof Type Green Roofs can be applied to most roof surfaces, although concrete roof decks are preferred. Certain roof materials, such as exposed treated wood and uncoated galvanized metal, may not be appropriate for Green Roofs due to pollutants leaching through the media.

Local Building Codes Consult local permitting authorities to obtain proper permits. In addition, the Green Roof design should comply with local building codes with respect to roof drains and emergency overflow devices.

6.3. Design

With the caveat that any Green Roof design should at least be examined and confirmed by an experienced design professional, the design elements are listed below. Material specifications for Green Roofs vary based on each roofing system. Obtain specific information from the appropriate roofing system manufacturer or retailer. The following information and specifications, which include acceptable materials for generic applications, are not exclusive or limiting. If the specifications below are too complex for the proposed application, use a pre-engineered kit suitable for the structure or consult with a Green Roof professional. The following material and media specifications are from the Green Roof section of the *Maryland Stormwater Design Manual*, Appendix B.4.A.

Green Roof layer, from bottom to top:

Deck Layer The roof deck layer is the foundation of a Vegetated Roof. It may be composed of concrete, wood, metal, plastic, gypsum or a composite material. The type of deck material determines the strength, load-bearing capacity, longevity, and potential need for insulation in the Green Roof system.

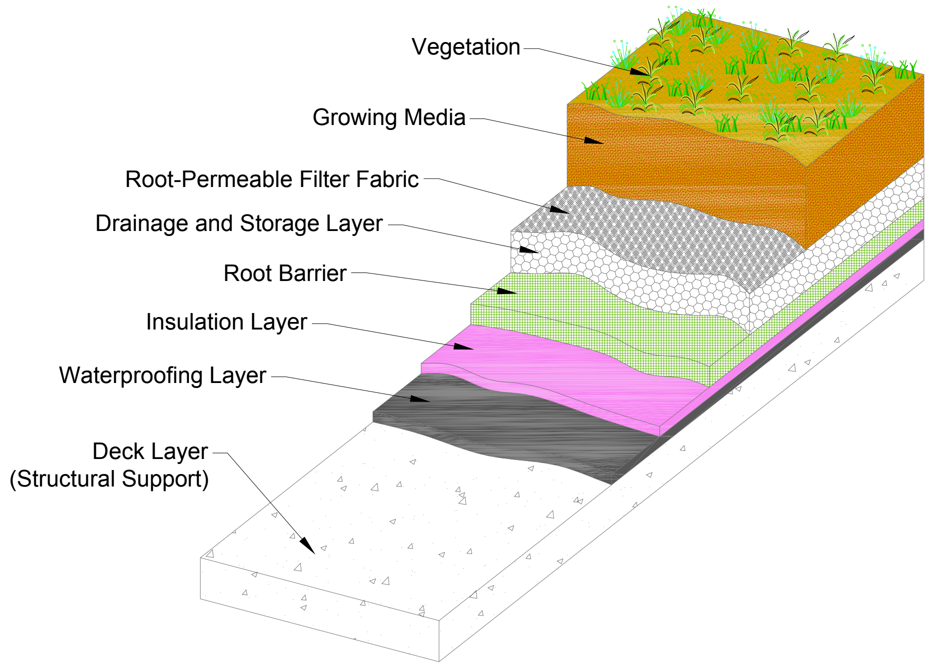


Figure 6.3. *Typical layers of a Green Roof*

Waterproofing Layer All Green Roof systems must include an effective and reliable waterproofing layer to prevent water damage through the deck layer. The waterproofing layer must be completely waterproof and have an expected life span as long as any other element of the Green Roof system, and ideally the roof itself.

Insulation Layer Many Vegetated Rooftops contain an insulation layer, usually located above, but sometimes below, the waterproofing layer. The insulation increases the energy efficiency of the building and/or protects the roof deck (particularly for metal roofs).

Root Barrier The next layer of a Vegetated Roof system is a root barrier that protects the waterproofing membrane from root penetration. Avoid chemical root barriers or physical root barriers that have been impregnated with pesticides, metals, or other chemicals that could leach into stormwater. Root barriers should be thermoplastic membranes with minimum thickness of 30 mils (0.030 inches).

Waterproofing Layer

It is vital that the waterproofing layer is both installed correctly, and suitably designed for the application. Subsequent installation and maintenance work must be performed carefully so as not to damage the waterproofing layer. If the waterproofing layer fails, serious damage can occur to the structure below.

Drainage Layer and Drainage System A drainage layer is placed between the root barrier and the growing media to quickly remove excess water from the vegetation root zone. The drainage layer should consist of synthetic or inorganic materials, such as gravel or recycled polyethylene, that are capable of providing fast drainage (see **Table 6.2** for specifications). The required depth of the drainage layer is governed by both the desired stormwater storage capacity and the structural capacity of the rooftop.

Table 6.2. Granular Drainage Media

(From MDE, 2000 p. B.4.2)

Saturated hydraulic conductivity	≥ 25 inches/minute
Total organic matter (by wet combustion)	≤ 1%
Abrasion resistance (ASTM C131-96)	≤ 25% loss
Soundness (ASTM C88 or T103 or T103-91)	≤ 5% loss
Porosity (ASTM C29)	≥ 25%
Alkalinity, CaCO3 equivalents (MSA)	≤ 1%
Grain Size Distribution	
% Passing #18 sieve	≤ 1%
% Passing 1/8 inch sieve	≤ 30%
% Passing 3/8 inch sieve	≤ 80%

Root-Permeable Filter Fabric Semi-permeable polypropylene filter fabric is normally placed between the drainage layer and the growing media to prevent the growing media from migrating into the drainage layer and clogging it (**Table 6.3**).

Table 6.3. Root-Permeable Filter Fabric - non-woven geotextile

(From MDE, 2000 p. B.4.2)

Unit weight (ASTM D3776)	≤ 4.25 oz. per square yard
Grab tensile strength (ASTM D4632)	≤ 90 pounds
Mullen burst strength (ASTM D4632)	≥ 135 pounds/inch
Permittivity (ASTM D4491)	≥ 2 sec^{-1}

Growing Media The next layer in an extensive Green Roof is the growing media, which is typically 2 to 8 inches deep. As the name suggests, this is the layer in which the plants grow. This can be soil or alternative materials designed to sustain plant growth. **Tables 6.4 and 6.5** provide typical specifications for the growing media.

Table 6.4. Growing Media

(From MDE, 2000 p. B.4.1)

Non-capillary pore space at field capacity, 0.333 bar (TMECC 03.01, A)	≥ 15% (volume)
Moisture content at field capacity (TMECC 03.01, A)	≥ 12% (volume)
Maximum media water retention (FLL)	≥ 30% (volume)
Alkalinity, CaCO3 equivalents (MSA)	≤ 2.5%
Total organic matter by wet combustion (MSA)	≤ 3-15% (dry weight)
pH (RCSTP)	6.8-8.0
Soluble salts (DTPA saturated media extraction - RCSTP)	≤ 6 mmhos/com
Cation exchange capacity (MSA)	≥ 10 meq/100 g
Saturated Hydraulic Capacity (MSA)	
>Single media assemblies	≥ 0.05 inches/minute
>Dual media assemblies	≥ 0.30 inches/minute

Table 6.5. Mineral Fraction Grain Size Distribution (ASTM D422)

(From MDE, 2000 p. B.4.1)

	Single Media	Dual Media
Clay fraction	0	0
% Passing #200 sieve	≤ 5%	5-15%
% Passing #60 sieve	≤ 10%	10-25%
% Passing #18 sieve	5-10%	20-50%
% Passing 1/8 inch sieve	20-70%	55-90%
% Passing 3/8 inch sieve	75%-100%	90-100%

Plant Cover The top layer of a Green Roof consists of slow-growing, shallow-rooted, perennial, succulent plants that can withstand harsh conditions at the roof surface. A mix of base ground covers (usually Sedum species) and accent plants can be used to enhance the visual appeal. Intensive Green Roofs with deeper growing media can have a variety of shrubs, small trees, and ground cover.

6.4. Materials

Materials will vary based on the type of Green Roof system and design and the particular manufacturer's specifications. **Table 6.6** is a less specific list of materials with approximate quantities in ranges relative to the roof area. General descriptions and specifications are above in the design section.

