

Roanoke Stormwater Ideabook



a guide for single-family homeowners

Acknowledgements

City of Roanoke Staff

Bob Boeren, Landscape Coordinator

Christopher Blakeman, Environmental Administrator

Daniel J. Henry, Urban Forestry Coordinator

Danielle B. Bishop, Development Review Coordinator

Dwayne R. D'Ardenne, Street & Landscape Superintendent

Megan Scott, Civil Engineer I

Phil Schirmer, City Engineer

Prepared for the City of Roanoke Engineering Division by



Stormwater Management
Best Management Practices

© 2014 City of Roanoke, Virginia. All rights reserved.

INTRODUCTION

The Stormwater Ideabook is a companion guide to the Roanoke Stormwater Utility Fee Credit Manual for Single Family Residential Properties (available at the City's website [here](#)). The Ideabook is oriented toward residents, property owners, home builders, and home buyers to help inspire thinking about how to reduce the amount of stormwater and improve the quality of stormwater leaving a single family residential property in the form of runoff. The Ideabook offers guidance on how residents can adapt some of the Best Management Practices (BMP) discussed in the Stormwater Utility Fee Credit Manual and implement them in an effective, safe and creative way on their property.

Disclaimer: This Stormwater Ideabook provides only general information about the BMPs. These BMPs may not be appropriate or safe for every property or situation. Each user of this Ideabook is solely responsible to be sure such user either has the knowledge and experience to undertake any BMP project or has engaged a person who has such knowledge and experience to do such project. Each user shall also be solely responsible for obtaining all required building, zoning, and all other permits and/or approvals for any such BMP project. Each user assumes all risks of any injuries and/or damages to any person or property. The City of Roanoke is not responsible for your modifications and disclaims liability for your actions.

Why worry about stormwater management?

Stormwater runoff plays a significant role in flooding, particularly in urban areas, where roads, buildings, parking lots and other developed areas create impenetrable surfaces that do not allow water to seep into the ground. Instead, water following rain or snow runs rapidly across these surfaces, entering waterways more quickly and causing more flooding in low-lying areas. As water travels, it picks up visible and invisible contaminants (litter, oil/grease, heavy metals, and other chemicals and toxic substances). These pollutants enter directly into streams and rivers, impacting the water sources for many communities and hurting the fish and other wildlife in these waters. The Roanoke River and six of its tributaries within Roanoke are impaired, prompting clean up plans that set maximum targets for the amount of sediment and bacteria entering these waterways. Some of these pollutant limits are exceeded within the City by up to twice the maximum target!



The BMPs presented here are proven practices that do one or more of the following:

- reduce or slow the amount of stormwater flowing across the land after a storm,
- allow stormwater to infiltrate into the ground to naturally recharge groundwater levels, and
- filter pollutants from stormwater as it flows across the surface or infiltrates into the ground.

The Ideabook is organized into information sheets for each stormwater BMP described in Roanoke's Stormwater Utility Fee Credit Manual for Single Family Residential Properties. Each technique is discussed in a one-page leaflet with:

- A description of the BMP and how it reduces stormwater runoff and/or improves stormwater quality.
- Discussion of the best conditions to implement the BMP.
- Illustrations of how to design, install and maintain the BMP.
- Sources for more in-depth technical information.

General guidelines:

- Call Miss Utility (811) to have underground utilities on your property marked prior to any digging.
- Make sure channeled water or discharged overflow is not directed toward building foundations or adjacent properties.
- Obtain any permits and approvals before you work! Contact the City of Roanoke Permit Center at 540-853-1090 to determine if you need building or zoning permits or other approvals to implement a BMP.

Symbols on each BMP information sheet rate each BMP in various categories, and the matrix below provides a summary.

	BMP Cost	Level of Difficulty of Installation	Level of Difficulty of Maintenance	Impact on Stormwater Quality	Impact on Stormwater Quantity	BMP Credit Value
Rain Barrel						10%
Vegetated Filter Strip						10%
Grass Channel						10%
Roof Drain Disconnection						10%
Trees						10%
Lawn Maintenance						10%
Other BMPs (waste/septic)						10%
Pervious Pavement						25%
Rain Garden						25%
Infiltration Techniques						25%
Cistern						25%
Green Roof						25%

Key: Low =

Medium =

High =



What is a rain barrel?

Typically located at the bottom of downspouts, a rain barrel catches rainwater from the roof gutters and stores it for future use in a large drum-sized container. A rain barrel has a number of benefits:

- It saves clean, free water for use on gardens, lawns, and outdoor cleaning.
- It provides water that is free of chemicals found in tap water.
- It reduces urban runoff and stormwater pollution.
- It reduces water bills, especially in the summer.

A rain barrel is low-tech and easy to build, and several rain barrels can be connected together to store more water. It is a great BMP for homeowners who currently use a large amount of tap water to irrigate their gardens and lawns, which can account for up to 40% of household water use in the summer months. A faucet near the base of the barrel can be connected to a garden hose or irrigation pipe, or simply used to fill buckets for watering.

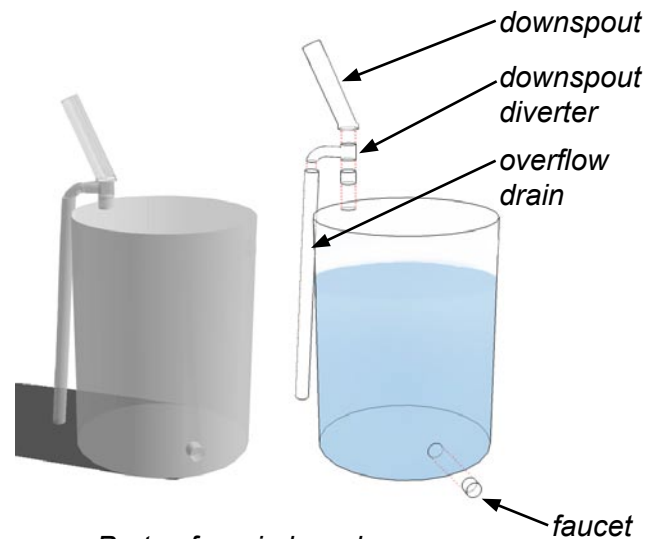
How do I design and install it?

Many home supply stores or internet retailers sell pre-assembled kits in a variety of styles, but you can even build one yourself with materials from a hardware store.

The instructions below include the installation of a downspout diverter with an integrated overflow drain. There are a variety of different downspout diverters available through retail and online outlets

– be sure to follow the manufacturer's installation instructions. Also make sure that your rain barrel has an overflow outlet, with the overflow directed away from all structures and paved areas (including those on adjacent properties).

To build your own rain barrel, start with a food-grade barrel or trash can that has not been used previously for oil or other dangerous chemicals.



Parts of a rain barrel

Step 1: Install the faucet: Drill a $\frac{3}{4}$ " hole a few inches above the bottom of the barrel. Screw a $\frac{3}{4}$ " brass faucet/hose bib into the barrel and secure it with $\frac{3}{4}$ " nuts or washers. Seal the opening with silicone waterproof caulk.

Step 2: Make an opening for the downspout diverter: Cut a hole in the lid of the barrel, a little larger than the size of the diverter. Cut a piece of fiberglass window screen to cover the top of the barrel and secure it in place with plastic strapping or with the barrel lid. The screen will keep out debris and mosquitoes.

