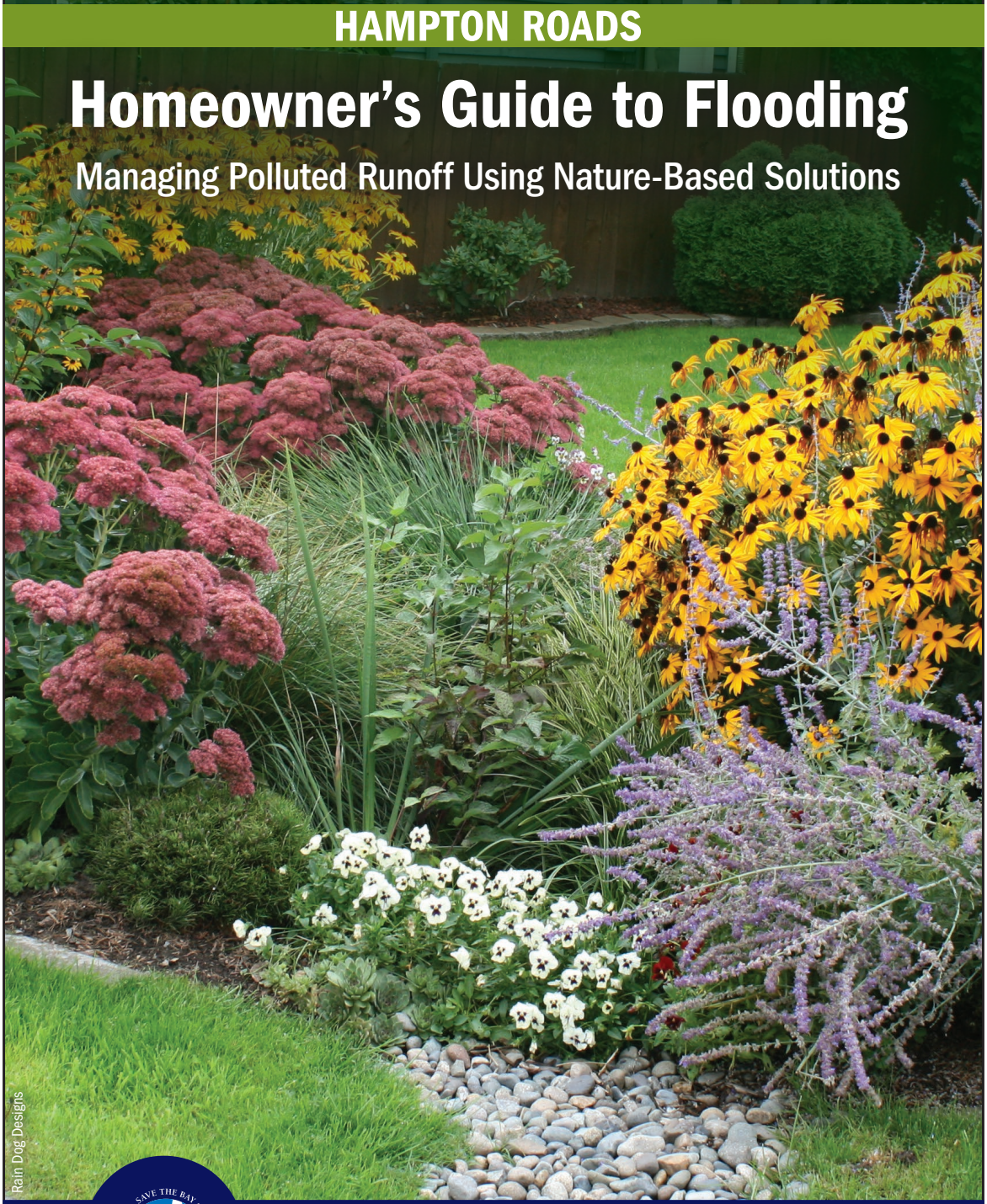
HAMPTON ROADS

Homeowner's Guide to Flooding

Managing Polluted Runoff Using Nature-Based Solutions



Rain Dog Designs

CHESAPEAKE BAY FOUNDATION
Saving a National Treasure

Technical Manual

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A HOMEOWNER'S GUIDE TO FLOODING
MANAGING POLLUTED RUNOFF USING NATURE-BASED SOLUTIONS

The Sea Level Rise / Polluted Runoff Problem: How Nature-Based Solutions Can Help

Cities and towns near the Chesapeake Bay are facing a major threat from sea level rise. In fact, coastal Virginia has seen the highest rate of relative sea level rise on the whole Atlantic coast, more than 14 inches since 1930 per Old Dominion University's Center for Sea Level Rise. The Hampton Roads region is particularly at risk because, in addition to rising seas, the land is also sinking. Many areas find their stormwater drains underwater at higher tides, leading to tidal flooding as well as rain-induced flooding since the water washing off roads and buildings has nowhere to go. With annual average rainfall of approximately 48 inches during 100 days of measurable precipitation, this translates into significant runoff events throughout the year.

The good news is that you can make a difference on your own property by incorporating natural solutions. For example, homeowners can put simple practices in place that hold and filter rainwater into the ground. That includes disconnecting rain gutter downspouts, installing rain barrels to capture rainwater, and installing rain gardens in flood prone areas.

These techniques can both help avoid flooding and reduce the amount of pollution that rainstorms wash into our waterways. They also relieve pressure on overwhelmed city systems that struggle to address the regular deluge of runoff. Every parcel of land in the Chesapeake Bay watershed impacts the health of the Bay. By implementing nature-based solutions, you are also helping clean up the Bay. If more homeowners address stormwater at its source, on their property, cumulatively we can make a big difference by reducing flooding in our cities and helping clean up the Bay.

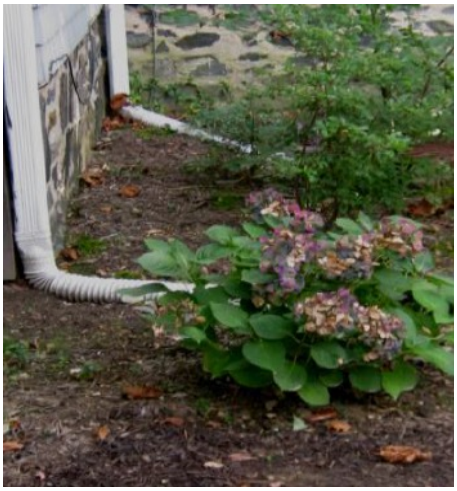
Did you know that a building with a 3,000 square-foot roof creates 1,870 gallons of runoff from just a one-inch rainfall? With 48 inches of rainfall per year, this building generates 89,724 gallons of runoff annually. A single 1,000 gallon cistern could fully retain a 0.5-inch rainfall. A network of nature-based solutions, like those presented below, could also reduce or even eliminate the runoff from this property. If this site were able to fully eliminate its runoff, imagine what an entire neighborhood or even a city could achieve in terms of flood reduction and pollution prevention if all of its residents took similar action.

If you would like calculate how much runoff your roof generates with 1 inch of rain, multiply your roof's square footage (multiply your roofs length by its width) by 0.083ft (for half inch of rain multiply by .0415ft). This gives you the volume of runoff in cubic feet. To convert to gallons, multiply this number by 7.48.

This guide presents many of the different nature-based solutions homeowners can use to reduce runoff. It also provides resources for how to design and install of several of these practices.

Once in place, these steps can help alleviate flooding problems and keep pollutants out of local waterways. The following are just some of the many practices that you can use to accomplish this and also beautify your neighborhood, save money, attract wildlife and provide other benefits.

Downspout Disconnection



This involves disconnecting rooftop drainage pipes and rerouting them away from storm sewers. This technique manages runoff close to its source by intercepting, infiltrating, filtering, treating, or reusing rainwater as it moves from the hard impervious surfaces to the drainage system.