Table 6.6. Materials List

Material Item	Required or Optional	Comments/Notes	Approximate Quantity
Deck layer	Required	Optional only if roof already has an acceptable base material	Roof area
Waterproofing layer	Required		Roof area
Insulation layer	Optional		Roof area
Root barrier	Required	*If* waterproofing layer is absolutely impermeable to root penetration, this is optional (not likely)	Roof area
Drainage layer	Required		Depends on how much storage is designed and the structural capacity of the roof *Per inch* of layer depth: (Roof area)/12
Root-permeable filter fabric	Required	Optional only if the growing media used is not loose, and cannot clog the drainage layer beneath	Roof area
Growing media	Required		Quantity can vary greatly *Per inch* of layer depth: (Roof area)/12 Probable range: (Roof area)/6 to (Roof area)/2
Plant cover	Required	Coverage area is the whole Green Roof, but the plant selection drives quantity of plants or seeds Consultation with a Green Roof specialist, specialty nursery, or design professional may be needed	Roof area

6.5. Construction

Given the diversity of extensive Green Roof designs, there is no typical step-by-step construction sequence for proper installation. The following general construction considerations are noted:

Do:

- Follow specific instructions of Green Roof material manufacturers
- Plan out how to maneuver around roof during installation
- Fertilize and water as needed to get the plants established

Don't:

- Damage waterproofing layer during installation of other layers – it is crucial!

Step 1 – Roof Deck Construct the roof deck with the appropriate slope and material, or ensure that the existing roof deck material can support and is adequate for a Green Roof.

Step 2 – Install Waterproofing Install the waterproofing method according to manufacturer's specifications.

Step 3 – Test the Waterproofing Conduct a flood test to ensure the system is watertight.

Step 4 – Install Other Layers Add additional system components (e.g., insulation, root barrier, drainage layer and interior drainage system, and filter fabric), taking care not to damage the waterproofing. Drain collars and protective flashing should be installed to ensure free flow of excess stormwater.

Step 5 – Add Growing Media Mix the growing media prior to delivery to the site. Spread media evenly over the filter fabric surface. Cover the growing media until planting to prevent weeds from growing. Sheets of exterior grade plywood can also be laid over the growing media to accommodate foot or wheelbarrow traffic. Limit foot traffic and equipment traffic over the growing media to reduce compaction.

Step 6 – Add Plants Moisten the growing media and plant with ground cover and other plant materials, as per the plan. Water plants immediately after installation and routinely during establishment.

Step 7 – Fertilize & Water Fertilize using slow release fertilizer (e.g., 14-14-14) with adequate minerals to support growth, if specified by the media manufacturer. Temporary watering may also be needed during the first summer, if dry conditions persist.

6.6. Maintenance

Access

It is important to think about access to and from the roof when considering whether to install a Green Roof. Maintenance requires getting onto and safely moving about the roof, most likely with some materials and tools.

Table 6.7. Recommended Maintenance for Green Roofs

Activity	Schedule
• Water to promote plant growth and survival • Inspect the roof and replace any dead or dying vegetation	As needed (following construction)
• Inspect the waterproof membrane for leaks or cracks and repair as needed • Weed to remove invasive plants (no digging or using pointed tools) • Inspect roof drains, scuppers, and gutters to ensure they are not overgrown or have organic matter deposits and remove any accumulated organic matter or debris • Inspect the roof for dead, dying, or invasive vegetation and plant replacement vegetation as needed	Semi-Annually
• Fertilize (first 5 years)	Annually

6.7. Resources

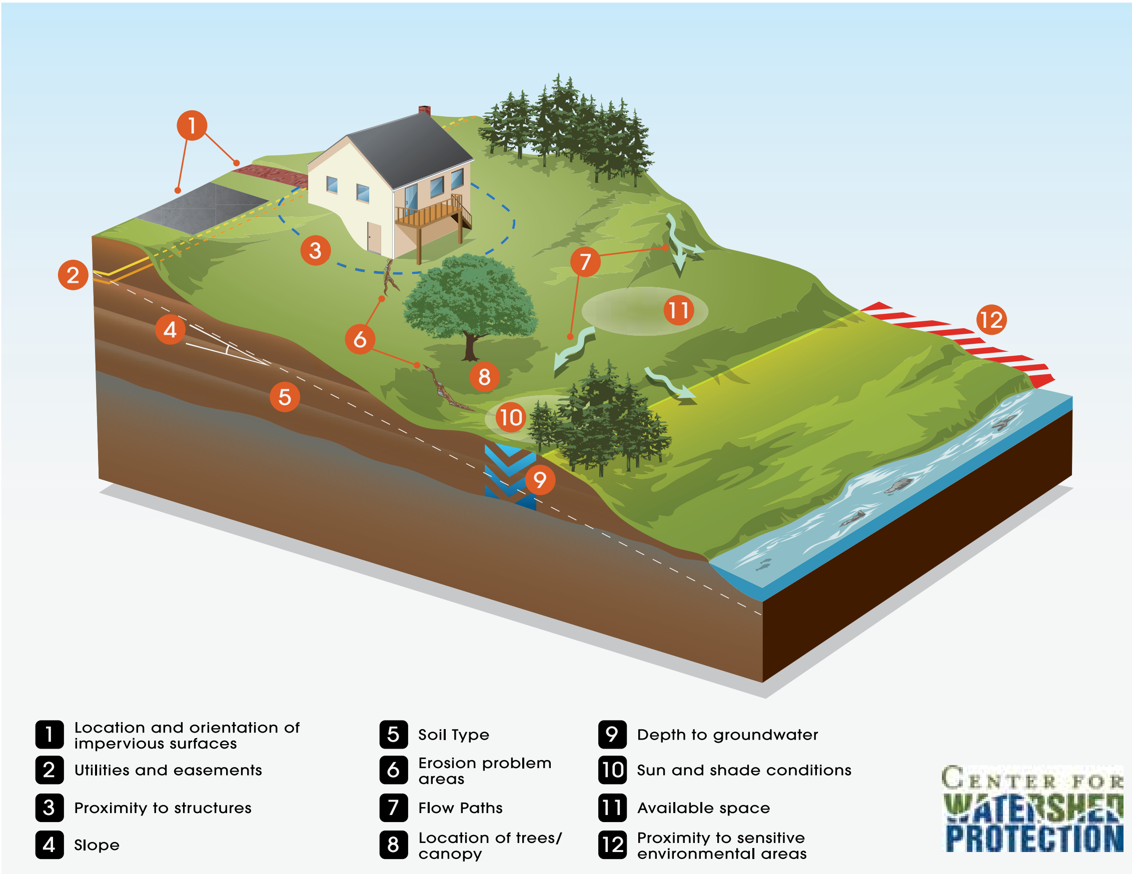
Green Roof Directory
http://www.greenroofs.com/resources.htm

Hirschman, D., & Collins, K. (2008). Technical Memorandum : *The Runoff Reduction Method.*

Maryland Department of the Environment. (2000). Maryland Stormwater Design Manual. Vol. 2. Appendix B.4.A Green Roof Specifications.

Virginia Department of Environmental Quality. 2013. *Virginia Stormwater BMP Specifications – Rev. 2013 (DRAFT).* Available at: http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications.aspx

Appendix A:
Site Assessment: Methods & Recommendations



Introduction

The first step to implementing a stormwater management practice is to assess the opportunities and the challenges specific to the site. A deliberate, multi-step process is critical to ensuring that the design benefits the environment, the best and most appropriate practices are selected, and undesirable impacts are avoided. Guidance is presented as a step-wise process, but the key points can be addressed in various ways. Some vital considerations are called out in information boxes.

> Even a video from yesterday might not show the site's accurate condition as of today. Be prepared!

> "Pace off" means to walk the length of a feature. An average stride length is about ½ of the person's height. For example, a 6-foot tall person has approximately a 3-foot length for 1 step at a normal walking stride. If a long tape measure isn't available, this can be a good substitute.

Much information can be gathered about a site before conducting a site visit, including layout, topography, and many soil and hydrologic conditions. However, a site assessment is never complete without a site visit. Note that conditions on residential sites can change rapidly. It is important to be prepared for changing conditions or information that may no longer be accurate.

Step 1 - Create an Existing Conditions or Base Map

Begin by obtaining a recent aerial photo of the property available at My Anne Arundel GIS (does not work with Google Chrome), LandServer, Google Earth, Google Maps, or Bing Maps (does not work with Google Chrome browser). **Figure A.1** below is a screenshot from Google Earth Pro, marked to help highlight the actions described in the next paragraph.

> Never install an in-ground stormwater practice under mature tree canopy. Digging can damage the roots and kill the tree. It is fine to plant trees that will eventually spread canopy over a practice. If the practice involves native plants, as in a Conservation Landscape or a Rain Garden, consider if the plant is suited to thrive in shade.

Next, outline the boundary of the property (dotted green box) and highlight the hard, impervious surfaces such as roof surfaces, decks, sheds, pools, the driveway and sidewalks (shaded red polygons). Mark major trees (shaded blue circles), taking into account the size and spread of the tree and existing landscaping beds. Pace off or use a tape to measure the approximate dimensions of all the impervious surfaces and landscaping areas, and calculate the area of each. Summarize this information in the table provided below to determine how much impervious surface is present. Google Earth has the capability of measuring these in the map view, but measuring on the site will provide more accurate measurements.