Step 3: Position the barrel: Place the barrel on a sturdy stand or cinder block base, elevated for easy access to the faucet and to increase gravity flow. Be sure it is located for convenient use on flower beds.

Step 4: Install a downspout flow diverter: Cut an 8" to 12" section of the downspout just above the level of the diverter. Attach the diverter to the upper portion of the downspout and to the top opening of the barrel. Attach the overflow spout of the diverter to the lower portion of the downspout. Make sure the bottom portion of the downspout empties the overflow away from the building foundation and paved areas.

Level 1 BMP

BMP cost:



Installation:



Maintenance:



Water quality:



Water quantity:



Want to paint your plastic barrel?

Clean the barrel with soapy water and rinse well. Apply a plastic primer, gently buff with sandpaper, then use acrylic paint to decorate your barrel in any color or design you choose. Apply a clear sealant to preserve your work!

Tips for maintenance

- Cover all openings in the rain barrel with screen to prevent mosquitoes from breeding and debris from clogging the system.
- Keep the overflow drain clear of debris, and divert water away from your home's foundation, paved areas, steep slopes and retaining walls.
- Disconnect the downspout and drain the rain barrel in the late fall so water does not freeze and crack the barrel over the winter. This is a good time to clean the barrel and remove any collected sediment in the bottom of the barrel.
- Keeping roof gutters clean and installing gutter guards will minimize debris and sediment in the barrel.
- A full rain barrel is extremely heavy. Make sure it safely rests on firm soil. Anchor the barrel if there is a risk of children climbing on it.
- Keep the barrel out of direct sunlight to inhibit algae growth. To get rid of algae, empty the barrel and wash it with a diluted bleach solution ($\frac{3}{4}$ cup of bleach to 1 gal water).



photo credit: SHIFT_DESIGN

Rain barrels come in a variety of styles and designs, and can be an attractive visual addition to any garden.

The following resources have more information on the design and installation of rain barrels:

Western Virginia Water Authority – general information on rain barrels: www.westernvawater.org

Chesapeake Bay Foundation Build Your Own Rain Barrel manual: www.cbf.org

Alliance for the Chesapeake Bay – Rain Barrels Structural BMP fact sheet: detailed information, with how-to videos: stormwater.allianceforthebay.org



What is a vegetated filter strip?

Vegetated filter strips are specially designed planted areas that slow the rate of stormwater runoff and treat stormwater entering as sheet flow from adjacent areas. Benefits of vegetated filter strips include:

- slowing the speed of stormwater runoff,
- effective removal of sediment, modest removal of pollutants, and
- allowing stormwater to infiltrate into the soil.

Vegetated filter strips can treat up to a 5,000 square foot area. They must be designed properly, however, to ensure an even sheet flow of stormwater into the vegetated filter strip; otherwise the filtering ability of the strip is diminished. Soils with high clay content should be amended to improve infiltration and further reduce stormwater runoff.

Vegetated filter strips can be an attractive part of an overall landscape design. However, where native or natural vegetation already exists, these should be maintained or enhanced, rather than removed and replaced with a vegetated filter strip.

How do I design and install it?

To maintain sheet flow, the area draining to a filter strip should be relatively flat, but a gravel trench (or other “level spreader”) can help spread out the flow before it enters the vegetated filter strip. The area draining into a filter strip should be no more than 75’ in length if the surface is impervious (150’ max if the drainage area is pervious). The filter strip itself should be wide and fairly level (6% slope maximum).

The design below describes a filter strip treating stormwater from an impervious paved surface, with a gravel trench at the top of the filter strip to distribute the incoming water evenly. If the filter strip receives stormwater from a turf area, no gravel trench is needed.

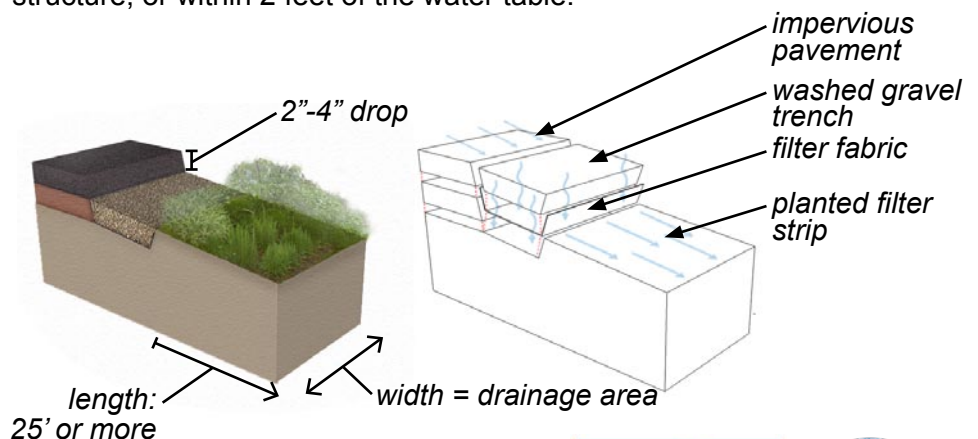
Install the gravel trench:

- Dig a trench 2’ wide and 1’ deep at the top of the vegetated filter strip. Make sure the trench is level.
- Lay filter fabric along the sides and bottom of the trench.
- Fill the trench with gravel, leaving a drop of 3” from the pavement above.

Install the vegetated filter strip:

- The total length of the filter strip should be at least 25’, but longer filter areas improve the strip’s capacity. Width should equal the width of the drainage area.
- Amend the top 12” of the filter strip area by raking in soil compost to improve water infiltration.
- Fine grade the filter strip area. The first 10’ of the filter strip should be fairly level (2% slope or less). The remainder of the filter strip should have no more than a 6% slope.
- Plant the filter strip with either turf or a mix of herbaceous (soft) plants, shrubs and trees. Mixed plantings are more effective at filtering and slowing runoff; turf filter strips need to be tolerant of wet and dry conditions, and able to withstand fast runoff.

A vegetated filter strip should never be installed closer than 10 feet to a structure, or within 2 feet of the water table.



Level 1 BMP

BMP cost:



Installation:



Maintenance:



Water quality:



Water quantity:



Did you know?

Vegetated areas along waterways are particularly important for water quality. These *riparian buffers* are undisturbed areas of plant growth along streams and creeks that intercept sediment, chemicals and pollutants in stormwater runoff, stabilize streambanks, and improve habitat for beneficial aquatic species. A 25' minimum buffer is recommended, but any buffer is better than mowing the lawn to the edge of the stream.

Want to test your soil's permeability?

Most soils in Roanoke are high in clay, and amending the bottom of your filter strip with compost will improve infiltration of stormwater. To test the infiltration rate of your soil, use the soil infiltration test found in the *Infiltration Technique* page.

Tips for maintenance

Maintenance of a vegetated filter strip is primarily focused on maintaining an even sheet flow and lush vegetative cover, as well as avoiding clogging.

- Visually inspect the gravel trench every few months while the filter strip plantings are being established. Remove sediment and debris build up, and correct any areas where rills or gullies are developing.
- Mow turf areas to a height of 4" to 6" (but no higher than 10" to avoid a City weed violation). Mow only when the ground is dry to avoid damage from tracking and soil compaction.
- Observe mixed plantings and replace unhealthy specimens with alternative species.
- If the vegetated filter strip shows signs of poor drainage or vegetative cover, soil aeration may be needed.