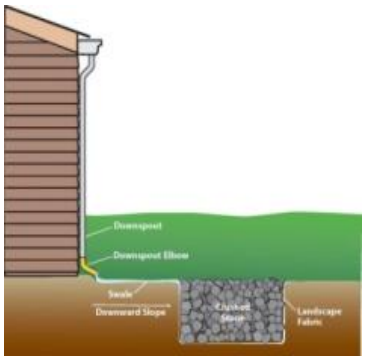
Two kinds of disconnection are possible: (1) Simple disconnection, whereby rooftops and other hard surfaces are directed to areas that can absorb the water, like a rain garden, and (2) Disconnection leading to an alternate runoff reduction practice adjacent to the roof, like a rain barrel, dry well, or small residential impervious area. *See pages 9-11 for technical guidance.*

Rain Barrels and Cisterns

Cisterns and rain barrels are used to capture roof runoff in a barrel or tank. The water is then slowly emptied into the lawn or landscape, or can be reused for outdoor watering or indoor uses. While rain barrels can be installed by a homeowner, larger tanks and cisterns require a qualified design and installation professional. If stored runoff is used for indoor purposes, special measures may need to be taken to improve water quality. *See pages 11-12 for technical guidance.*

Dry Wells

Dry wells are created by excavating a shallow trench that is filled with stone and used to temporarily store runoff so it can soak into the ground. Dry wells can be designed and installed by the owner, although some technical assistance may be needed if they are located close to a basement or within an area with a high water table. *See pages 12-13 for technical guidance.*



Rain Gardens

Rain gardens accept runoff from a roof, driveway, or parking lot that would otherwise go to the street or storm drain. The garden has a shallow depression that allows stormwater to collect. Natural soils are replaced with sandier ones to allow the water to soak into the ground instead of running off into the storm sewer system or stream. The garden is planted with a mix of native plants that filter out pollutants, attract wildlife, and beautify the property. *See pages 15-31 for technical guidance.*

Tree Planting

Planting deciduous or evergreen trees in grassy areas will create a leafy canopy that intercepts rainfall and reduces runoff. Native tree species are preferred. Trees can be planted by the owner or a contractor, but species should be selected that will grow best at the site's conditions, including the soil conditions and sun exposure at your planting site. A typical street tree can intercept from 760 gallons to 3,000 gallons per year, depending on species. That means less flooding! More trees on a property can also reduce your air conditioning costs, increase the real estate value, as well as create more attractive neighborhoods. *See page 14 for technical guidance.*

Conservation Landscaping

Conservation landscaping is the creation of mulched beds that are planted with perennial plants, shrubs, or small trees that retain rainfall and absorb runoff from adjacent turf or paved surfaces. Native plants are preferred, but ornamental plants are acceptable if they are adapted to regional climates and are not invasive species; however, ornamentals require more fertilization and watering.

Permeable Hardscapes

Permeable hardscapes involve the installation of pavers on driveways and sidewalks that let rainfall rapidly pass through the paver and into a shallow stone reservoir that allows the water to soak into the ground. The practice applies to both residential and non-residential paved areas, and may be a great option to replace deteriorating pavement. Most permeable pavers require the assistance of an experienced designer and pavement installation contractor.

Impervious Cover Removal

Impervious cover removal consists of breaking up existing hard surfaces and the proper disposal or recycling of the asphalt or concrete. The next step is roto-tilling the underlying soils to relieve compaction. Finally, they are planted with grass or other vegetation. Some homeowners may be able to remove their own pavement, but it is often a good idea to hire a contractor to do the job.

Hard surfaces like asphalt and concrete are a real problem in developed areas. One acre of pavement releases 36 times more runoff than a forest. During a one-inch rainfall, one acre of forest will release 750 gallons of runoff, while a parking lot will release 27,000 gallons, according to Penn State Extension.

Other Practices

Several other environmental site design practices may be used to treat runoff from some properties. That includes bioswales, landscape infiltration, submerged gravel wetlands, and stormwater planters. In addition, property owners can reduce their impact on local streams and the Bay by using Bay-friendly lawn care practices, such as reduced fertilizer applications and taller mowing heights.

Step 1. Study How and Where Stormwater Runs Off Your Property

THE SITE ASSESSMENT

1) Draw the general layout of buildings on your site (if you have an old survey, this may be a great place to start, graph paper and aerial images like Google maps also help)
2) Add impervious areas like the driveway, sidewalks, or parking areas.
3) Use a tape measure to measure the length and width, then multiply the two together to get the area. Estimate hard or impervious areas where water runs off.
4) Note the measurements on the map.
5) Locate the downspouts that drain water from your roof and mark them on your map. Note the rooflines and area draining to the downspout.
6) If you don't see downspouts, the building may have an internal drainage system. If so, contact a professional for help.
7) Look at other impervious surfaces on your site. Try to figure out where runoff from these areas goes. If it isn't raining, use a hose to track where your water flows. Use arrows to note on your map the direction the water flows.
8) Look at other surfaces of your property and mark any noticeable hills and dips. Note areas that stay wet and muddy. Note areas where water soaks in or are soft (lawns, planting beds, and trees).
9) Soil type has a lot to do with how well rainwater soaks into the ground. Sandy, loamy soil soaks up water very quickly. Heavier soils with clay or that are compacted don't soak up water as well. Soil information is available at http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx. Look up the Hydrologic Soil Group of your site. Soils in groups A and B drain well, while soils in Groups C and D have slower infiltration rates. If you are unsure, you can test your soils' infiltration rates after a period of 3-7 days of no rain when the soil is relatively dry (saturated soils percolate much more slowly). To test your soil, dig a hole at least 12 inches deep in one of your green spaces, fill it with a hose, let it drain and fill it a second time. If the water on the second run does not drop at least 3/4 inch in an hour, your soils may not drain well enough to consider an infiltration practice.

10) Locate your property lines to determine how much space you have for a stormwater practice. Your practice must meet general building code safety rules.
11) After mapping, study your downspouts… Are they draining to your lawn or a drywell OR do they discharge directly to an impervious area, like your driveway, that then runs onto a public road or drainage system? If your downspouts drain directly to a drywell that is in good working order, you don't need to change how that rain water is managed, but you may want to in order to avoid future maintenance or replacement costs.

Step 2. Map Out Other Utilities

Underground utilities are definitely one of the great inventions of the 20th century, but they can complicate the design of residential stewardship practices. The following are things to locate on your lawn and avoid (and add to your 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

Most states have "call before you dig" rules and provide a hotline to help you locate your underground utilities. The following table provides the contact information for individual Chesapeake Bay states however, in any state you can call "811" and you will be directed to your local call center.

In many cases you will need to call several days in advance so you should check with your specific state. More information about this free resource can be found: http://www.call811.com/state-specific.aspx

State	Resource	Contact Information
MD	Miss Utility of Maryland*	811 or 1-800-257-7777**
DE	Miss Utility of Delmarva	811 or 1-800-282-8555
DC	District One Call	811 or 1-800-257-7777
PA	Pennsylvania One Call System, Inc.	811 or 1-800-242-1776
VA	**Virginia 811**	**811 or 1-800-552-7001**
WV	WV811	811 or 1-800-245-4848
* For the Eastern Shore of MD call Miss Utility of Delmarva ** or use website link http://www.missutility.net/homeowners/		

Please note that Miss Utility and similar hotlines do not mark private utilities. You will need to scout your lawn to locate where utilities leave the street or right of way, and cross your yard to enter or leave your home. Box C provides some examples of "visual indicators" for locating underground utilities. You should try to mark these on your property sketch and work around them when locating the best area for your stewardship practices. In general, it is not advisable to install practices in your street right of way, since your local government and utilities have the right to dig it up for street improvements and utility repairs.

Box A. Visual Indicators for Areas to Avoid When Assessing Your Yard for Stewardship Practices		
		
Water Lines	Natural Gas Lines	Sewer Lines
		
Underground Cable	Storm Drain Manhole	Sewage Pipe Cleanout
		
Basement	Sump Pump Discharge	Street Right of Way

THE GOAL: DIRECT STORMWATER TO AREAS THAT CAN SOAK UP RAIN

DOWNSPOUT DISCONNECTION

Disconnection of a downspout is an easy way to move water away from building foundations and let it soak into the ground. This includes….Cutting the downspout, attaching elbows, extensions, and splash blocks to direct water to flow away from the house and into a pervious area where the water can infiltrate.

<table>
<tr><th colspan="2">Where Does Your Downspout Discharge?</th></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td colspan="2">Downspouts discharging near driveways are usually connected to the street, and are prime candidates for locating a rain garden</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>This downspout is plumbed directly to the street, and would be quite easy to retrofit with a rain garden</td><td>This downspout is too far away from any pervious areas for a rain garden, but a rain barrel might work</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td colspan="2">Runoff from both of these downspouts travels at least 40 feet over grass. Unless your lawn is very steep, that distance should allow the runoff to be absorbed.</td></tr>
</table>

Safety Considerations:

1) Add or remove soil to make sure that the slope of the ground allows water to flow away from structures. Do not disconnect downspouts on slopes greater than 10 percent.
2) Avoid disconnecting downspouts in an area too small for good drainage.
3) Disconnected downspouts must be extended to discharge water at least 6 feet from a structure basement, and 2 feet from a crawl space or slab foundation.
4) Downspout extensions must drain away from any structure.
5) End of downspout must be at least 5 feet from neighbor's property line and 5 ft from the public sidewalk. You may need more room if your yard slopes towards your neighbor or the sidewalk.
6) Avoid disconnecting downspouts or adding extensions across a walkway, patio, driveway, or front gate because of possible tripping hazards. However, downspout connections available at local hardware stores can be placed underground to drain under these areas, but be sure to have enough slope to allow gravity to drain the water.
7) Do not extend downspout directly over a septic system, drain field, or an underground storage tank, unless they have been decommissioned. Do not disconnect within ten feet of a retaining wall.
8) Make sure you have enough landscaped area for rain to safely soak into the ground. Ground area must be at least 10 percent of the roof area that drains to the disconnected downspout. If roof area is 500 square feet, landscaped area should be 50 square feet (10 percent of 500).