The quantities in the following table can be automatically calculated, for the most part, using the Clean Water Communities online calculator. If the site of interest is in Anne Arundel County, click here to use the tool, find out how much impervious cover there is on site, and the stormwater benefit of installing certain practices.

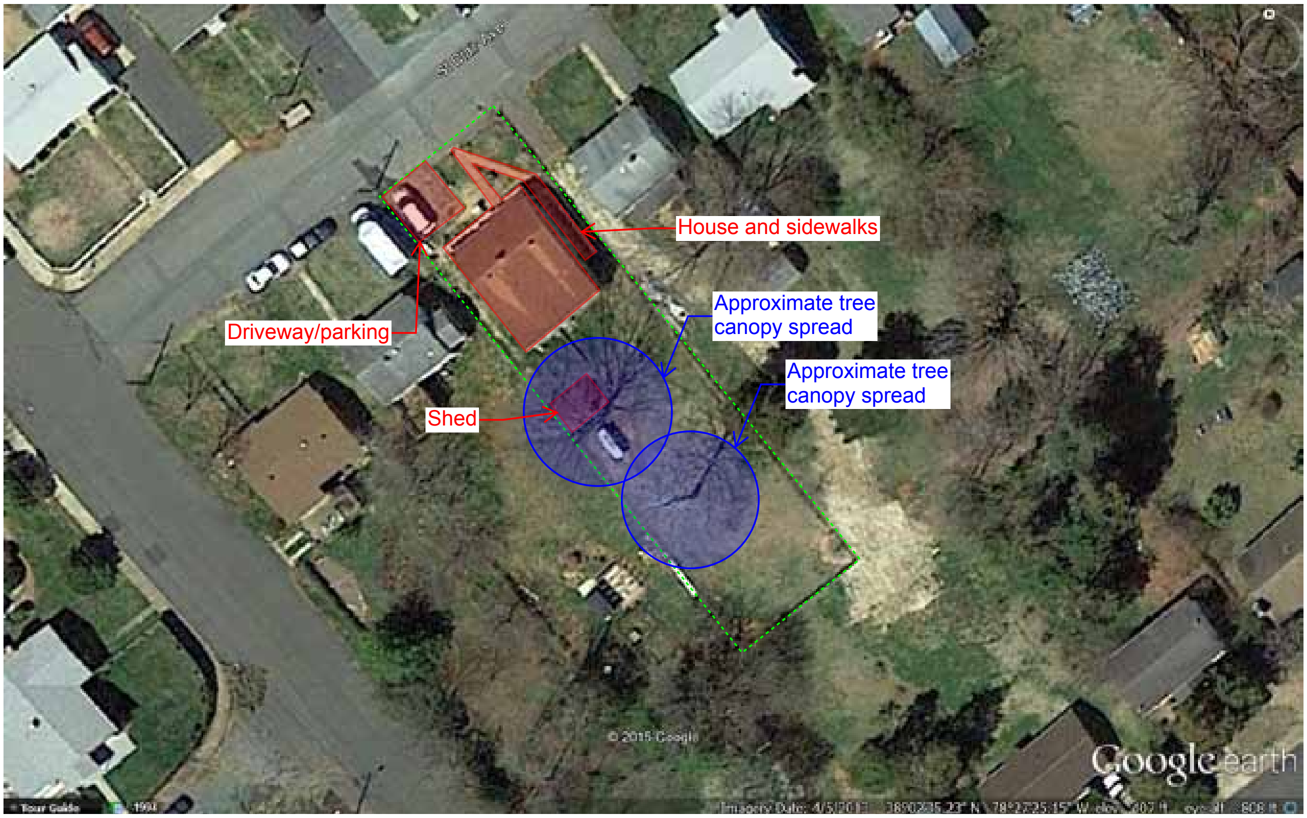


Figure A.1. *Google Earth Pro screenshot with lot features marked and highlighted*

LOT COVERAGE	Area: Square Feet
Hard Surfaces	
Rooftops	
Driveway/Sidewalk/Patios	
Pervious Cover	
Trees/Landscaping	
Lawn	
TOTAL	

Step 2 - Map Flow Paths

The next step is to map how water flows on the site. In general, most lots are graded to move rainwater away from the home and down to the street or, in some cases, the back yard. The best way to assess how water flows on the site is to watch and take note during a rain event. Observe how water is flowing off of sidewalks and driveways, look closely at downspouts, note which way they are pointing and how much water is coming out relative to the other downspouts. On the map, indicate the flow paths (most lots have multiple flow paths) using arrows. Note the movement of water from the house or driveway on the map, and any areas where water naturally ponds after a heavy rain.

If the site visit does not coincide with a rain event, it is still possible to get a good idea of the water flow. Water always follows the path of least resistance. It flows downhill, and given obstacles, it will push through softer material and move around immovable barriers. The most accurate way to gauge flow paths is by measuring relative elevations using a site level or even a hand level, as the eye can be deceiving when trying to ascertain the slope of the land, particularly on relatively flat sites. Also, take note of any gullies that have formed, particularly adjacent to solid structures like steps, sidewalks, and under downspouts. Look for accumulation of sand or soil deposits carried by runoff. **Figure A.2** shows a gully large enough to be seen in aerial imagery where the water flows from a gravel parking lot downhill toward a house next door. Flow paths should also be confirmed with the resident or owner, as they will have first-hand knowledge of where water flows, ponds, or is causing a problem.

Figure A.2. *Google Maps aerial image showing significant gully along stormwater flow path*

It is possible to get an idea of the drainage pattern of a site before or without visiting it. In Google Earth, hovering the cursor over a point on the map will show the elevation in the lower right corner, as shown in **Figure A.3** below. Other online mapping tools may show elevation contours, though the contours may not be at a high enough resolution or accuracy for residential scale assessment, especially for relatively flat sites. Depending on the locality, contours are often at 2-foot or 10-foot elevation changes, and residential assessment often may require a scale as fine as a 1-foot resolution.

Figure A.4 shows a screenshot from a local GIS viewing tool. The red box shows where a user can select the topographic data layer, which in this case is at the 2-foot resolution. The red arrows drawn on the site show the general direction water will flow, since it flows downhill.

Figure A.3. *Google Earth screenshot, showing cursor position and elevation reading*

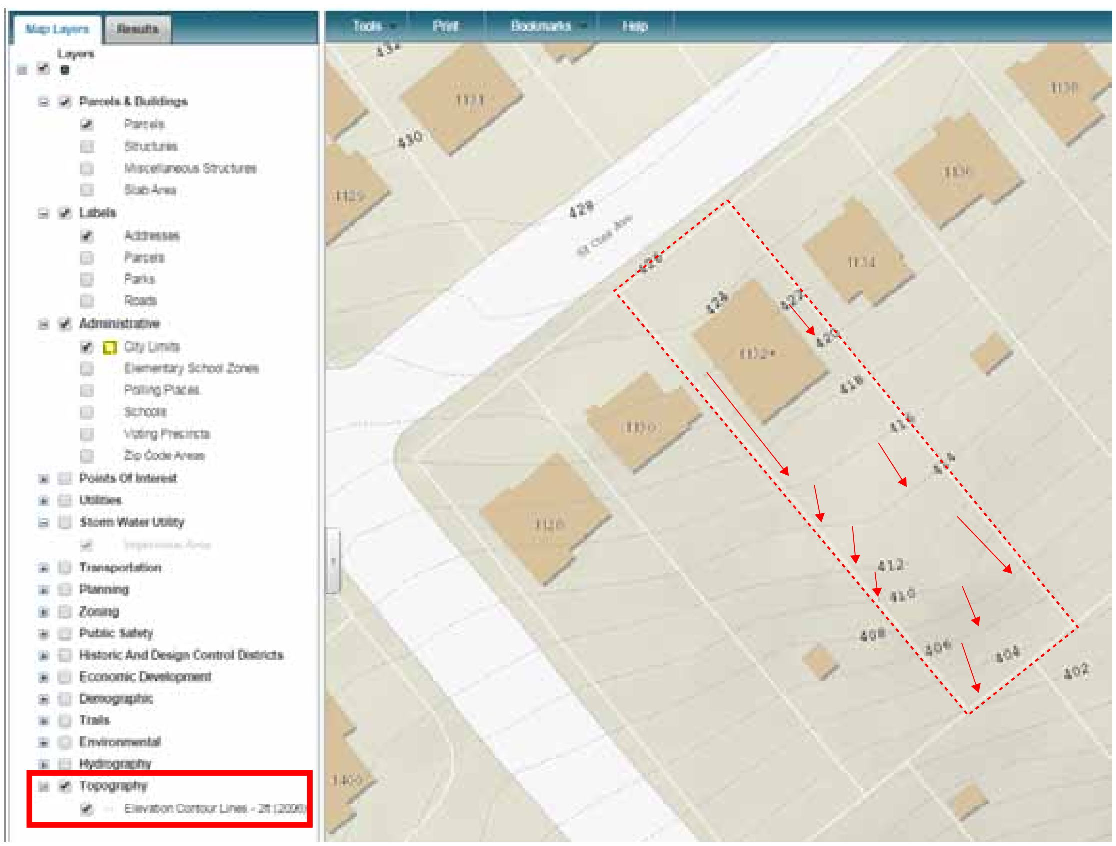


Figure A.4. *A local GIS Viewer screenshot, showing contour layer selection at left, parcel of interest outlined in dotted red, and general flow direction of runoff in red arrows*

Step 3 - Map Utilities and Easements

Utilities can be located almost anywhere and can complicate the design of a residential stewardship practice. Many of these utilities are located below ground and are not easily recognized. Therefore, contact a utility marking service to identify the location and type of underground utilities. Maryland requires calling the Miss Utility Hotline (1-800-257-7777 or 811) before excavation. Miss Utility and similar hotlines consolidate utility marking services but do not mark private utilities, such as invisible dog fences, some street lights irrigation lines, etc. It is necessary to scout the property to locate where these utilities leave, enter, and cross the yard.