Even a modest buffer of unmowed vegetation along streams will help filter runoff before it enters the waterway.

The following resources have more information on implementing vegetated filter strips:

EPA Fact Sheet with detailed guidance on design, installation and maintenance of filter strips:
cfpub.epa.gov

Vegetated Filter Strip fact sheet from the Pennsylvania Stormwater BMP Manual:
www.elibrary.dep.state.pa.us

Virginia DCR Stormwater Design Specification: Sheet Flow to Filter or Open Space:
vwrcc.vt.edu/swc



What is a grass channel?

Also known as a grass swale, a grass channel is a wide and shallow linear depression planted with grass and designed to direct stormwater across the landscape. Grass channels help both stormwater quantity and quality.

Traditional curb and gutter, storm drains, and pipes allow runoff to flow quickly, without any infiltration. Grass channels slow runoff and allow some water to soak into the ground. More infiltration occurs when the soil at the bottom of the channel is amended with compost. The result is less water and fewer pollutants flowing into the City's stormwater system and waterways.

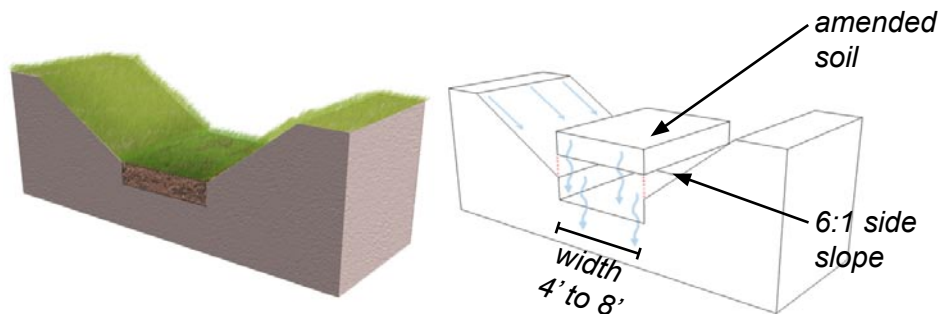
On a residential site, grass channels can replace standard drainage ditches to improve stormwater treatment. Because they are linear, grass channels work well along drives or roadways. A grass channel can be linked with other BMPs, such as by directing stormwater into a rain garden or infiltration well.

How do I design and install it?

Grass channels should be installed in areas with adequate space and low slope, where stormwater needs to be directed to a particular area. A grass channel should work with the natural shape of the land, without forcing water flow to make sharp, unnatural changes in direction. The drainage area leading to a grass channel should be limited to prevent erosion within the channel. Make sure the grass channel is at least 10' away from a building foundation (50' when on the uphill side). The bottom of the channel should be at least two feet above the water table, and channels installed with compost amendments to the soil will improve infiltration. The outlet at the bottom of the grass channel should be designed to return water to sheet flow or else direct water to another existing stormwater route.

The ideal grass channel is between 4' and 8' wide at the bottom, with shallow side slopes no steeper than 6' (vertical) to every 1' (horizontal). The slope of a grass channel, in the direction of water flow, is best between 1% and 2%, though they can be up to 4%. Slope should be uniform for the length of the channel. Plant the channel with a grass species that will grow into a dense cover, with deep roots and high tolerance for water and inundation.

Channels with a higher slope may need one or more "check dams," or small barriers which interrupt and slow the flow of water. These may be treated wood timbers, concrete, stone, or other suitable material.



Grass channel

Level 1 BMP

BMP cost:



Installation:



Maintenance:



Water quality:



Water quantity:



Be creative!

In the fall or early spring, plant your favorite perennials and ornamental grasses in your grass channel. It will need less maintenance and provide a safe habitat for birds and bees.

Want to test your soil's permeability?

Most soils in Roanoke are high in clay, and amending the bottom of the channel with compost will improve infiltration of stormwater. To test the infiltration rate of your soil, use the soil infiltration test found in the *Infiltration Technique* page.

Tips for maintenance

Maintenance is fairly simple. Grass in the swale should be mowed regularly (keeping a height of 3-6 inches) and reseeded where necessary. Sediment that has accumulated behind check dams should be cleared, and any damage to check dams repaired. Repair and stabilize any areas showing erosion, both within the grass channel and within the contributing drainage area. See the Lawn Maintenance BMP for information and resources on responsible care for lawns in grass channels.

Some residential subdivisions were developed with swales along property lines. These channels should remain open and free from obstructions such as outbuildings, fences and fill dirt to prevent flooding of homes during storm events.



*A grass channel along a residential street.
Photo by the Natural Resources Conservation Service*



Check dams in a grass channel slow runoff. They can be made of rocks, as above, or timbers, concrete, or other suitable material.

The following resources have more information on the design and installation of grass channels:

Virginia Tech guidance on grass channel construction: vwrrc.vt.edu/swc/

Environmental Protection Agency technical guidance on grassed swales: cfpub.epa.gov/npdes



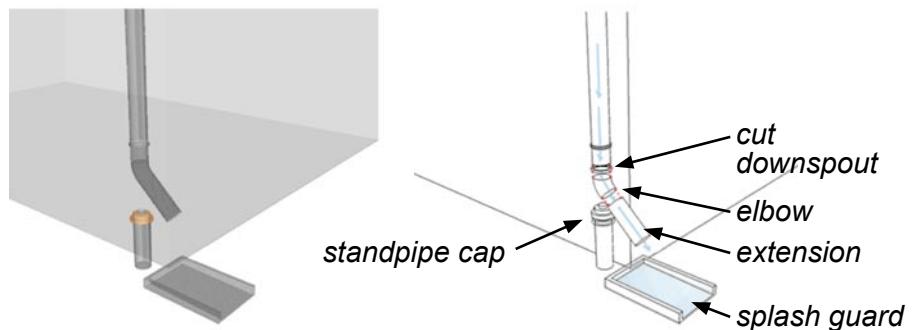
What is it?

In some areas of Roanoke, the downspouts of roof gutters are tied into the City's storm sewer system through a pipe to the street gutter or a stormwater inlet. Some downspouts are even routed directly into a stream or creek. This means that rain falling onto the roof is sent directly into the City's waterways, with no opportunity to soak into the ground or filter out impurities. The stormwater travels rapidly to the waterways, increasing the chance of flooding downstream. Roof drain disconnection lets the stormwater flow onto your property, where it can soak into the soil, water the lawn, and run off more slowly through the yard, restoring a more natural water cycle.

How do I do this?

Downspout disconnection is a simple, inexpensive BMP and is a good idea for any property with downspouts leading into the storm sewer or the public right-of-way. A disconnected downspout can simply direct runoff onto a lawn or garden, but make sure the water flows away from the foundation and not onto a neighbor's property. This BMP can be combined with others for even greater water quality treatment and runoff reduction. For example, a disconnected downspout can be directed to rain barrels or cisterns for storage, to a grass channel and on to a rain garden, or to an infiltration well.