How to Disconnect:

1) Many local hardware stores have all the materials needed to disconnect and extend your downspouts. If your downspouts are typical modern gutters, there are often basic color options in a variety of lengths and configurations. There are also extensions that can be attached and placed underground (generally black corrugated plastic in 8 foot lengths). If your downspout is older, hardware stores should have other options to disconnect and extend your downspouts. When in doubt, you can take a photo to show to your hardware store professional.
2) Use a hacksaw to cut off downspout about 9 inches above where it connects to the sewer.
3) If your downspout was connected to the sewer system or to hardened public stormwater conveyance system, plug or cap the standpipe (the part of your downspout remaining, probably going into the ground, that was connected to the sewer system) using an in-pipe test plug or an over-the-pipe cap secured by a hose clamp. Do NOT use concrete to seal your standpipe.
4) Attach an elbow extension OVER the end of the downspout. Do NOT insert the extension into the downspout or it will leak. If the elbow does not fit over the downspout, be sure that you have the appropriate sized extension. There are a number of rain gutter sizes and specific extensions for each of those sizes. You can also use crimpers or needle-nose pliers to crimp the end of the cut downspout so you can more easily slide your extension OVER the end of the downspout.
5) Measure and cut the downspout extension to the desired length. Attach the extension to the elbow by slipping the extension OVER the end of the elbow. Do NOT install the elbow over the extension or it will leak. The length of the extension will depend on site conditions and where you want the downspout to drain.
    - Downspouts must drain at least 6 feet from basement walls and at least 2 feet from crawl spaces and concrete slabs.
    - The end of the downspout must be at least 5 feet from your property line, possibly more if the yard slopes to the neighbor's house.

6) Secure the extensions to your downspout with sheet metal screws at each joint where the downspout, elbow, and extension connect. It helps to pre-drill holes for screws. If you are using the black plastic extensions, they have prefabbed connector locks that keep the extensions together; however, they may still need to be anchored to your downspout with a screw.
7) Using a splash block at the end of the extension is optional, but it will help prevent erosion.
8) UNDERGROUNDING EXTENSIONS: If you are placing your extension under a pathway, across a driveway, etc., dig a trench across the area where your extension(s) will be placed with a drainage pitch of 1/8 inch per foot so that the water will drain properly via gravity. (1/8 inch per foot pitch= 1/8 inch deeper for every foot you move away from the downspout)
9) The end of your undergrounded extension can either be day-lighted naturally if the slope of your property allows, or you can use a surface emitter that consists of an elbow attachment with a pop-up surface cover that pops up to release water when flowing.

RAIN BARRELS AND CISTERNS

Rain barrels and cisterns are used to capture roof runoff in a barrel or tank which can then slowly empty into the lawn or landscape or be reused for outdoor irrigation/watering and/or for selected indoor uses. While rain barrels can be installed by a homeowner, larger tanks and cisterns require a qualified design and installation professional. If stored runoff is used for indoor purposes, special measures may need to be taken to improve water quality. A simple rain water collector can capture and store a portion of runoff from a roof downspout for non-potable, exterior uses, such as irrigation. This practice is a sure money saver on your water bill.

Safety Considerations:

1) A rain barrel must be secured on a firm, level surface. A full 55-gallon rain barrel weighs over 400 pounds. Tipping is a risk.
2) Your barrel must be structurally sound and capable of withstanding the pressure of holding water. Trash cans are not designed for the pressure of water.
3) A lid and sturdy mesh covering are required to keep debris and mosquitos from getting inside.
4) MOSQUITO PREVENTION: Mosquitos breed in standing water. Place a 12 inch mosquito dunk in your rain barrel to naturally prevent mosquitos from breeding in your rain barrel. Typical dunks will kill mosquitos via mosquito larvae eating bacteria for 30 days. They are completely biodegradable and will not harm fish or other animals.
5) Water from rain barrel should NEVER be used for drinking, cooking, or other potable uses.
6) Larger and more complex rainwater collection systems (cisterns) have a larger storage area, and/or use pumps. Consult a professional to review design, construction, and safety considerations.

Installing Your Rain Barrel:

1) Install rain barrels near where you will use the water in your yard, factoring in the length of the hose that you will attach to the barrel. The barrel must be located at the base of a downspout. It may be possible to re-hang your gutter and move the downspout to a more desirable location. Consider multiple rain barrels throughout your property, as well as individual locations with rain barrels connected in series to allow for extra retention volume.
2) Your barrel must have an overflow relief valve that allows overflow to discharge to a safe location (at least 6 feet from basement walls and at least 2 feet from crawl spaces and concrete slabs). In general, barrels have a device near the top of the barrel that allows extra water to be discharged. Attach an appropriately sized extension (e.g. sometime a simple rubber hose will work) to the overflow valve and run the extension to an impervious area to discharge your overflow.

3) Elevate the rain barrel about 12 inches to provide pressure. Be sure to secure your rain barrel with straps to the house or by some other means to prevent tipping and possible injury.
4) In general, for every inch of rain, a 1,000 square foot roof generates about 625 gallons of runoff. For example, after one inch of rain, an 800 square foot roof would generate 500 gallons of runoff. Ten 50 gallon rain barrels would be need to capture ALL of the rain. If your property only has room for one or two rain barrels, that is okay. Work within your property parameters. Cumulatively we can have a big impact, if we all install one or two rain barrels on our properties.

DRY WELL

An underground structure that disposes of unwanted water by dissipating it into the ground.

A dry well is another option to direct water away from downspouts and can be used for wet spots or small flood prone areas on your property. Dry wells can also be used for water from outdoor showers and pool pumps.

Safety Requirements:

- Infiltration practices have the greatest runoff reduction capability of any stormwater practice and are suitable for use in residential and other urban areas where measured soil permeability rates exceed 1/2 inch per hour.
- If you are unsure if your site can accommodate an infiltration practice, you can test your soil's infiltration rates after a period of 3-7 days of no rain when the soil is relatively dry (saturated soils percolate much more slowly). Dig a hole at least 12 inches deep in one of your green spaces, fill it with a hose, let it drain, and fill it a second time. If the water on the second run does not drop at least 3/4 inch in an hour, your soils may not drain well enough to consider an infiltration practice.
- The dry well should be in a spot lower than the area being drained.
- Be at least 15 feet away from any building.
- Be sited so that it will not saturate the foundations of any buildings.
- Be sited so that the base of the infiltration system is above the water table so that it can infiltrate into the ground.
- Be sited far enough away from any other infiltration devices to ensure that their capacity is not impacted and the ground itself is not impaired.
- Be sited so there is no risk of contamination from pollutants.

How to Install a Dry Well

1) Calculate the size of the dry well required for your site.
    a) Calculate the volume for water you are planning on infiltrating.

$$\textbf{Volume}_{\textbf{water}} = \textbf{A x (Rainfall Rate}_{\textbf{local}}\textbf{) x (Time}_{\textbf{100-yr storm}}\textbf{) x (1 ft/12in)}$$

Use a rainfall rate for the closest city near you at the following site:
https://www2.iccsafe.org/states/Virginia/Plumbing/PDFs/Appendix%20B_Rates%20of%20Rainfall%20for%20Various%20Cities.pdf

For Norfolk, VA, the rainfall rate is 3.4 inches per hour based on one hour duration of a 100-year return period storm event. 100-year return period means it has a 1 percent chance of occurring in any given year.

Example: Let's say you want to drain a 100 square foot area in Norfolk, VA and design for a 1 hour 100-year return period storm.

$Volume_{water} = 100\ ft^2 \times 3.4\ inches/hr \times 1hr \times 1\ ft/12in = 340\ ft^3$

So the volume of water you would need to accommodate is 340 cubic feet.

b) Now you can calculate the size of your dry well.