More information about this free resource can be found: http://www.call811.com. Once Miss Utility marks the locations of the underground utilities, draw these on the property sketch. Typical utilities are listed in the table below.

Locate and Add to Property Sketch:		
Natural gas feeder line	Underground electric lines	Street right of way
Sewer lateral and cleanout	Cable and fiber optic lines	Septic field (if present)
Water lines and wells	Sump pump discharges	Overhead forest canopy

Also, some GIS and other public resources will show the locations of utilities. **Figures A.5** and **A.6** below show a random site in Anne Arundel County using the My Anne Arundel GIS viewer, and the example site fto help illustrate this process. The property shows both an underground gas line, and a sanitary sewer line. The sewer laterals, the connections between the houses and the main sewer line, are not shown in this viewer. Similarly, only the water main is shown, but not the lateral connections to the residences. These laterals are utilities that must be marked by the utility locators. **A call to Miss Utility** (or equivalent location service, if the site is in another state) **is always required!**

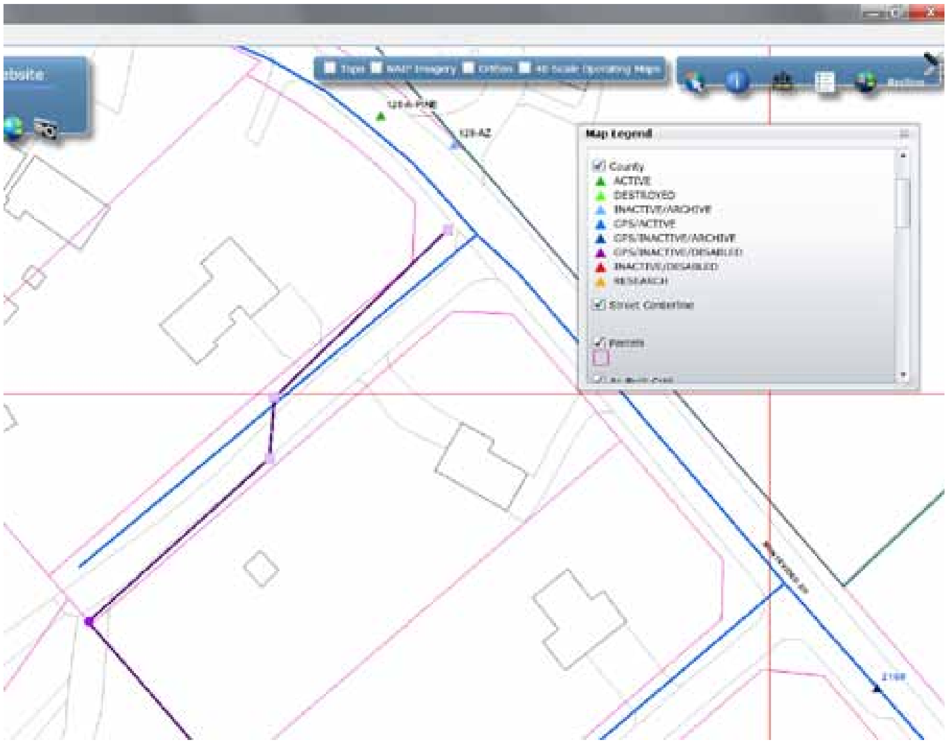


Figure A.5. *My Anne Arundel GIS Viewer screenshot showing utility locations*

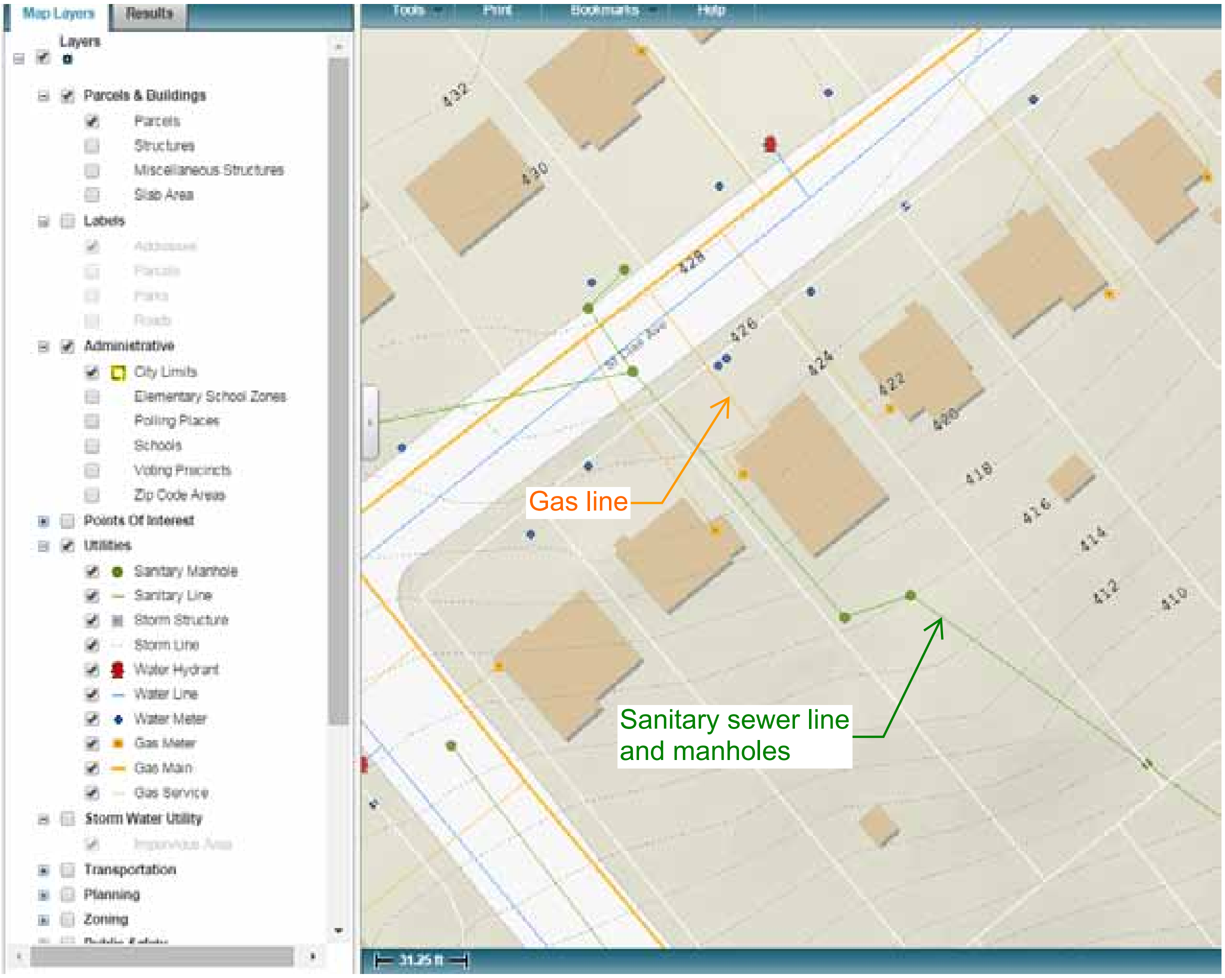


Figure A.6. *GIS Viewer highlighting utility locations*

Always check the property to confirm GIS data to the extent possible. GIS data is not always current.

Step 4 - Map Problem Locations and Areas of Interest

There are a number of other potential challenges unique to the site that should be documented on the map. These include areas that are soggy or wet for prolonged periods; areas that have signs of erosion, poor grass cover, invasive plants, steep slopes, rocky areas; and areas where there are other planned activities (play areas for kids and pets). Environmentally sensitive and historic areas are often regulated and must be observed carefully. Floodplains, wetlands, stream buffers, critical resource protection areas and wildlife habitats, and historic landmarks and assets have additional constraints that are beyond the scope of this manual. GIS data often includes layers with these critical areas. Consult with local and state government or land management entities, such as Maryland Department of Natural Resources, if there is any question about the location or status of the project site relative to these sensitive areas.