- Cut the downspout above the pipe leading underground and cap the pipe. To direct runoff to your yard, attach an elbow piece to the downspout and an extension piece to the elbow. Make sure the extension leads water at least five feet from the foundation wall (fifteen feet is preferred) and that the ground slopes away from the house. Also make sure that water is not directed onto adjacent properties. Stabilize the area where the water exits the new spout with a splash block, a stone or brick bed, or some other method to prevent erosion.
- To combine roof drain disconnection with another BMP, cut the downspout, then follow the instructions for the design and installation of your secondary BMP.



Roof drain disconnection

Level 1 BMP

BMP cost:



Installation:



Maintenance:



Water quality:



Water quantity:



Don't send the downspout into the curb and gutter!

Remember that the curb and gutter along your street is part of the City's storm drain system, and anything that empties into the street gutter goes straight into our waterways! When you redirect the roof drains away from the curb, you are helping the City's overall stormwater system.

Tips for maintenance

There is little maintenance associated with disconnected roof drains beyond normal gutter and downspout care. Check periodically to make sure there is no erosion where water leaves the downspout, and look for leaks in the downspout. Keeping gutters clear of leaves and debris will help keep the downspout free of clogs.



Many homes in Roanoke's older neighborhoods still have downspouts that empty into the street. Look for downspouts that lead into a standpipe in the ground (above left) and empty onto the sidewalk or through open drains at the curb (above right).

The following provides more information on downspout disconnection:

The Alliance for the Chesapeake Bay has helpful information, with an instructional video, on disconnecting roof drains: stormwater.allianceforthebay.org



Why trees?

Trees have many benefits for stormwater quality and quantity:

- Tree canopies and leaf litter cushion the impact of rainfall on the ground, reducing soil erosion and allowing more water to penetrate into the soil.
- Roots help hold soil in place and are the first to absorb water from runoff, natural drainage, and rain.
- Trees help filter out some impurities before water infiltrates into the subsoil.
- Trees increase property values and add aesthetic quality.
- They are easy to install, with less design and planning than other BMPs.

Use native and adapted trees, as they are well-adapted to the Roanoke climate and better withstand extreme weather conditions.

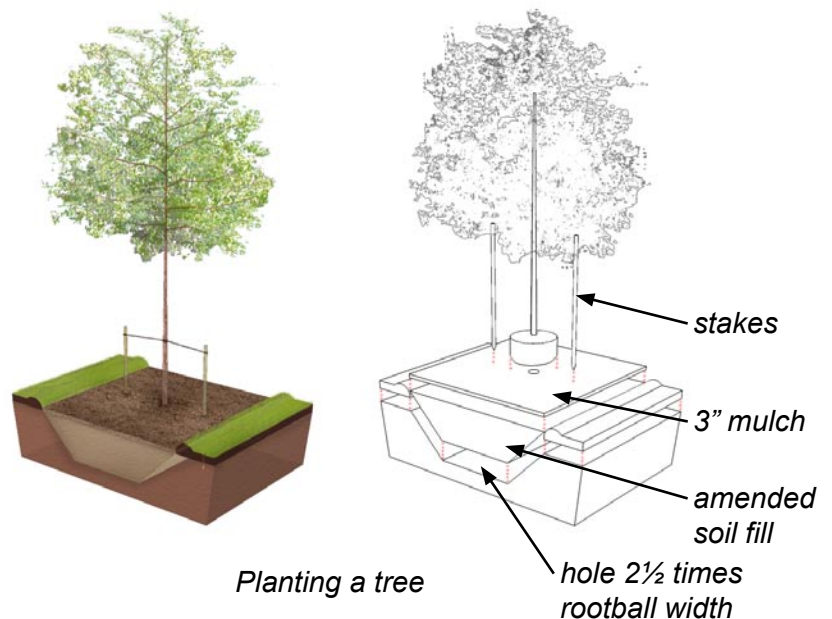
Selecting the right tree, planting it correctly, and preserving existing trees are effective, easy, and low cost ways to help stormwater quality and quantity.

How do I plant new trees?

Select new trees that are appropriate for the area you want to plant (see the resources section on the next page). Consider how large the tree will be at maturity to avoid future conflicts with overhead utilities, buildings, and other structures.

To reduce stress, trees should be planted between March 1 and May 15 or between October 15 and December 15.

- Locate and mark all utilities on your property. Call Miss Utility at 811 (this is a free service). Plant trees no closer than 10' from an underground utility.
- Dig a hole $2\frac{1}{2}$ times the width of the root ball and as deep as the rootball for planting.
- Carefully loosen the roots by hand, particularly if the roots have grown into a tight, circular root ball within the pot. Remove any burlap or wire from the top and sides of the rootball.
- Place the tree within the hole, with the trunk flare at the level of the surrounding soil. Place soil around the root ball in layers, tamping gently. Water thoroughly.
- Staking a newly-planted tree is optional. Stake large or unstable trees using wood stakes and flexible tree ties wrapped loosely around the trunk.
- Apply a 3" layer of mulch around the tree; avoid placing mulch against the trunk.
- Prune out dead or broken branches, but do not prune healthy, live limbs at the time of planting, or within the first three years following planting.



Level 1 BMP

BMP cost:



Installation:



Maintenance:



Water quality:



Water quantity:



Did you know you can move trees?

With careful planning (and a lot of sweat) a tree with a 1½" trunk may be relocated by an ambitious do-it-yourselfer. Large, prize trees also can be transplanted by professionals using specialized equipment and techniques. The process is expensive, but is a great way to preserve an important specimen and create an instant "mature" look to the landscape.

Did you know?

Root barriers help keep tree roots away from walks and utilities. Many kinds, from plastic rolls to panels, are available online and at local home garden retailers.

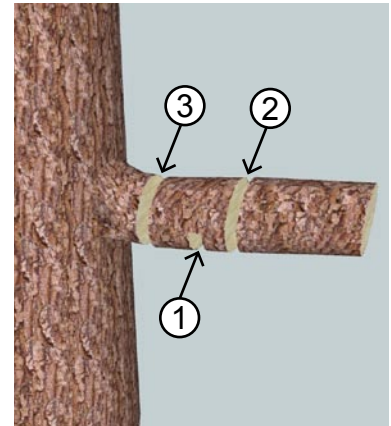


Topped trees, as in the photo above, limit the stormwater benefit of trees.

How do I preserve and maintain existing trees?

Preserving existing trees is often better than planting new trees. Well-established, mature trees often need little maintenance, particularly native varieties, which are better adapted to resist pests and weather extremes of the area. Limited pruning may be needed, and roots should be protected for the tree to remain healthy.

- *Remove dead, diseased, or injured limbs*, as well as limbs interfering with structures or utility lines, through careful pruning. Spring is the best time to prune live limbs. Use a certified arborist for any off-the-ground pruning. Do not work within 10 feet of an energized line.
- *Prune large limbs* with a three-cut method to prevent the limb from splitting and tearing the bark. First, cut halfway through the underside of the limb, 1 to 2 feet from the trunk. Second, cut from the top of the limb, 2 to 3 inches further out, until the limb falls. Finally, cut cleanly through the limb closer to the trunk, just beyond the raised bark ridge of the branch.
- *Don't top your tree!* Topping a mature tree, or cutting the vertical stem and main limbs at the same height, disfigures the tree, stimulates messy "sprouts" at the cut line, promotes decay, and reduces the real estate value of the tree. Drop-crotching is an alternative to topping that selectively cuts limbs to reduce the size of the tree while maintaining its natural form (see link below).
- *Protect the tree roots!* Roots allow the tree to take in water and nutrients, as well as resist toppling in high winds. Roots for deciduous trees can extend well beyond the limbs of the tree, and most roots are found in the top 2 feet of soil. Avoid soil compaction by not parking vehicles or placing outbuildings beneath trees. Avoid cutting through the root zone, especially when constructing a building, a walkway, or patio, to minimize damage to the roots.