To calculate the size of your dry well, you will need to account for the available void space in the drain rock you will be using to fill your well. On average, ¾" drain rock has around 40% available void space where water can drain. Alternatively, you can purchase a stormwater retention system that will reduce the amount of drain rock you will need by increasing the amount of void space. For example, NDS Inc.'s Flow-Well system can be placed in a dry well to increase void space. NDS Inc. also manufactures a number of additional stormwater solutions that can be added in many residential stormwater BMPs. http://www.ndspro.com/nds-solutions?residential

$Volume_{dry\ well} = Volume_{water} / Void\ Space_{drainrock}$

$Volume_{dry\ well} = 340\ ft^3 / .4 = 850\ ft^3$

Your dry well will need to have a volume of 850 cubic feet.

You can use the following formula to determine the dimensions of your dry well. ($Volume_{dry\ well}$ = length x width x height) Example dimensions: $Volume_{dry\ well}$ = length x width x height = 20 ft x 8.5 ft x 5 ft = 850 ft^3

NOTE: You can downsize your dry well by simply reducing the amount of water you hope to capture, if your site doesn't accommodate this much space or if the groundwater table is a limiting factor. Simply reduce **Local rainfall rate** and/or $\mathbf{Time_{100\text{-}yr\ storm}}$.

2) Locate the appropriate location for your dry well given the safety requirements outlined earlier.
3) Excavate an area using the dimensions you calculated.
4) Cover area with landscape fabric to prevent soil from filling the drain rock to be laid in dry well.
5) Fill dry well with drain rock within 8 inches of the ground level.
6) Cover dry well with landscape fabric.
7) Add soil to within 2-3 inches of ground level.
8) Add sod layer which should put you at ground level.

PLANT A TREE

Tree planting is the practice of planting deciduous or evergreen trees in grassy areas. Trees grow and create a leafy canopy that intercepts rainfall and reduces runoff. Native tree species are preferred. Trees can be planted by the owner or a contractor, but species should be selected that will grow best given a variety of conditions, including the soil conditions and solar exposure at your planting site.

A typical street tree can intercept in its crown between 760 gallons to 3,000 gallons per tree per year, depending on species. **That means less flooding!**

Go back to your aerial photo of your yard that you retrieved in Step 1: Site Assessment, and check to see how much tree canopy exists over your yard. If you have less than 25% tree canopy, you may want to consider planting more trees since they add to the market value of your home and can help reduce your heating and cooling costs.

There are a few tips to locate the best spots to plant a tree and figure out which tree species will grow best under your yard conditions and landscaping preferences. Not to worry, the Center for Watershed Protection has a handy reference called *Part 3 Urban Tree Planting Guide* which can help you quickly figure out which tree species you want and where to plant them. The guide can be accessed at:

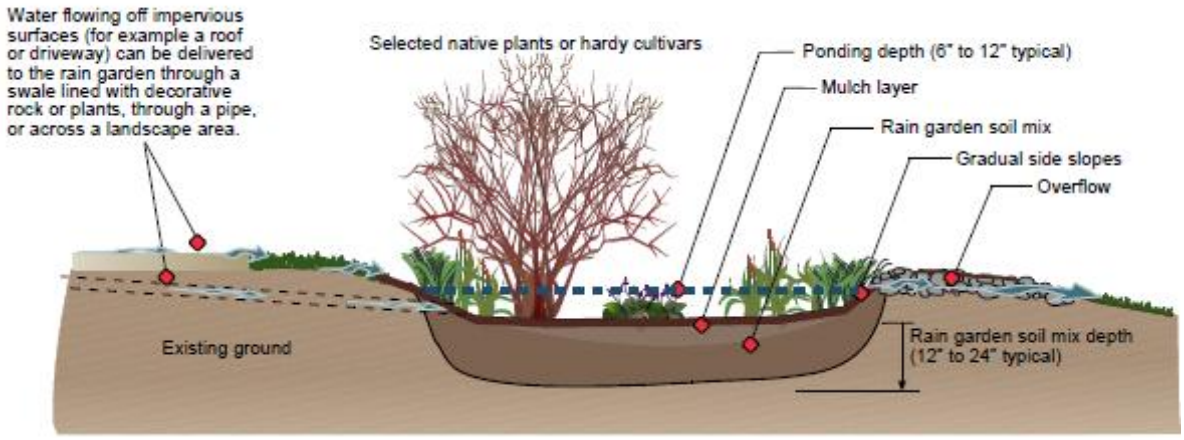
http://www.na.fs.fed.us/pubs/uf/watershed3/urban_watershed_forestry_manual_part3.pdf

The next task is to determine the solar exposure of your property to see if the plants will receive full sun or will be partially shaded. Your solar exposure is determined by three factors: the orientation of your property in relation to the east-west path of the sun, shading by the existing tree canopy in your yard (and often your neighbors), and the shading effect of your home.

Often, north or west-facing areas of your yard will be shadier, but you can do a quick shade analysis and add it your property sketch by clicking: http://www.thegardencontinuum.com/blog/bid/28513/How-much-sun-does-your-garden-have. The shade analysis will help you decide whether to buy sun or shade tolerant plants for your yard.

RAIN GARDENS

- A shallow depression between 100 square feet and to 300 square feet that collects rain water and is often planted with native plants.
- A rain garden is a great place to direct water from downspouts or paved areas, or capture the overflow from a rainwater harvesting system.
- The garden is planted with a mix of native plants that filter out pollutants and attract wildlife.



Cross Section of a Rain Garden

Test Your Soils to See if a Rain Garden Will Work

You will need to run some additional soil "tests" in order to design and build your rain garden.

Step 1: Figure out your maximum digging depth and get a better sense of the actual soil properties where you intend to dig your rain garden. Using a post hole digger, do a penetration test to see how deep into the soil profile you can physically dig. The goal is to see if you can make a hole that is at least two feet deep, although sometimes tree roots, clay layers or even bedrock can prevent you from reaching that far.

If you do encounter bedrock or the hole fills up with water, then it may not be feasible to install a rain garden in that location. In general, you need a digging depth of at least 18 to 24 inches to make a rain garden work.

Step 2: Examine your soil properties. Next, look at the profile of soils that you have excavated to see the break between your topsoil layer and the underlying sub soils which you will need to remove during construction (Box D).

Box D. Use Your Hole Digging to Check Out Soil Quality

The first 6 inches or so of soil are usually dark, loamy and rich in organic matter and nutrients

As you go farther down into the sub soils, soil quality gets poorer, and often has more clay. The soils in the bottom 6 inches to 12 inches of soil are always removed from the rain garden and disposed of somewhere on your yard. This can be a lot of dirt -- 4 to 6 cubic yards -- for a typical rain garden, so have a plan where you can fill depressions, holes or create berms somewhere on your property.

Otherwise, you can end up with a pile of dirt that is extremely hard to grow anything on. One option is to mix the fill soil with a lot of leaf compost and eventually spread it over a conservation landscaping area.

Step 3: Do a simple infiltration test in your hole to see how quickly water will soak into the bottom of your planned rain garden. Simply follow the procedures shown in Box E and you can calculate the soil infiltration rate (in inches per hour). Once again, you should jot this number down, as you will need it later in the design stage.

Box E. The Post Hole Digger Method to Measure Your Soil Infiltration Rate

Using the post hole digger, make a hole about two feet deep

Fill bucket of water and fill hole to brim

Note the time that you started

Note the number of hours it takes for the hole to completely drain

Divide the depth of the hole (inches) by the number of hours to drain

In this case, 24 inches/12 hours = 2 inches/hour, which is a good infiltration rate

If your infiltration rate is less than 0.5 inches/hr, you will need to increase the surface area of the rain garden by 50%.

You now have all of the information you need to design your rain garden, so grab a calculator and tape measure, and get cracking.

Designing Your Rain Garden

Step 1: Estimate rooftop area draining to each of your most promising downspout(s). Simply, take the total rooftop area you entered in Box A of the property assessment section, and divide by the total number of downspouts at your home:

Total Roof Area	No. of Downspouts	Area Draining to Rain Garden
2650 square feet	5	530 square feet
Note: For the most accurate estimate, you can measure the actual roof area draining to each downspout		

Step 2: Determine minimum surface area for rain garden. Assume that the ponding area of your garden will be at least 6 inches deep, and will capture the first inch of rainfall that lands on your roof. The minimum surface area for your rain garden is computed using the following equation:

Surface Area Draining to the Rain Garden	"Engineering Factor" (multiply by 0.12)	Minimum Surface Area For Rain Garden
530	0.12	64 square feet
Note that one 4 by 8 tarp would be 32 square feet, so you would need an area equivalent to two tarps to locate a rain garden at this downspout		
The engineering factor computes how much surface area is needed in your rain garden to capture one inch of rainfall that falls on your roof.		