Mark these areas on the map and indicate the specific concern or condition. Wet areas are very likely not appropriate for infiltration-dependent practices like Conservation Landscapes and Rain Gardens. Erosion (like the aforementioned gullies) is a sign that a large amount of water is passing that area and the soil needs stabilized. Steep slopes are typically very difficult and not practical for many stormwater practices. Rocky areas may be difficult for practices that require excavation and/or infiltration. Refer to the Soil Assessment section (Appendix B) for more detail.

In-ground stormwater practices should not be installed under mature tree canopy. Excavation could damage roots, harming the tree. Also, the tree itself is providing stormwater runoff reduction, in addition to many other benefits. Newly-planted trees may be co-located with other plants and be part of a stormwater practice like a Conservation Landscape or a Rain Garden. Newly-planted trees should be installed properly. Some example guidance can be *found here*. Established, healthy areas of native vegetation should not be removed or damaged in order to install new stormwater management practices. Instead, these areas should be protected and, if practical, expanded or enhanced with increased plant and wildlife diversity.

Step 5 - Create Proposed Conditions Map

Mark on the map the locations available for projects. Based on the location of the project, estimate the area available to treat stormwater. Most practices should be downhill and within the flow path of uphill impervious surfaces or other yard areas. The intention of the practice is to treat runoff from these areas.

If desired, use the one of the BMP worksheets to help determine the ideal size of the stormwater treatment practice for the site and compare to the available space. If less than the ideal amount of space is available, the practice will likely still have a positive effect. However, if the practice is severely undersized, perhaps only ¼ of the ideal size, and downhill from a lot of drainage area, the water draining to it may damage or otherwise negatively affect the practice.

Figure A.7 shows two viable areas for stormwater practices on the example property previously referenced. The green polygons downhill from the impervious surfaces on the site, not under tree canopy, are 250 square feet and 500 square feet in size. The red circles indicate the locations of the centers of the trees.

Don't excavate under tree canopy. Tree roots extend outward from the tree trunk approximately as far as the branches (the "dripline"). It is advisable to excavate carefully within about 1 ½ times the tree canopy diameter as some trees send roots out farther. Damage to tree roots can harm, or even kill, a tree. This can also create a threat of falling trees or limbs to people and any adjacent structures. Hand excavation may be required. Root pruning of small (1-2 in diameter) lateral roots *may* be an option outside a circle 5 times the trunk diameter without any impact on tree stability. A professional arborist must be consulted if root pruning is being considered.

Figure A.7. *Google Earth Pro screenshot, showing red circles at tree trunk locations, and green highlighting at two possible, recommended project locations*

Step 6 - Choose Appropriate Practices

The map should now show areas to avoid and areas to install the planned project. These steps provide the basic data for the decision-making process of locating a stormwater practice on the site. This information, combined with the additional factors listed below will help in selecting the stewardship practice that meets the clients' environmental objectives and lawn and landscaping preferences. The stormwater best management practice (BMP) chapters describe how to design and install the different options for stormwater practices.

In **Figure A.7** above, the smaller practice location is a good candidate for a Conservation Landscape. The larger practice location could be a very good candidate for a Rain Garden since the low side could be built up as a berm using some of the excavated soil. Rain Barrels or cisterns are an excellent choice for the downspout(s) at the corners of the southeast side of the house (back). The back of the roof is larger than the front, and a relatively short distance from the smaller practice location. The water from the downspout(s) and Rain Barrel(s) would need to be guided to the practice using either a pipe or an open channel, perhaps lined with river rock.

The depth to water table in these locations is more than 80 inches (6 feet, 8 inches) according to the Web Soil Survey. Apart from the known sanitary sewer line, it is unlikely that any other utilities are in the marked locations in the back yard; the water main will come from the street and go to the house, the sewer lateral connection will likely take a short path to connect to the sewer main, the gas line is in the front and on the southwest side of the house, and the electric is overhead on that same side (known from site visit, and barely visible in aerial imagery).

Table A.1 provides an "at a glance" comparison of site constraints and the practices that may work, given those constraints.

Table A.1. Site constraints comparison for practices presented in this manual

Constraint/ Condition	1. Conservation Landscape	2. Rain Garden / Bioretention	3. Permeable Hardscape	4. Infiltration	5. Rainwater Harvesting	6. Vegetated Roof	Notes
Next to building	✓[1]	✓[2,3]	✗	✗	✓[3,4]	✓	1. Refer to chapter for guidelines, section "Location and Feasibility." 2. Stormwater planters or ultra-urban bioretentions are an option. 3. Overflow should be directed at least 5 ft. from foundation. 4. Underground tanks should be at least 10 ft. from foundation.
Next to drinking water well	✗	✗	✗	✗	✓[1]	N/A	1. Overflow should be directed at least 25 ft. from well.
Next to septic drain field	✗	✗	✗	✗	✓[1]	N/A	1. Should not sit directly on drain field, due to potential compression.
Under tree canopy	✗	✗	✗	✗	✓	✓[1]	1. Plant selections should match sunlight conditions.
Sandy soils	✓	✓	✓	✓	✗	N/A	
Clay soils	✓[1]	✓[1]	✓[1]	✗	✓	N/A	1. Soil amendment, or localized replacement may be necessary. See Soil Assessment for more detail.
Top of slope	✓	✗[1]	✓[2]	✗[1]	✓	N/A	1. Rain Gardens and infiltration basins generally handle more water than other practices, and therefore should be located where they can accept more runoff. 2. Permeable Hardscapes can be at the bottom of a slope, but care should be taken in sizing to not overload the practice.

Table continued next page

Constraint/ Condition	1. Conservation Landscape	2. Rain Garden / Bioretention	3. Permeable Hardscape	4. Infiltration	5. Rainwater Harvesting	6. Vegetated Roof	Notes
Bottom of slope	✓[1]	✓	✓[1]	✓	✓	N/A	1. It is important not to send too much water to these practices.
Near/over utility lines	✓[1]	✗[2]	✗[2]	✗[2]	✓[3]	N/A	1. Allowable proximity to utility lines should be confirmed by utility company or municipal government. 2. Under certain special circumstances, it may be possible to locate these over underground utilities, with careful coordination with the utility companies. 3. Underground tanks have the same considerations as below-ground practices. (See note 2)

Additional Considerations and Resources

Other factors to consider include soil types and the amount of sun available for plants in the practice. See Appendix B for simple soil testing instructions, and resources and guidance for gathering more detailed information. Observe how much sun hits the areas identified for stormwater practices throughout a typical day. The soil characteristics and sun/shade situation will help determine feasibility of the practice and appropriate plants.

The *WSA Conservation Landscape Design Tool* provides additional tips and guidance for assessing the site and sizing the project. The tool provides step-by-step guidance for choosing a layout, provides recommendations and options on plant types and sources, installation instructions, maintenance plans, and material quantities and costs.

Anne Arundel County GIS Mapping
http://gis-world2.aacounty.org/silverlightviewer/?Viewer=WERS
Note: Google Chrome does not work well with this site.

Anne Arundel County Watershed Stewards Academy
http://aawsa.org/

Appendix B:

Soil Assessment

B.1. Introduction

This appendix provides additional guidance on assessing soils for the following practices: **Conservation Landscapes, Rain Gardens, Infiltration Trenches, and Permeable Hardscapes.** As mentioned in the respective chapters, practices that depend on stormwater infiltrating into the ground must be located and designed according the characteristics of the underlying soil. Several factors determine the soil suitability at a particular site. This appendix describes how to test on-site soils for:

- Texture
- Infiltration rate (percolation test)
- Depth to groundwater

While this appendix gives basic guidance on soil assessment techniques, it is not comprehensive. For further assistance, the local Soil Conservation District or Extension Service office may provide more guidance or a referral to a good resource.

B.2. Soil Texture

Not all soils allow water to percolate through them easily. In general, soils with a lot of sand tend to allow water to flow through them easily, while soils with high clay content do not allow water to pass through as well. The average particle sizes of sand, silt, and clay decrease in that order, and the spaces between the particles also decreases. Smaller pore spaces between the particles make it more difficult for water to infiltrate through them. In addition to particle size, compaction is another factor that can reduce the size of pore spaces. Urban soils, especially those around buildings, can be quite hard due to compaction from grading equipment, mowers, cars, and even foot traffic. To determine the soil suitability for a Rain Garden, Infiltration Practice, or Permeable Hardscape, follow the processes below.