Three-cut pruning method

The following provide a range of resources on selecting, planting, and caring for trees:

Virginia Cooperative Extension has a wealth of information available online on landscape plants and trees. Brief publications can be found [here](#). The Extension office serving the Roanoke area also offers a help desk for guidance on plant selection, diagnosis, and other technical advice.

Virginia DCR has an extensive native plants list, with plant characteristics to aid in selection. Choose plants from the mountain native plants list: www.dcr.virginia.gov/natural_heritage/nativeplants.shtml

The International Society of Arboriculture offers helpful resources at treesaregood.org



The yard surrounding your house is an extension of your home, and homeowners take pride in maintaining attractive, leafy gardens and lawns. Too often, this “natural” green look is achieved with loads of chemicals, which can wash into Roanoke’s waterways after a rain. There are simple, inexpensive practices that will prevent chemicals entering the water supply, improve the health and infiltration capacity of the soil, and avoid other contaminants of stormwater runoff.

Learn how you can make a big difference in stormwater quality while making your yard a nicer place for your family to spend time.



Lawn care:

Green lawns are often the centerpiece of a yard, but some common practices take a toll on the quality of our water. What can you do to help?

- Select a turfgrass variety well adapted to the Roanoke climate, your site, and your lifestyle. Virginia Cooperative Extension has excellent guides on *choosing the right grass* for your lawn (see resources on the next page).
- Use less fertilizer. Fertilizers are a huge pollutant in waterways, and many homeowners use more than necessary. Conduct a soil test to know specifically what fertilizers are needed, and try natural alternatives to boost your lawn’s health. Only apply fertilizers during the growing season, and avoid fertilizers and pesticides within 20 feet of a stream. Consider slow release fertilizers.
- Leave lawn clippings on the lawn after mowing – these return nutrients to the lawn.
- Mow at 3” or taller. The taller height slows runoff and produces healthier, deeper grass roots.
- Keep grass clippings and granular fertilizers/pesticides off hard surfaces where they more easily flow into the storm drains and out to waterways.
- Reseed bare areas to prevent erosion. If grass does not grow well in particular area, convert it to a planting bed, with shrubs, flowers, and mulch.
- Don’t irrigate too much. A newly seeded lawn should get light, frequent waterings. An established lawn requires longer and deeper watering, typically around 1” per week in summer, but less if water puddles on the surface.
- Consider aerating lawns where soil is compacted. A mechanical or manual corer removes plugs up to 3”, helping water, nutrients and air reach roots.

Soil Amendments:

Many Roanoke yards have compacted soils that are high in clay, which limits stormwater infiltration and increases runoff. Tilling these soils and amending them with compost will improve the health of the soil and increase stormwater infiltration. Typically, a subsoiler or mechanical tiller is used to incorporate 6” to 10” of compost into the soil, at a depth of up to 2’.

Compost can be purchased in bulk from local compost suppliers. Ask for compost with the following characteristics:

- pH between 6 and 8
- has been passed through a half inch screen

Level 1 BMP

BMP cost:



Installation:



Maintenance:



Water quality:



Water quantity:



Did you know?

Don't use pet waste in the compost bin, as it may not get hot enough to kill disease-causing bacteria.

- free of plastics, metals and other manufactured debris
- organic matter content between 35% and 65%
- stable (does not emit odor or heat in a moist, warm setting)
- mature (most decomposition has already taken place)
- low salinity

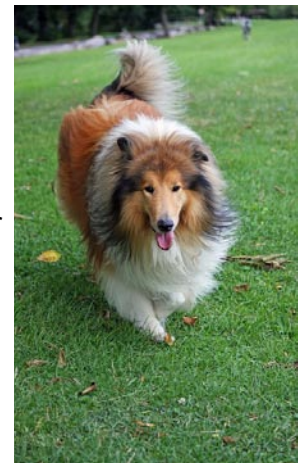
Homeowners can also generate their own high quality compost by maintaining a composting bin, where plant-based food scraps, leaves, and grass clippings are allowed to decompose. The resources below have detailed information on how to get started.

Pet Waste:

Pet waste as a pollutant? Definitely. Pet waste can transmit harmful bacteria, including E.coli, salmonella, hookworms and more. When stormwater runoff carries pet waste into storm drains and waterways, it contaminates the water supply. Clearing your yard of these "land mines" eliminates this fecal contaminant and makes your yard more pleasant to use.

What can you do?

- pick up pet waste and seal it in a plastic bag for disposal with the trash
- bury it in the yard, away from the vegetable garden
- flush it down the toilet



The following provide additional information on safe lawn care, composting, and dealing with pet waste:

Alliance for the Chesapeake Bay guidance regarding lawn care: stormwater.allianceforthebay.org

Virginia Cooperative Extension's homeowner guides for lawns and lawn care: www.pubs.ext.vt.edu/category/lawns.html

Home composting tips from the Western Virginia Water Authority: westernvawater.org

Alliance for the Chesapeake Bay guidance regarding pet waste: stormwater.allianceforthebay.org

DCR Tips on Keeping Your Lawn Green and Virginia's Waters Clean: www.dcr.virginia.gov/water_quality



OTHER LEVEL 1 BMPs: WASTE AND SEPTIC

What about it?

Managing waste disposal is important, and proper maintenance of onsite septic systems and trash/recycling containers will help keep your yard, and the City's waterways, clean.

Waste and Refuse Management:

Trash and litter in waterways is a visible, ugly form of pollution, posing choking hazards to wildlife and disease risks to humans. While some of this trash comes from littering and other improper disposal, it often comes from open, unprotected trash cans and recycling bins. Exposed to wind, containers can blow over or trash can blow out, scattering across the landscape. Exposed to the rain, water passes through the refuse, picking up contaminants that migrate with stormwater to the waterways.

- Keep waste and recycling bins covered and out of the rain. Consider keeping your bins in a storage building, garage, under a deck, or in a specially built container with a roof.
- Keep waste and recycling bins secured from the wind and animals. Secure with a rope or chain if necessary.
- Keep trash in the container. Avoid placing bags in the street, where animals can break open bags and rain can wash contaminants and loose trash into the storm drains.



Commercially-available garbage sheds secure waste containers from rain and animals

Septic Maintenance:

Most Roanoke homes are connected to the sanitary sewer system, but some properties still use private septic tanks or alternative sanitary sewage systems to treat waste on-site. Properly maintained systems work effectively to treat sewage and keep bacteria out of the environment. Failed systems, however, can flood yards with untreated waste, threatening the health of your family and neighbors, and allowing stormwater to carry untreated waste into waterways. Odors, surface wetness, sewage backup in drains/toilets, slow drains, and patches of green grass in dry weather are typical signs of a failed system.