Step 3. Go outside to your downspout with some tent stakes and mark out the potential surface area available for your rain garden. Place the first stake at least 5 feet away from the downspout (if you don't have a basement) or 10 feet (if you do).

Check your property sketch to see if there are any underground utilities in the vicinity of your planned rain garden and then stake out a line at least two feet away from them. Contact Miss Utility to request an on-site utility check: they will usually come to your home within a few business days to confirm that your proposed digging area is utility free (see page 15 for hotline numbers).

Walk in a downhill direction until you reach the bottom of the hill or your property boundary (whichever comes first) and place a stake there. The line from your downspout to this stake is called the plumb line. Tie a string to the stake and then run it back to the bottom of the downspout so that the string is level. The vertical distance between the level of the string at your stake and the lawn surface is where you measure how many inches of drop you have.

If you have more than six inches of drop, you will be able to construct a soil berm on the downstream end of the rain garden to increase the ponding area.

Walk in a perpendicular direction on each side of the plumb line until you reach a major tree (think roots), hard surface, or start going seriously uphill. Stake out the lateral boundaries, and you have now defined the maximum envelope that is available for digging your rain garden.

Go out to your garage and get a small tarp and multiply its length and width to see how many square feet it covers. I use a 4' by 8' tarp that is 32 square feet in area. If I can get the equivalent of two tarps within the envelope defined by the stakes, then I am good to go (e.g. minimum area needed = available area).

You can still make a rain garden work with only half of the recommended minimum surface area, but you should expect that your rain garden will be wet-footed (see planting guide).

If you still can't make it work, consider another practice, such as a rain barrel with the overflow directed to a conservation landscape...especially if you have an infiltration rate of less than a quarter inch per hour. Some tips for installing rain barrels can be found in the previous section on rain barrels.

Step 4: The last step is to figure out how much excess fill needs to be disposed of, and how much sand and mulch to order. So we go back to our earlier measurements of the maximum digging and topsoil depth, and use the calculator provided below (also provided in Appendix B).

Calculator to Estimate Excess Fill and Materials to Buy		
Design Factor	Example	Your Calculation
EXCESS FILL		
Max Digging Depth	24 inches	
Ponding Depth	6 inches	
Top Soil Depth	6 inches	
Subsoil Depth	12 inches	
Divide Subsoil Depth by 2, and then divide this by 12	[12 inches/2] /12 X = 0.5 feet	
Garden Surface Area	64 square feet = Y	
Z = Multiply X and Y and divide the product by 27	[(64)(0.5)] / 27 = 1.2 cubic yards	
Note: About six wheelbarrow loads per cubic yard	**About seven loads of subsoil to dispose of elsewhere on your lawn**	
MULCH CALCULATOR		
Garden Surface Area	64 square feet	
1 cubic yard for each 64 square feet of garden area	1 cubic yard of mulch to order [1]	
SAND CALCULATOR		
Take Z and multiply by 1.4	= 1.7 tons of sand to order (round up to 2 tons)	
RIVER STONE CALCULATOR		
Assume 0.2 tons per inlet	0.2 tons (400 pounds) [1]	
[1] Most bulk orders must be done in one cubic yard or ton increments.		

Some Rain Garden Design Solutions

Not every rain garden design is the same. Box F demonstrates some creative ways to fit in a rain garden in a specific design situation.

<table>
<tr><th colspan="2">Box F. Some Cool Rain Garden Design Solutions</th></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Two downspouts, one rain garden and a large area of conservation landscaping</td><td>Stone walkway over rain garden</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Narrow stone trench across driveway leads to rain garden on the other side</td><td>Under drain pipe collects runoff from the bottom of the rain garden and discharges it down-gradient (which may be a good option if you have poor infiltration rates)</td></tr>
</table>

Constructing Your Rain Garden

Step 1: Use a hose, heavy rope or can of spray paint to delineate where you plan to dig, keeping at least 3 feet from any known utilities and out of the street right of way. If you have not yet called Miss Utility, get on the phone now.

Step 2: Connect a flexible connector pipe to your downspout and use it to move any rainwater away from where you are digging. Dig a shallow trench at least a foot wide and 6 inches deep that extends at least 10 feet from the foundation of your house to the head of the rain garden. Make sure that you have enough slope to move runoff away from the house: 3 to 6 inches of drop from the downspout to the head of the rain garden is usually enough.

Box H. Options for Your Rain Garden Inlet

Attach flexible connector pipe to downspout

Make sure it extends at least 10 feet if you have a basement

Black plastic to line the bottom of inlet trench

Example of river stone Inlet

Step 3: Line the trench with plastic sheeting that can be purchased at any home and garden store. The impermeable black plastic (3 to 5 ml thick) is used to wrap the bottom and sides of the inlet channel to make sure runoff gets to your rain garden and not in your basement. You can test how water-tight your inlet is by running a garden hose to make sure water quickly reaches the downstream end of your inlet trench.

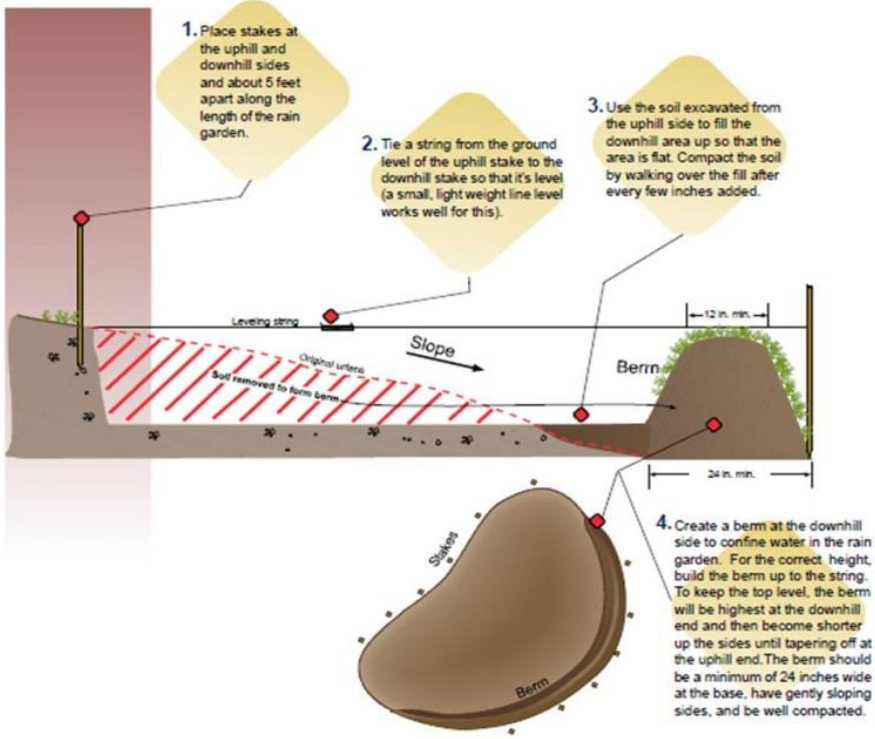
Step 4: You have two options at this point (Box H). You can either bury the connector pipe in the shallow trench and cover it with soil up to the existing lawn grade, or preferably you can create a river stone channel.

Step 5: Now is the time for some serious digging. The first part is pretty tedious, and includes separating the turf from your topsoil and throwing them onto the first tarp. You may need to use the root axe to get around underground tree roots, but keep going until you dig down about 9 inches to 12 inches, where you will reach your poorer sub-soils or clay layer (see Box D).

Step 6: At this point you will need to use a pick or adze to break up these compacted soils. Make sure to separate these lousy soils from the good ones by throwing them onto a second tarp. Keep on digging until you reach your maximum possible digging depth, which is usually around 18 to 24 inches.

Step 7: The bottom of the bed should generally be flat, although it is OK to have a few inches of drop going in a downhill direction. At this point, you want to take a pick or a hoe and loosen up the subsoil at the bottom of your rain garden to improve infiltration.

Step 8: Install a ponding berm (optional). If you measured more than six inches of drop from your original plumb-line, you can take some of your lousy dirt from Tarp 2 and form a soil berm nine inches wide and six inches high (or level with the bottom of the downspout) around the perimeter of your rain garden. Make sure to tamp the berm down so it can hold water during a storm. More details on ponding berm are provided in the graphic on the next page.



Step 9: Install a surface overflow channel. Remember that your rain garden is only designed to capture one inch of rain, so larger storms must be able to find an easy downhill exit out of the rain garden. I

usually dig a small overflow channel at the down-gradient end of the rain garden that is about three inches below the grade of the bottom of the garden. The overflow channel should connect the bottom of the garden, extend through the berm (if present), and discharge directly to the street or right of way. The channel can be back-filled with river stone to prevent erosion and make it more attractive.