Note: Remember to call Miss Utility (1-800-257-7777 or 811 in Maryland) at least 48 hours before digging to mark underground utilities. **Always call before digging!**

Take Soil Sample To take a soil sample, first dig a test hole down to approximately the *bottom* level of the practice that will be installed. (***Example:*** If installing a 2-foot deep Rain Garden with 6 inches of ponding, dig to 2 ½ feet deep.) The hole should be wide enough to remove dirt as the hole is dug and wide enough to get a hand trowel to the bottom to take the soil sample. Once the hole is deep enough, use a hand trowel to scoop out a handful of dirt from the lowest part of the test hole and put it into a bucket or other container. (To look at the soils *below* the depth of the practice, either dig the test hole even deeper or use a soil auger to pull out a deeper sample.) For large practices, take samples at a few locations, since the soil can change from location to location. Collect one sample per every 100 square feet.

Compaction While digging the test hole(s), take note of how hard it is to dig through and loosen the soil. If the soil takes a lot of effort to break up and remove, it is likely excessively compacted and will need to be tilled well if a Rain Garden or Infiltration Practice is to be installed there. Of course, this is a low-cost, low-tech method of testing soil compaction. There are also quantifiable ways (not discussed here) to test soil compaction with instruments such as a penetrometer.

Handle the Sample Next, have a container of water and a ruler available to conduct the following soil texture tests on the sample (see **Figure B.1**):

Ball Test - Take about 1 tablespoon of the soil sample and knead it together by hand, wetting it gradually. If the soil will not form a cohesive ball it is a sandy soil. If the soil forms a ball, conduct the feel test and ribbon test.

Feel Test - Squeeze and knead the soil in a ball. The sandiest soils will feel gritty and emit a grinding sound while it is squeezed and kneaded. The least sandy soils will be smooth and silky, with no grinding sound.

Ribbon Test - Finally, placing the soil between the forefinger and thumb, use the thumb to gently push the soil and try to form the soil into a ribbon. Soils with higher clay content will form longer ribbons.

Figure B.1. *Shown from left to right: Ball test, feel test, and ribbon test*

The flow chart shown in **Figure B.2** provides a schematic for these tests and gives more detail. The soils represented in the blue-shaded area are not likely to infiltrate well. However, performing an infiltration test (described in the next section) will help further clarify how suitable the site is for different stormwater practices.

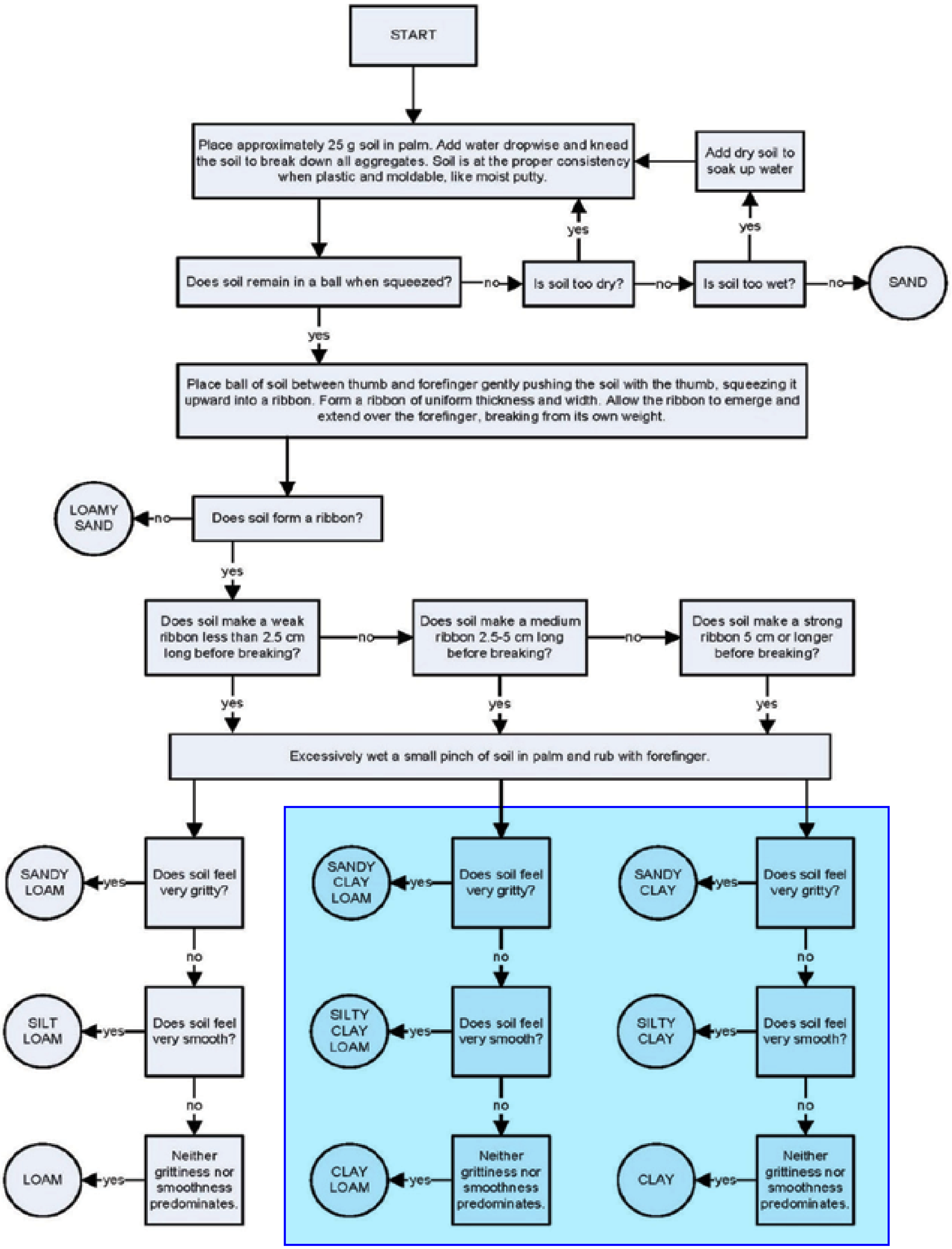


Figure B.2: *Flow chart to decipher soil texture type*

(Source: United States Department of Agriculture, National Resources Conservation Service)



B.3. Infiltration Rates

A basic infiltration test, sometimes called a percolation or "perc" test, is relatively easy to perform as long as the tester has adequate time for observation. In its simplest form, one simply digs a hole, fills it with water, waits until the next day and fills it again, then observes how long it takes for the water to soak completely into the ground. A little care and a few measurements will provide confidence in a relatively accurate infiltration rate.

In the references listed in **Section B.5**, soils are often assigned to one of four hydrologic soil groups (HSG). These groupings provide information about runoff and infiltration characteristics.

Distilled from USDA/NRCS TR-55 documentation:

Soils in the U.S. are classified in four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D), conveying information about their infiltration rates when thoroughly wet.

Group A
- Low runoff potential, high infiltration rates, well- or excessively drained soils

Group B
- Moderate infiltration rates, moderately well- to well-drained soils

Group C
- Low infiltration rates, typically having a layer that impedes downward movement of water

Group D
- High runoff potential, very low infiltration rates, typically clay soils, often with permanently high water table or impermeable clay layer near the surface

Dual classifications: Soils that, due to high water table, have a drainage problem. Once these soils are effectively drained, the group changes.

The essential steps and tools needed to conduct an infiltration test are as follows:

Do not conduct the infiltration test during a period when the forecast calls for rain. However, it is beneficial to conduct the test after a rainfall since saturated soils will provide more accurate infiltration rate measurements. To avoid digging another hole, use the same test hole used for the soil sample.

Tools Needed:
- Shovel or post hole digger
- Tape measure or measuring stick
- Watch or clock
- Garden hose or other water source
- Pencil and paper for taking notes
- Section of 4-inch diameter PVC or metal pipe, at least as long as the hole is deep
- Digging bar (optional)
- Enough gravel to cover the bottom surface of the hole to 2-inch depth (optional)

Procedure:

1. Dig a hole to at least the depth of the intended practice and ideally at least 1 foot in diameter.
2. Fill this hole with water, and let it sit overnight.
3. Tap a section of vertical PVC pipe securely into the soil at the bottom of the hole so that the water only infiltrates through the bottom of the hole. Add about 2 inches of gravel into the bottom of the pipe so that any clay particles do not form a seal along the bottom of the hole. The pipe will prevent water from infiltrating sideways, which could falsely increase the infiltration rate results.
4. Fill the pipe with water a few inches short of the top and measure the height difference between the water surface and the top of the pipe.
5. Mark the measurement and time. An example is shown in **Table B.1**.
6. Approximately once per hour, measure the depth from the top of the pipe to the surface of the water, until the water has completely infiltrated, or the test must be abandoned for other reasons. At each measurement, write down the depth and the time.
7. After completing the test measurement, calculate the infiltration rate for each time period: mark the difference in depth and the amount of time that has passed, and then divide the depth by the amount of time. After calculating the infiltration rate for each time period, divide the total change in depth by the total amount of time taken for the test.