The following tips will help keep your system operating well.

- Avoid large surges of water in the system by staggering your water use. Run the dishwasher and clothes washer at different times and avoid doing multiple loads of laundry in one afternoon.
- Limit the use of bleach. Bleach harms your system's bacteria and interrupts the biological digestion of waste in the system.
- Have a licensed onsite sewage system professional inspect the system every three to five years to ensure it is functioning properly.

Level 1 BMP

BMP cost:



Implementation:



Maintenance:



Water quality:



Water quantity:



- Have the tank pumped when the combined depth of sludge and scum equals one-third of the tank liquid volume. At a minimum, the tank should be pumped every five years.
- Grow grass above the system; keep shrubs and trees clear above the drainfield. Do not drive or park vehicles on the drainfield.
- Use water conserving fixtures in the home to reduce the amount of water going into the system. Fix leaky showers, sinks and toilets.
- Minimize the use of chemicals, including cleaners, pesticides, and solvents, to prevent them going into the septic system.
- Do not flush objects other than toilet paper, as these will clog the system.

The following provide additional information on waste/septic maintenance and stormwater:

Virginia Department of Health Onsite Sewage information: www.vdh.virginia.gov/EnvironmentalHealth

EPA guidance – SepticSmart Home: water.epa.gov/infrastructure/septic/septicmart.cfm



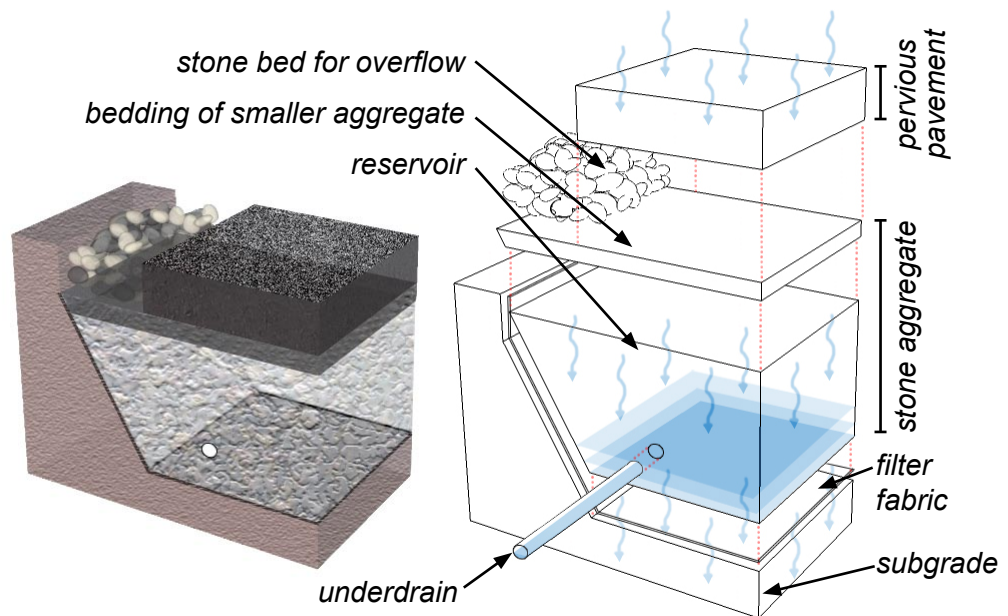
What is pervious pavement?

Unlike traditional pavement, pervious pavement (also called permeable or porous pavement) allows stormwater to soak through it. Pervious pavement lacks fine particles in the aggregate mix, leaving small voids in the pavement. Pervious pavement can be asphalt, concrete, or concrete pavers, and it includes a “reservoir” layer of aggregate stone beneath it where rainwater is stored as it slowly soaks into the surrounding soil or is released slowly to the storm drain system. This reservoir layer makes pervious pavement effective at reducing runoff. Pervious pavement is also designed with a filter layer that removes pollutants from stormwater before it seeps into the groundwater supply.

Pervious pavement is great for driveways, parking lots and patios, but avoid using in areas with slow-draining soils, high water tables, steep slopes, or near the uphill side of a house.

How do I design and install it?

Pervious pavements have three basic layers: the surface pavement itself, the underlying stone aggregate layer that serves as the reservoir, and a filter or fabric layer at the bottom. Roanoke soils are typically high in clay, with low infiltration; pervious pavements will likely need an underdrain in the reservoir to drain excess water. The aggregate layer can vary in thickness from 12” to 30” and must be level at the bottom to allow uniform infiltration. A 6” wide stone bed strip at the edge of the pavement may help with overflow drainage and keep fine debris from washing onto the pavement.



Pervious Pavement Layers

Pervious pavement should be used only where the slope is no more than 5%, and with a 10’ setback from a building (50’ if the pervious pavement is upslope from the building). Check with your utility provider if installing over an underground utility.

Designing and installing pervious pavement is not a do-it-yourself project. Homeowners should get technical advice from a civil engineer or landscape architect and work with a contractor with a track record of successfully installing the kind of pervious pavement you would like to use.

Level 2 BMP

BMP cost:



Installation:



Maintenance:



Water quality:



Water quantity:



Did you know?

Gravel driveways are not considered pervious. The ground below the drive is very compacted, keeping rainfall from infiltrating the ground and causing as much runoff as a standard impervious surface!

Test your soil's permeability

Most soils in Roanoke are high in clay, so pervious pavements probably will require an underdrain. To test the infiltration rate of your soil, use the soil infiltration test found in the *Infiltration Technique* page.

Tips for maintenance

- Be sure that runoff flowing onto pervious pavements is not laden with dust and sediment. These will clog the pavement, making it ineffective for infiltration.
- Vacuuming is needed every two to five years to remove sediment and prevent clogging of the voids in asphalt and concrete pavement. Pervious pavers, however, cannot be vacuumed; follow manufacturer's recommendations for pervious paver maintenance.
- Pervious pavement should not be pressure washed, which forces sediment into the pavement and clogs it. Similarly, porous pavement should never be sealed; sealant makes the pavement impermeable.
- Never use sand for winter de-icing on pervious pavements, as sand will clog the pavement. Research suggests pervious pavement requires less salting than impervious surfaces because melted ice infiltrates quickly through the pavement's voids.



Upper left: Pervious pavers installed at Elmwood Park.

Upper right: Lattice-style pervious pavers with grass infill. These are manufactured in a variety of styles and can be filled with gravel or sand.

Left: A cross section of pervious concrete.

The following resources have more information on pervious pavement design and installation:

Virginia Department of Environmental Quality technical guide on pervious pavement: vwrrc.vt.edu/swc

US Environmental Protection Agency Fact Sheets on various BMPs, including permeable interlocking concrete pavement, pervious concrete pavement, and porous asphalt pavement: cfpub.epa.gov/npdes/



What is a rain garden? Why would I want one?