Example of a river stone overflow channel from a rain garden

Step 10: You can backfill now by alternating a shovelful of sand with a shovelful of your good topsoil from the first tarp until you are about six inches below the grade of your lawn. The goal is to have at least a 50:50 mix of good topsoil and sand, but it is fine to have more sand than soil. Over the next month or so it will settle a few more inches, but that's not a problem. You can also add leaf mulch or compost in the areas you plan to dig planting holes.

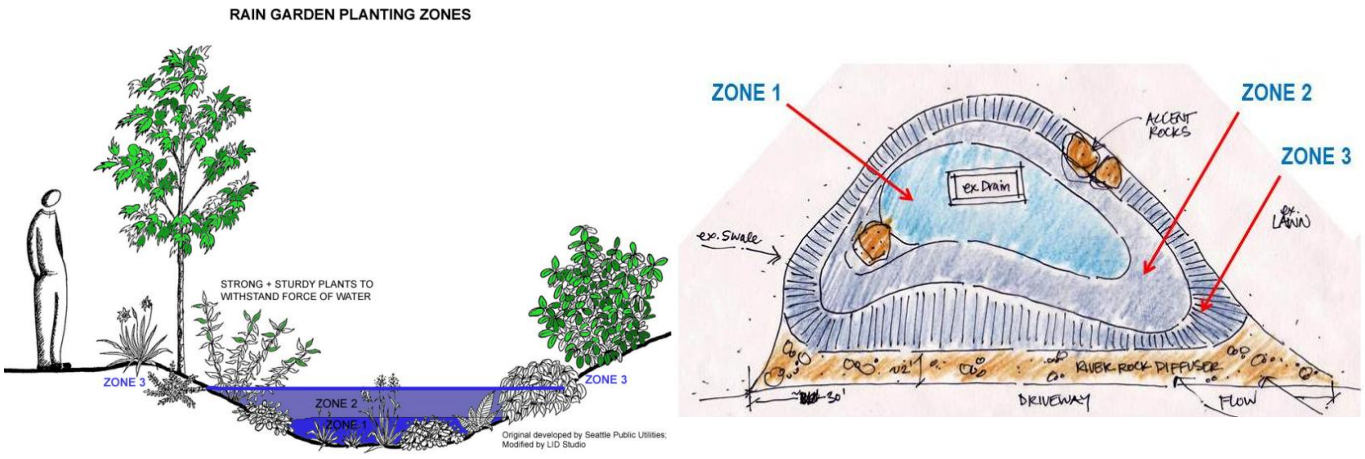
Step 11: Spread no more than 3 inches of double shredded hardwood mulch on the bed.

Step 12: You can then dispose of your fill soils elsewhere on your yard to fill holes, depressions or gullies. It is a good idea to amend the soils with compost, and re-seed them with a grass or conservation landscaping seed mix. You may also need to reseed the turf underneath your tarps if they were on the ground long enough to kill the grass. You can now retire to your deck, partake of another cold beverage and admire your work.

Planting Your Rain Garden

It is easiest to design a successful rain garden if you think about the anatomy of a rain garden, how they retain water, and how plants are selected and planted in the three zones. The three zones are (Zone 1) plants that tolerate sitting in water for an extended period of time, (Zone 2) some that tolerate water for a shorter period of time, and (Zone 3) plants that do not tolerate sitting in water. After determining your zones and what native plants you are going to use, some homeowners may choose to wait a few weeks after construction to see how the water settles in the different zones before they begin planting.

Box I. The Water Zones in a Rain Garden and What they Mean (profile and plan)



Source: Anne Guillette, Low Impact Design Studio

Group plants together in a series as they will have more visual impact.

Vary plants heights, textures, colors, shapes, and sizes throughout the garden

1) Consider the planting zones. Make sure you locate Zone 1 plants in the basin, Zone 2 plants in the sides, and Zone 3 plants on the edge. Separate them out accordingly.

2) Think about the "structural" components of the garden first:
    - What will it look like in the winter when all of the perennials have died back?
    - Do you have any evergreen plants?
    - Are there any grasses, rushes or sedges that have winter interest, or look good in winter?

    This will help you locate plants with winter interest first. As a note, sometimes people place accent stones and/or river rock through the middle of the rain garden so that there is more visual interest in the winter. A focal element such as a sculpture or garden ornament is also an option.

3) Locate the taller plants along the back or the edges, such as shrubs, hibiscus, or ironweed.

4) Place sturdy plants near where the water flows into the rain garden. Blue flag iris, soft rush, and white turtlehead are good candidates as they will withstand some velocity of water.

5) Think about the visual characteristics of the plants you would like to use to include their leaf structure (whether rounded or grass-like), bloom color, height and width. ***The most important aspect here is that you place taller growing plants behind shorter plants.*** Other than that there are no rules. Place them in an arrangement which pleases you.

6) Consider the bloom time of the plants, as it is rewarding to have a garden with spring, summer and fall blooms spotted throughout the garden.

In summary, have fun designing the plants where you want! Aside from placing them in the right zones there is no right way or wrong way. Besides, you can always move them around. Enjoy!

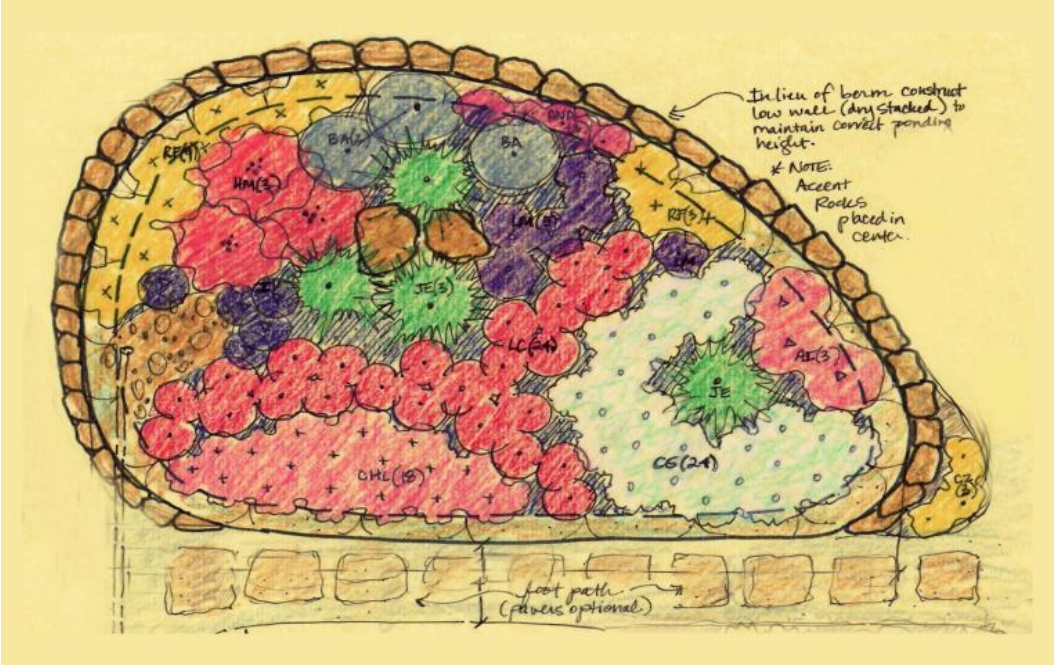
Sample Planting Plans

This section offers some sample planting plans for rain gardens based on the amount of sun they receive. Each planting plan includes and overhead view of the design followed by a table providing the plant list complete with common names, the number of plants needed for the sample design, and the zones where the plants can best thrive. Planting plans are provided for rain gardens that:

- Receive full sun
- Are partially shaded, or
- Are in full shade

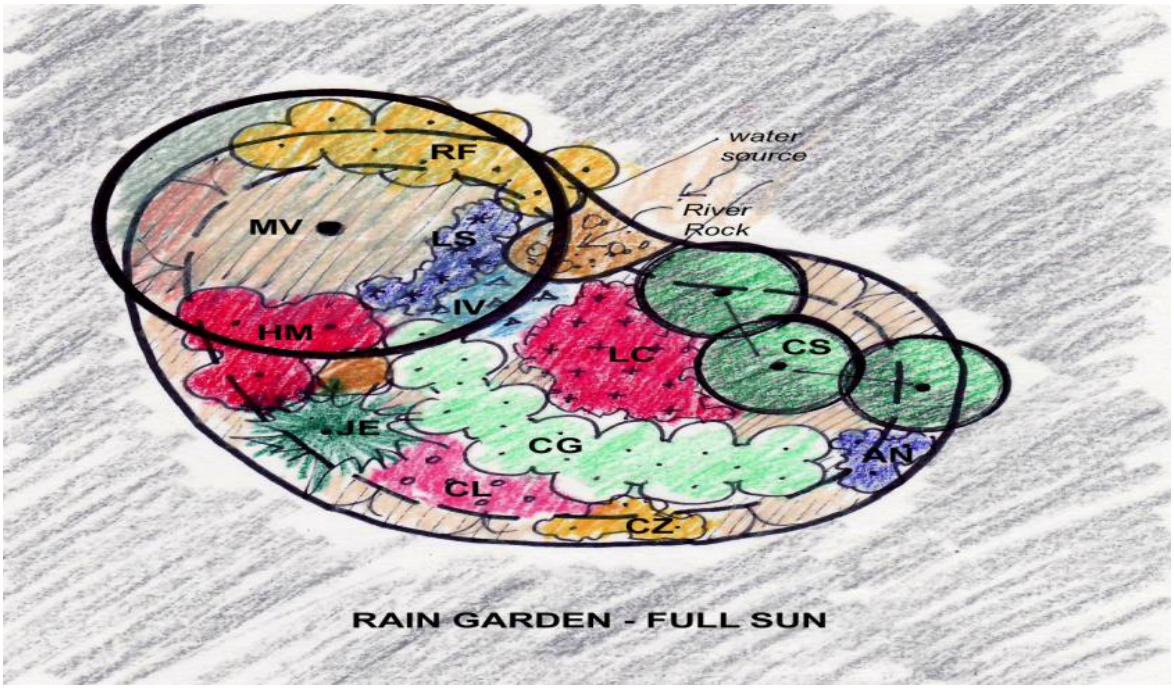
The planting plans can give you some good ideas of perennials, shrubs and tree species that work well in rain gardens across the Bay watershed.

Option 1 Sunny Rain Gardens w/ Perennials



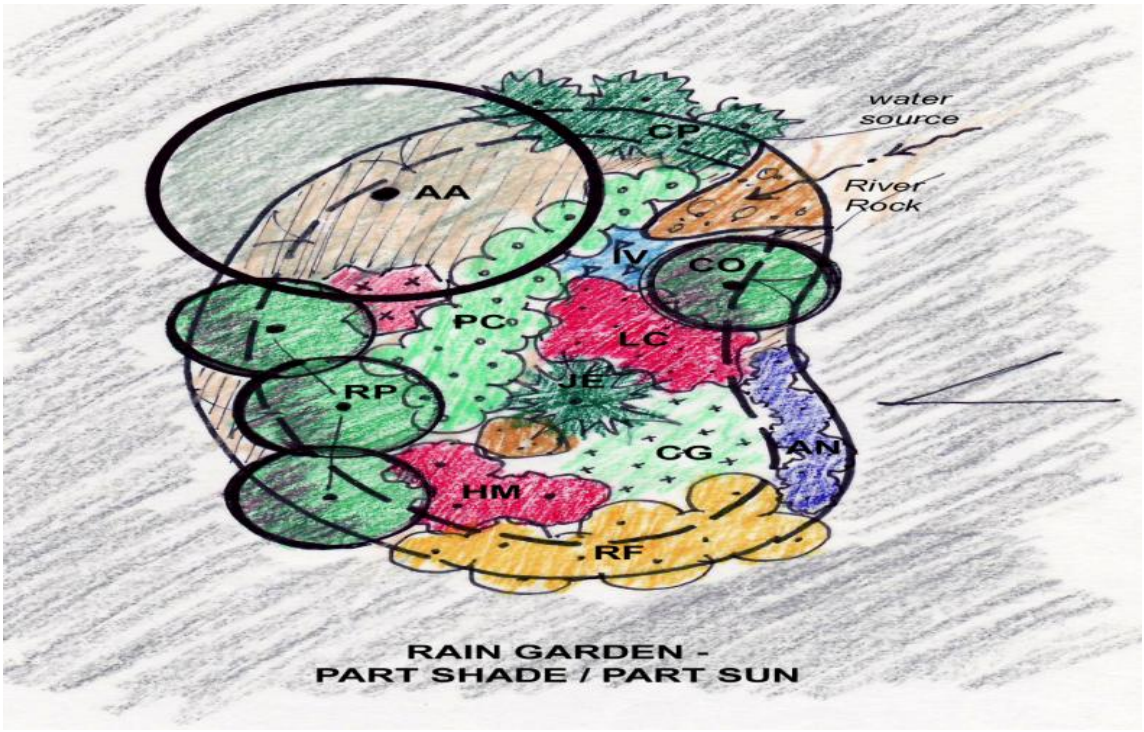
Plant List for a Sunny Rain Garden with Perennials							
LABEL	**LATIN NAME**	**COMMON NAME**	**SIZE[1]**	**QTY**	**PLANTING ZONE**		
					1	**2**	**3**
PERENNIALS, SEDGES + GRASSES							
ANA	Anemone Canadensis	Windflower	#1	3			◆
AT	Asclepias incarnata	Swamp Milkweed	#1	3	◆	◆	
BA	Baptisia australis	False Indigo	#1	3	◆	◆	
CG	Chelone glabra	White Turtlehead	QT	24	◆	◆	
CHL	Chelone 'Hot Lips'	Pink Turtlehead	QT	18	◆	◆	
CZ	Coreopsis 'Zagreb'	Tickseed Coreopsis	#1	3			◆
EP	Echinacea purpurea 'Magnus'	Coneflower	#1	12		◆	◆
HM	Hibiscus coccineus 'Blaze Star'	Rose Mallow	#1	3	◆	◆	
IC	Iris cristata	Crested Iris	QT	6	◆	◆	
IV	Iris versicolor	Blue Flag Iris	#1	5	◆	◆	
JE	Juncus effuses	Soft Rush	#1	4	◆	◆	
LM	Liatris microcephela	Gayfeather	#1	6		◆	
LC	Lobelia cardinalis	Cardinal Flower	QT	24	◆	◆	
RF	Rudbeckia fulgida	Black Eyed Susan	#1	12		◆	◆
SL	Sisyrychium ang. 'Lucerne'	Blue Eyed Grass	QT	6	◆	◆	
[1] Refers to the size of the container: gallon (#1) or quart							

Sunny Rain Garden Option with Perennials/Shrubs and Trees



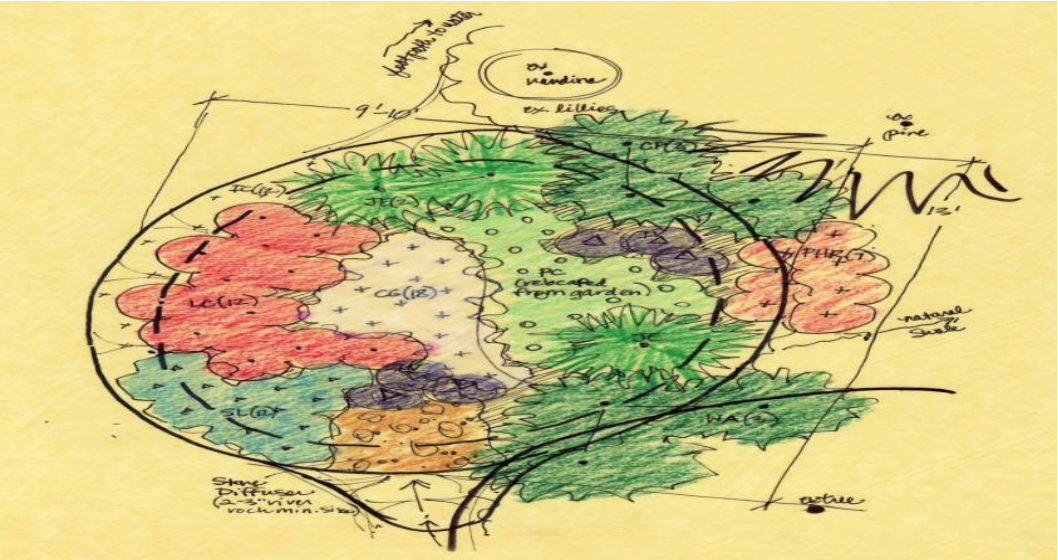
Plant List for a Sunny Rain Garden with Perennials, Shrubs and Trees							
LABEL	**LATIN NAME**	**COMMON NAME**	**SIZE[1]**	**QTY**	**PLANTING ZONE**		
					1	**2**	**3**
TREE and SHRUB							
MV	Magnolia virginiana	Sweetbay Magnolia	8-10’	1	◆	◆	◆
CS	Cornus sericea	Red Osier Dogwood	5 gal	3	◆	◆	◆
PERENNIALS, SEDGES + GRASSES							
AN	Aster novae-angliae	New England Aster	QT	3			◆
CG	Chelone glabra	White Turtlehead	QT	18	◆	◆	
CL	Chelone llyoni	Pink Turtlehead	QT	9	◆	◆	
CZ	Coreopsis ‘Zagreb’	Tickseed Coreopsis	QT	3			◆
HM	Hibiscus coccineus	Rose Mallow	#1	3	◆	◆	
IV	Iris versicolor	Blue Flag Iris	#1	5	◆	◆	
JE	Juncus effuses	Soft Rush	#1	1	◆	◆	
LC	Lobelia cardinalis	Cardinal Flower	QT	12	◆	◆	
LS	Liatris spicata	Gayfeather	#1	6	◆	◆	
RF	Rudbeckia fulgida	Black Eyed Susan	#1	9	◆	◆	◆
[1] Refers to the size of the container: gallon (#1) or quart							