Table B.1. Example of Infiltration Test Record

A	B	C	D	E
Depth (inches)	Time	Difference in depth (inches)	Time elapsed (hours)	Infiltration rate (Column C/D)
3.5	8:30 AM	-	-	-
4.7	9:30 AM	1.2	1	1.2 inches/hour
5.5	10:30 AM	0.8	1	0.8 inches/hour
6.8	11:45 AM	1.3	1.25	1.04 inches/hour
7.6	1:30 PM	0.8	1.75	0.46 inches/hour
8.9	2:30 PM	1.3	1	1.3 inches/hour
9.8	3:30PM	0.9	1	0.9 inches/hour
10.6	4:15 PM	0.8	0.75	1.07 inches/hour
11.8	5:30 PM	1.2	1.25	0.96 inches/hour
			Average rate	**0.92 inches/hour**

The hypothetical test shown in **Table B.1** shows an average infiltration rate of approximately 0.92 inches per hour. See calculation below.

11.8 inches – 3.5 inches = 8.3 inches
5:30 PM – 8:30 AM = 9 hours
8.3 inches / 9 hours = 0.92 inches per hour

Notice that the infiltration rate can vary over time – this is not unusual. If the infiltration rate changes *significantly* over time, one of the following conditions may have caused this:

- The water was infiltrating through the sidewalls quickly into a layer of soil with higher infiltration. There are layers of different soil types at different depths. The bottom of the layer with the higher infiltration is probably at roughly the depth where the rate slowed considerably. This is not necessarily a problem.
- The soil was not completely saturated when the test started. Initially, the water was soaking into unsaturated soil, and once the soil became saturated, the rate slowed.
- If the infiltration starts slow, then speeds up, this may be a surface tension issue. If time permits, while there is still water in the hole, add more water and see if the rate stays somewhat steady. If so, it is probable that a layer of air was "blocking" the water, but once the water settled past that level, the rate increased.

If the test results seem suspicious or the average rate is very close to the minimum infiltration rate required, it is wise to test again.

Interpreting Results Interpreting the results of the infiltration and soil texture tests depends on the type of practice to be installed. Rain Garden designs can be adjusted to work in soils with low infiltration rates, whereas Infiltration Trenches, Dry Wells, and Permeable Hardscapes must have a minimum infiltration rate of 1 inch per hour. **Table B.2** shows the design options available for these practices based on infiltration rate and soil texture.

Table B.2. Design Options Based on Infiltration Rate & Soil Texture

Practice	Infiltration Rate	Design Options
Rain Garden		
	<½ inch per hour	Replace existing soil with a soil mix and use an underdrain
	½ – 1 inch per hour	Replace existing soil with soil mix
	>1 inch per hour	Use existing soil (as long as soil texture is not in a clay category) Compost amendments recommended
Infiltration Trench, Dry Well, and Permeable Hardscape		
	<1 inch per hour	Do not install practice in this location
	1 – 2 inches per hour	Acceptable to install practice here (as long as soil texture is not in a clay category)
	>2 inches per hour	Acceptable to install practice here

If infiltration rates are too low or soils have too much clay to use the type of practice initially proposed, consider using a different stormwater management practice in that location, such as Rainwater Harvesting or Conservation Landscapes.

B.4. Depth to Groundwater

The location of the groundwater table is another consideration for any practice that infiltrates water. When the groundwater rises up near the bottom of a stormwater practice, there is a danger that the surface runoff can contaminate the groundwater. Also, the practice will not drain properly if the groundwater rises up high enough to start filling the practice.

Stormwater practices that rely on infiltration should be designed with at least a 2-foot vertical separation from the seasonally high water table. Groundwater rises and falls throughout the year, so the bottom of the practice should be at least 2 feet above the highest elevation to which the groundwater rises.

Check Data Available Online databases and web tools (described in **Section B.5**) are available to look up the high groundwater levels for the area where the practice will be located. As a first step, use one of these websites to see if the recorded high groundwater level in the area is close to the minimum depth needed. If the seasonally high groundwater level reported suggests that there may be less than 2 feet of space between the bottom of the practice and the water table, visual inspection is recommended.

The test hole used for the previous tests should provide some clues. If the soil in the bottom of the hole was noticeably wet upon initial excavation, but the soil above it was dry, there is likely high groundwater in that location. If the bottom of the hole was not wet, look for the following signs that the soil is periodically saturated with water.

Gleying and Mottling When soil is saturated for a long period, it often turns a bluish-grey color (gleying), with red spots or stripes (i.e. mottles). A mottled soil has streaks or spots of reddish or reddish-brown color. This is caused by iron leaching out of the soil when it is wet and rusting when it is exposed to oxygen during the dry period. These conditions indicate the high groundwater level.

Figure B.3: *Soil with gleying and mottling due to high groundwater*
(Source: http://soilscienceaustralia.com.au/)

Smell Soils that are wet for a long time begin to have a sulfur or rotten egg smell. If this smell is present when excavating the test hole, it almost certainly indicates the groundwater level has been reached.

Interpreting Results If the investigation into groundwater level at the proposed site suggests that the groundwater levels may be too high for the particular practice, several options are available: (1) design the practice to be shallower and broader (as practical) to give more vertical separation from the groundwater while still treating the same volume of runoff or (2) choose a different type of practice for the site.

B.5. Web-based Tools

Performing location-specific, on-site tests like the ones described in the previous sections is the best way to determine the soil texture, infiltration rates, and seasonally high groundwater levels at the specific location of the proposed stormwater practice. However, broader-scale tools are also available to determine soil characteristics within a general area. Three such tools are described below.

- The USDA's national *Web Soil Survey* provides soil type, expected infiltration rates, approximate depth to water table, and much more information.

- Maryland's Environmental Resource and Land Information Network (*MERLIN*) is a user-friendly mapping tool that contains information on all kinds of natural resources in Maryland. **Figure B.4** shows a screenshot of MERLIN with the soil data layer selected and shown. Clicking on an area of the map with this data layer on will show a variety of data, including the high groundwater level (in red box).
- Users of *Google Earth or Google Earth Pro* (both free programs) can add the *SoilWeb plugin* which also offers a very fast and user-friendly portal to most of the same data, with the exception of depth to groundwater. Visit Appendix A: Site Assessment for more information about the utility of Google Earth. **Figures B.5** and **B.6** show examples of the interface and output of SoilWeb.

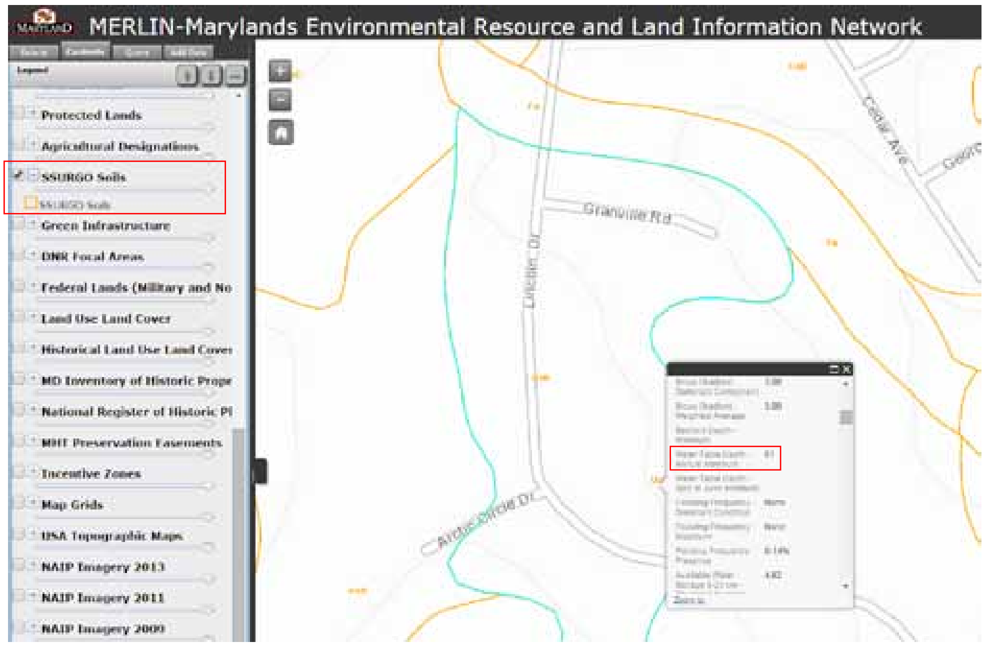


Figure B.4: *Screenshot of web-based tool, MERLIN, showing soil data and groundwater level*

(Source: MD Department of Natural Resources)