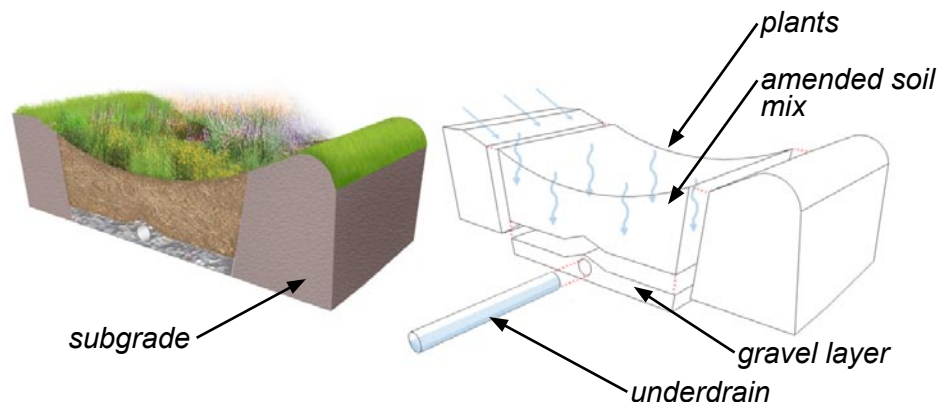
A rain garden is a planted and landscaped area that is specifically designed to receive and hold stormwater runoff, allowing it to infiltrate into the soil. Rain gardens on developed property help re-create the natural water cycle, where more stormwater filters through uncompacted soil. Typically designed as a shallow, planted bowl or basin where stormwater can pool and soak into the ground, a rain garden has many benefits.

- it reduces the amount of runoff leaving your property
- it filters pollutants from stormwater
- it helps recharge aquifers
- it is an attractive feature in the landscape
- it is simple to implement

How do I design and install it?

Putting in a rain garden is a fun do-it-yourself project for people who enjoy yard and garden work. A rain garden consists of three parts: an inflow area, the ponding area, and an overflow mechanism.

- First, select an area that can receive runoff, but will also allow overflow stormwater to leave the area without impacting adjacent properties. A rain garden should be at least 10' from a structure or utility, out of any easements, and in an area with soil that drains well. Call 811 to have utilities marked by Miss Utility before digging (this service is free).
- Determine how big your rain garden should be. A rain garden can be any size, but 100 to 300 square feet is usually manageable for a residential yard. A smaller rain garden may overflow more frequently, particularly in heavy rainfalls. Overflow is normal for all rain gardens, but gardens should be located and designed to accommodate overflow without channeling water toward structures or adjacent properties. Be sure that runoff leading into the rain garden does not flow over bare soil. Sediment and particles will be carried into the rain garden, ultimately clogging it.
- Excavate the rain garden by removing soil to form a basin; the soil is then used to form a berm or dam on the downhill side. The full excavated depth will likely be between 18" and 36". The depth of the ponding area, from the top of the soil to the top of the dam or berm, should be between 6" and 12". Design an overflow for excess water by installing a gap in the dam, a swale, or even allowing water to pass over the dam itself, as long as it is reinforced and not subject to erosion.
- Install an underdrain by placing a perforated pipe in the excavated basin, draining downslope to a stabilized aboveground outlet. Backfill with 6" of washed gravel or pea gravel.
- Fill the garden with an amended soil mix of 50% sand, 25% topsoil, and 25% compost. Soil mix components are available at local landscape suppliers.



Parts of a Rain Garden

Level 2 BMP

BMP cost:



Installation:



Maintenance:



Water quality:



Water quantity:



What plants do I use?

Choosing plants for the rain garden is the fun part of the process, but make sure your plants work for the location! The resources at the bottom of this page have lists of plants appropriate for rain gardens in different conditions. Be sure to consider:

- the size of plants at maturity
- plants for year-round interest (flowers, showy berries, fall colors, etc.)
- attracting birds and butterflies

Test your soil's permeability

Most soils in Roanoke are high in clay, which means you must amend the bottom of the rain garden with compost to improve infiltration of stormwater. To test the infiltration rate of your soil, use the soil infiltration test found in the *Infiltration Technique* page.

- Install the plants: Carefully select plants that will work for the location in terms of sun/shade and adaptability to wet/dry conditions. Native, non-invasive plants are recommended since these are better adapted to the Roanoke area and establish deeper root systems. See the resources section below for recommended plant lists. Place 3" of mulch throughout the rain garden, without touching plant stems.



The rain garden pictured above is an attractive landscape feature for this rear yard.

Tips for maintenance

Plants should be watered regularly until they are well-established. Like any garden, the rain garden should be periodically weeded and mulched. After rains, look for signs of erosion leading into or out of the rain garden; repair any eroded areas with more soil and plants or stones to keep soil in place. Geotextile fabric may be needed to help stabilize tough cases of erosion.

If water stands for three days or longer in the rain garden, the system may be clogged. Look for signs of sediment on the mulch surface and remove it. Till or aerate the top of the soil to improve permeability. If these solutions don't help, the soil may need to be amended with a mixture of sand and compost. For rain gardens initially installed with these amendments, auger several holes down to the bottom of the rain garden – if water begins to drain, simply fill these holes with sand.

The following have more information on design, installation and maintenance of rain gardens:

Fairfax County, Virginia, guide: www.fairfaxcounty.gov/nvswcd/raingardenbk.pdf

Virginia Department of Forestry Rain Gardens Technical Guide: www.dof.virginia.gov

Rain garden plants, Virginia Cooperative Extension: pubs.ext.vt.edu

Backyard Rain Gardens, North Carolina Cooperative Extension: www.bae.ncsu.edu/topic/raingarden/

The Low Impact Development Center offers technical information on rain garden design, including rain garden templates for sunny or shady areas. Be sure to select templates for Virginia's Mountain region: www.lowimpactdevelopment.org/

Alliance for the Chesapeake Bay technical guide on rain gardens: stormwater.allianceforthebay.org



What is an infiltration technique?

An infiltration technique is a dry well, pit or trench located underground and designed to accept stormwater from a driveway, parking area, or gutter downspout. The well is filled with gravel, creating an area that fills with stormwater, which gradually seeps into the surrounding soil.

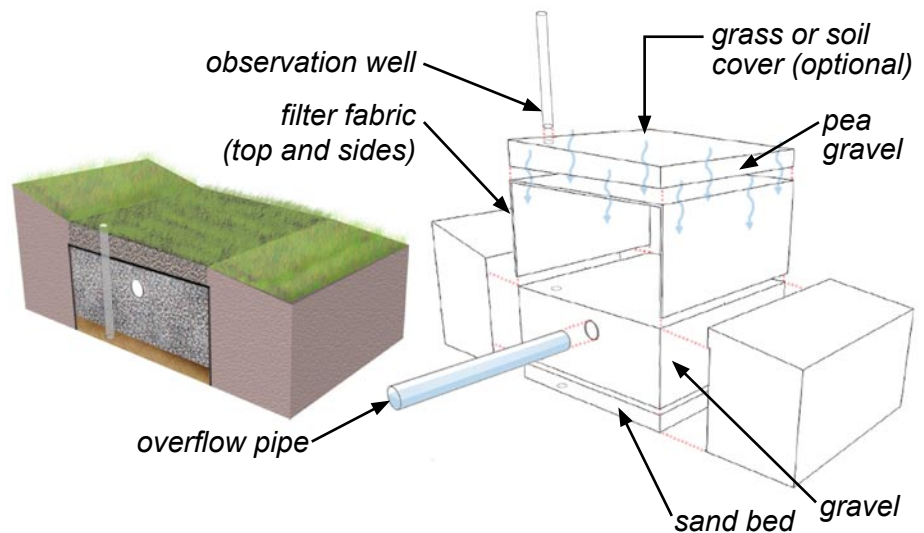
- This BMP has the greatest potential to reduce the amount of stormwater runoff, but also improves water quality.
- Infiltration wells filter impurities in stormwater before it seeps into the groundwater.
- Because it is underground, this technique is a good option where space is limited.
- A linear infiltration trench alongside a paved driveway collects and filters runoff from the drive. (Make sure the drive pitches toward the trench.) Avoid areas where leaf litter and other debris could clog the system, reducing infiltration.