Partial Shade Rain Garden



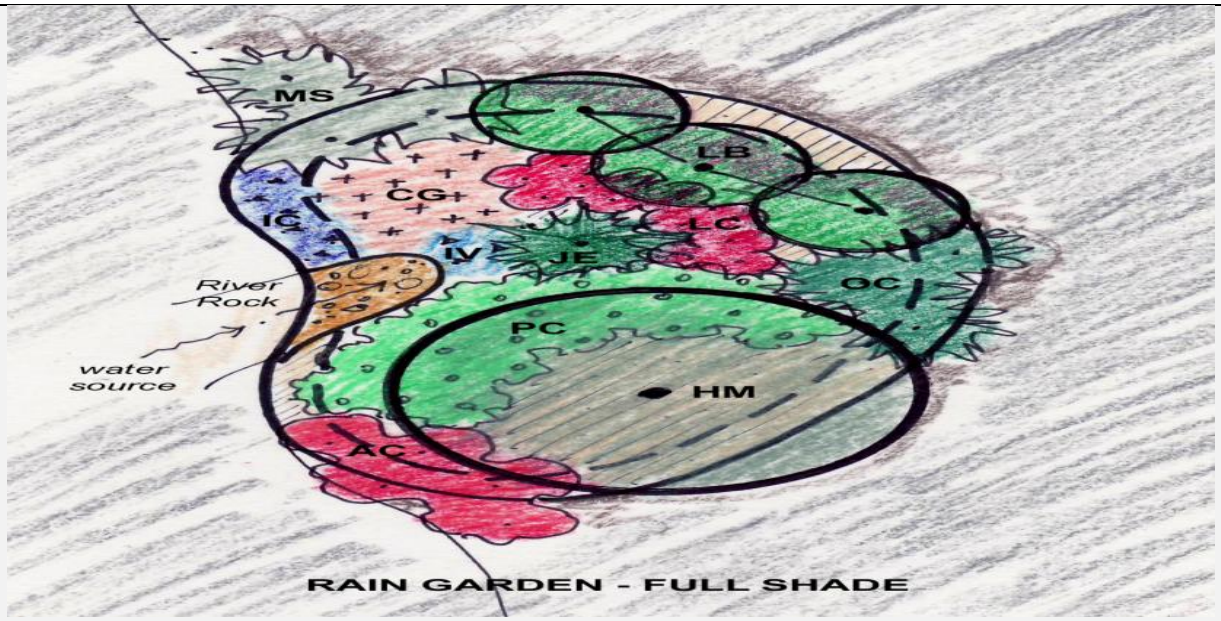
Plant List for a Partially Shaded Rain Garden with Perennials, Shrubs and Trees							
LABEL	**LATIN NAME**	**COMMON NAME**	**SIZE[1]**	**QTY**	**PLANTING ZONE**		
					1	**2**	**3**
TREE and SHRUBS							
AA	Amelanchier arborea	Downy Serviceberry	8-10’	1	◆	◆	◆
CO	Cephalanthus occidentalis	Buttonbush	5 gal	1	◆	◆	◆
RP	Rhododendron periclymenoides	Pinxterbloom Azalea	5 gal	3	◆	◆	◆
PERENNIALS, SEDGES + GRASSES							
AC	Aquilegia Canadensis	Columbine	QT	3	◆	◆	◆
AN	Aster novae-angliae	New England Aster	QT	7			◆
CG	Chelone glabra	White Turtlehead	QT	12	◆	◆	
CP	Comptonia peregrina	Sweet Fern	#1	5		◆	
HM	Hibiscus coccineus	Rose Mallow	#1	3	◆	◆	
IV	Iris versicolor	Blue Flag Iris	#1	3	◆	◆	
JE	Juncus effuses	Soft Rush	#1	1	◆	◆	
LC	Lobelia cardinalis	Cardinal Flower	QT	12	◆	◆	
PC	Polygonatum commutum	Solomon’s Seal	#1	18	◆	◆	
RF	Rudbeckia fulgida	Black Eyed Susan	#1	9	◆	◆	◆
[1] Refers to the size of the container: gallon (#1) or quart							

Full Shade Rain Gardens



Option 1: Plant List for a Shaded Rain Garden with Perennials							
LABEL	**LATIN NAME**	**COMMON NAME**	**SIZE[1]**	**QTY**	**PLANTING ZONE**		
					1	**2**	**3**
PERENNIALS, SEDGES + GRASSES							
CG	Chelone glabra	White Turtlehead	QT	18	◆	◆	
CP	Comptonia peregrina	Sweet Fern	#1	3		◆	
IC	Iris cristata	Crested Iris	QT	12	◆	◆	
IV	Iris versicolor	Blue Flag Iris	#1	6	◆	◆	
JE	Juncus effuses	Soft Rush	#1	3	◆	◆	
LC	Lobelia cardinalis	Cardinal Flower	QT	12	◆	◆	
PHR	Penstemon 'Husker Red'	Beardtongue	#1	7			◆
PC	Polygonatum commutum	Solomon's Seal	#1	18*	◆	◆	
SL	Sisyrychium ang. 'Lucerne'	Blue Eyed Grass	QT	12	◆	◆	
WA	Woodwardia areolata	Netted Chain Fern	#1	3		◆	◆
[1] Refers to the size of the container: gallon (#1) or quart							

Full Shade Rain Garden Option 2



Option 2: Plant List for a Shaded Rain Garden with Perennials, Shrubs and Trees

LABEL	LATIN NAME	COMMON NAME	SIZE[1]	QTY	PLANTING ZONE		
					1	2	3
TREES and SHRUBS							
HM	Hamamelis virginiana	Witchhazel	7 gal	1	◆	◆	◆
LB	Lindera benzoin	Spicebush	5 gal	3	◆	◆	◆
PERENNIALS, SEDGES + GRASSES							
AC	Aquilegia Canadensis	Columbine	QT	5	◆	◆	◆
CG	Chelone glabra	White Turtlehead	QT	12	◆	◆	
MS	Matteuccia struthiopteris	Ostrich Fern	#1	3	◆	◆	◆
IC	Iris cristata	Crested Iris	QT	7	◆	◆	
IV	Iris versicolor	Blue Flag Iris	#1	3	◆	◆	
JE	Juncus effuses	Soft Rush	#1	1	◆	◆	
LC	Lobelia cardinalis	Cardinal Flower	QT	12	◆	◆	
OS	Osmunda cinnamomea	Cinnamon Fern	#1	3		◆	◆
PC	Polygonatum commutum	Solomon's Seal	#1	18	◆	◆	
SL	Sisyrychium ang. 'Lucerne'	Blue Eyed Grass	QT	6	◆	◆	◆

[1] Refers to the size of the container: gallon (#1) or quart

Resources

- Rain Gardens Across Maryland (University of Maryland)
  http://extension.umd.edu/sites/default/files/_docs/articles/Rain_Gardens_Across_MD.pdf
- Rain Garden Design Templates (Low Impact Development Center)
  http://www.lowimpactdevelopment.org/raingarden_design/templates.htm
- Rain Garden Manual, RainScapes Program (Montgomery County, MD)
  http://www6.montgomerycountymd.gov/content/dep/downloads/Rainscapes/MocoRainGardens.pdf
- The Chesapeake Ecology Center's Rainscaping Campaign
  http://www.rainscaping.org/

Contact

For further information please contact: Christy Everett, Hampton Roads Director, Chesapeake Bay Foundation at (757) 622-1964.

**Practice Descriptions and Images Adapted from the Chesapeake Stormwater Network's Homeowner Guide for a More Bay-Friendly Property*