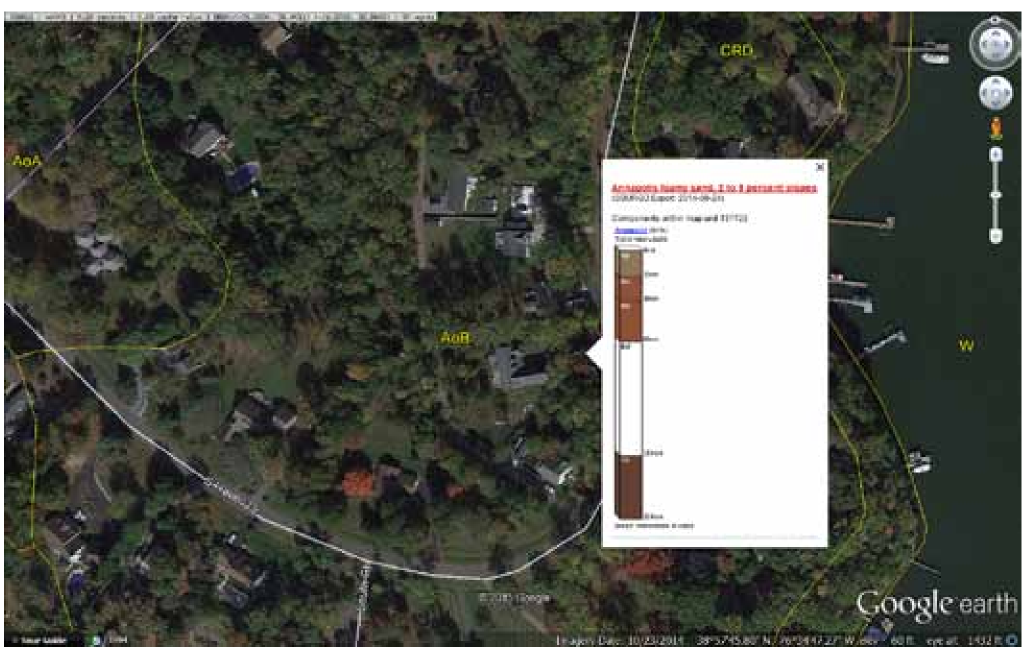
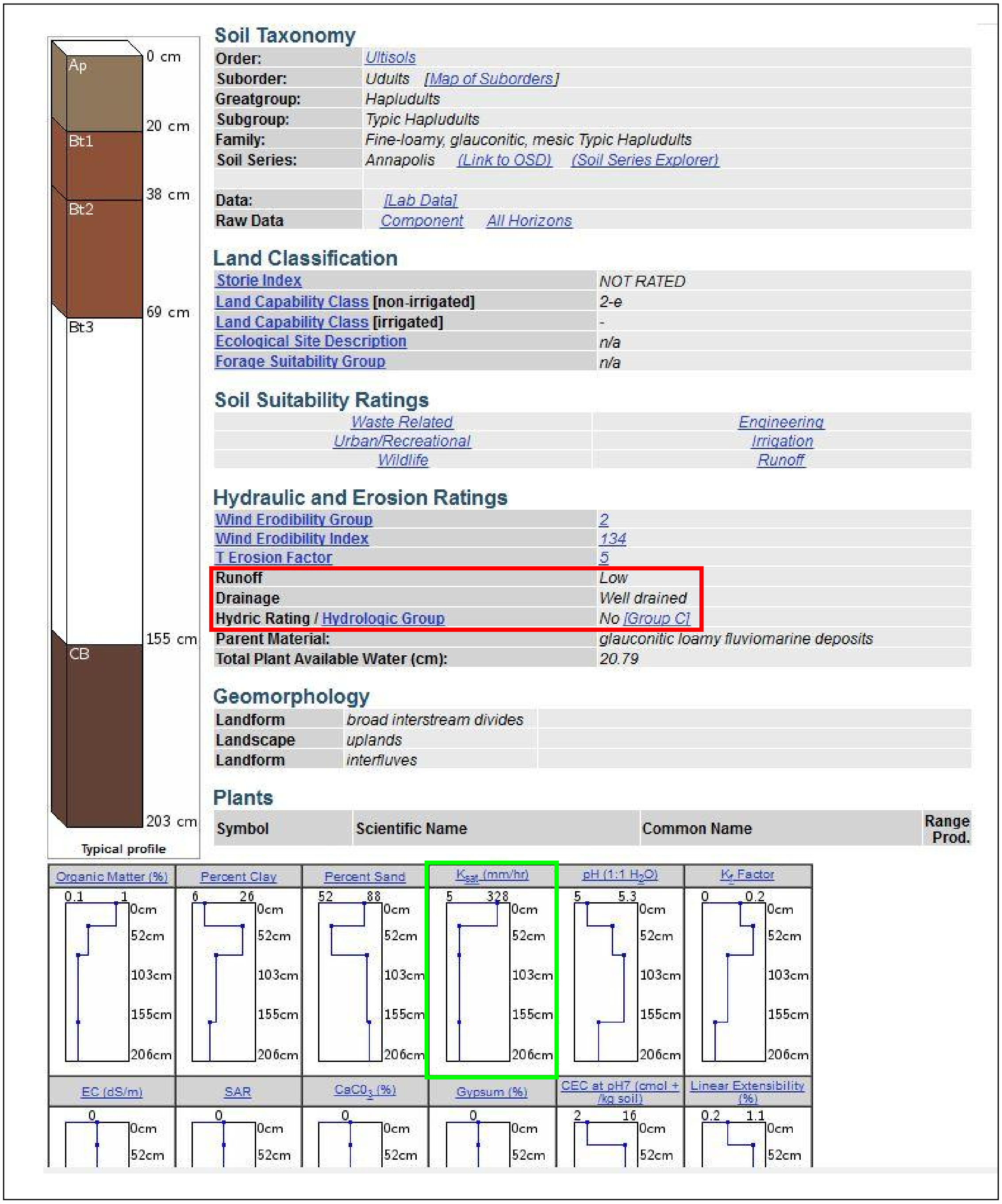


Figure B.5: *Screenshot of Google Earth's SoilWeb tool showing soil type delineations and a vertical soil type profile for the selected subarea*

(Source: Google)



Soil Taxonomy

Order:	Ultisols
Suborder:	Udults [Map of Suborders]
Greatgroup:	Hapludults
Subgroup:	Typic Hapludults
Family:	Fine-loamy, glauconitic, mesic Typic Hapludults
Soil Series:	Annapolis (Link to OSD) (Soil Series Explorer)
Data:	[Lab Data]
Raw Data	Component All Horizons

Land Classification

Storie Index	NOT RATED
Land Capability Class [non-irrigated]	2-e
Land Capability Class [irrigated]	-
Ecological Site Description	n/a
Forage Suitability Group	n/a

Soil Suitability Ratings

Waste Related	Engineering
Urban/Recreational	Irrigation
Wildlife	Runoff

Hydraulic and Erosion Ratings

Wind Erodibility Group	2
Wind Erodibility Index	134
T Erosion Factor	5
Runoff	Low
Drainage	Well drained
Hydric Rating / Hydrologic Group	No [Group C]
Parent Material:	glauconitic loamy fluviomarine deposits
Total Plant Available Water (cm):	20.79

Geomorphology

Landform	broad interstream divides
Landscape	uplands
Landform	interfluves

Plants

Symbol	Scientific Name	Common Name	Range Prod.

Figure B.6: *Report from Google Earth's SoilWeb tool, showing results for the "Annapolis" soil type. Runoff/drainage characteristics and soil type are highlighted in red box. The infiltration rate profile graph is shown in the green box. This depicts a fast infiltration rate to a depth of approximately 1½ feet and very slow infiltration at greater depths.*

(Source: Google)

B.7. References & Resources

Association of Professional Landscape Designers Guide to Sustainable Soils
http://apld.org/_media/Sustainability/Sustainable%20Soils%20Brochure%20-%205-1-12.pdf

Building Soil – Resource Efficient Natural Landscaping
http://www.buildingsoil.org/tools/Landscaping_Guide.pdf

Google Earth *SoilWeb* plugin
http://www.gelib.com/soilweb.htm

Maryland's Environmental Resource and Land Information Network
http://geodata.md.gov/imaptemplate/?appid=a8ec7e2ff4c34a31bc1e9411ed8e7a7e

USDA Natural Resource Conservation Service *Web Soil Survey*
http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

United States Department of Agriculture (1986). Urban Hydrology for Small Watersheds (PDF). Technical Release 55 (TR-55) (Second Edition). Natural Resources Conservation Service, Conservation Engineering Division.
http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf

Anne Arundel County GIS Mapping
http://gis-world2.aacounty.org/silverlightviewer/?Viewer=WERS

Anne Arundel County Watershed Stewards Academy
Arlington Echo Outdoor Education Center
975 Indian Landing Rd. Millersville, MD 21108
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