How do I design and install an infiltration well?

The first step is to ensure proper soil conditions for installing an infiltration area. Much of Roanoke's soil is high in clay, limiting the ability for soils to absorb stormwater. The infiltration well should have a perforated overflow pipe to direct excess water away.

An infiltration area can be combined with other stormwater practices to remove more contaminants from stormwater. For example, stormwater might filter through a grass channel before entering an infiltration pit.

The infiltration area will include filter fabric to keep out clogging debris, large aggregate gravel where water is held to seep into the soil, and an "observation well," or a pipe to see how much water is in the trench and how quickly it is draining.



Parts of an Infiltration Area

The description below is for a small-scale infiltration area, such as a well or pit, appropriate for a small residential scale; work with a qualified professional if your infiltration area is to be deeper than 24".

- Carefully dig the trench or pit to a maximum of 5' deep, with the floor of the pit completely level. Avoid putting heavy equipment on the floor area to prevent compaction of the ground, which reduces infiltration of water into the soil.
- Line the sides (but not the bottom) with filter fabric, leaving enough fabric to cover the top as well. Spread a 6" layer of sand at the bottom of the trench. If you want extra water storage capacity, place large perforated pipes horizontally at the bottom of the trench.
- Fill the trench with aggregate stone with a diameter between 1-1/2" and 3-1/2".

Level 2 BMP

BMP cost:



Installation:



Maintenance:



Water quality:



Water quantity:



A simple soil infiltration test:

1. Dig a 24" deep hole where you are considering an infiltration technique and fill it with water.
2. Allow the water to saturate the surrounding soil for at least 1 hour.
3. Fill the hole again with water and observe.
 - If the water drains within 48 hours, the site may work for an infiltration technique. Soil should still be amended with compost and sand, to help infiltration.
 - If the water does not drain within 48 hours, the site will not work for an infiltration technique without intensive work to replace the soil or install an underdrain.

A comprehensive soil infiltration analysis can also be conducted by soil scientists, local health department, engineers, and professional geologists.

- Cover the trench or pit with the remaining filter fabric. Spread a layer of pea gravel over the fabric. You may leave the pea gravel exposed or cover it with an optional layer of topsoil and sod.
- Plant sod or seed turf for 10 feet on either side of the infiltration area.

An infiltration area is best installed downhill from a building. Where it is located uphill, it should be no closer than 25' from the building, so the water seeping into the soil does not compromise the building's foundation.



*This backyard infiltration trench (under construction) will receive runoff from downspouts, as well as surface runoff.
(photo by Ian Maddox)*

How do I maintain it?

- Keep debris out of the infiltration area to avoid clogging it. Excess debris on top can be removed by hand or leaf blower. Where gutter downspouts lead to a dry well, use a debris filter on the gutter to prevent clogging.
- Verify through the observation well that water is infiltrating. If the well has become clogged, it may need to be reconstructed.

The following resources have more information on the design and installation of infiltration wells:

Virginia Department of Conservation and Recreation Design Specification for infiltration practices: vwrrc.vt.edu/SWC

U.S. Environmental Protection Agency fact sheet on infiltration trench BMP: cfpub.epa.gov/npdes

Virginia Cooperative Extension guidance on infiltration practices: www.pubs.ext.vt.edu



What is a cistern?

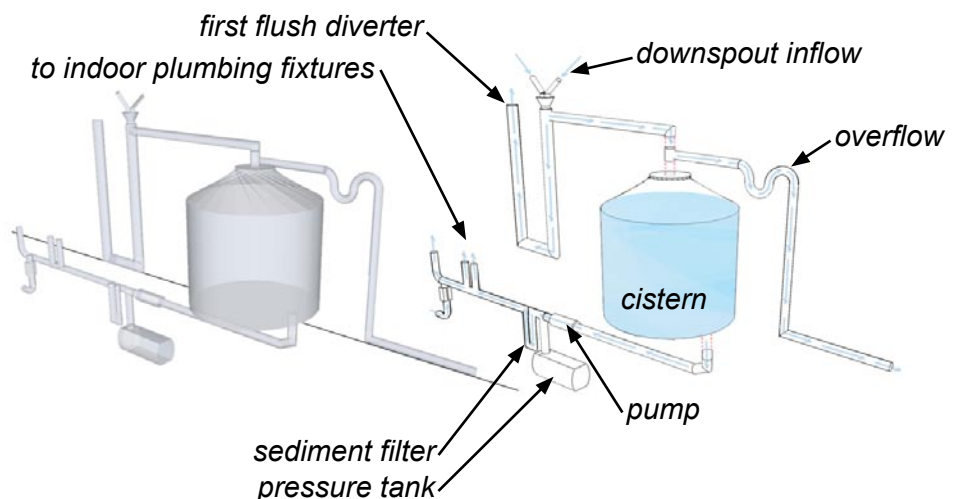
Cisterns collect and store rainwater for future use. Outdoor uses include landscape irrigation, washing, and supplying water features and pools. Non-potable indoor uses include toilet flushing, cleaning floors, and washing laundry. Filters are required to ensure adequate treatment of water for indoor uses.

Cisterns can significantly reduce stormwater runoff and filter contaminants. Cisterns are great for homeowners who need large volumes of water for re-use, particularly if they are interested in connecting the cistern to indoor toilets or sophisticated outdoor irrigation systems. Connecting the cistern to indoor plumbing fixtures will have a high up-front cost, as plumbing for this system must be separate from the municipal (or private well) system that serves as a backup water source if the cistern runs dry.

How do I design and install it?

Cisterns can be placed at grade, elevated above ground, or buried below ground, depending on the design and needs of the homeowner. The supplier of the tank, pump, and other components of the cistern system will provide detailed direction and specifications for installation, but the following is an overview of the basic steps for installing an aboveground cistern for non-potable indoor water use. Cistern design and installation is not a do-it-yourself project; use a qualified engineer to design your cistern and a licensed contractor for installation.

- Level the ground and place 4" to 6" of packed sand, aggregate, or poured concrete over packed earth.
- Place the cistern tank, ensuring that it is level.
- Install a screen over the inlet at the top of the cistern tank to keep debris and mosquitoes out of the tank.
- Install the first flush diverter to redirect the first few gallons of water away from the cistern and keep debris and contaminants out of the cistern. Connect the diverter to direct the first flush safely away from building foundations.
- Connect the downspout to direct roof runoff into the inlet at the top of the cistern tank.
- Install the overflow outlet pipe (3"-4" diameter is recommended, but no smaller than the downspout diameter). Consider designing the overflow with a trap (as in a sink drain) to keep mosquitoes and rodents out. Extend the overflow pipe to direct excess water at least 10' from a building foundation and away from adjacent properties. Consider directing overflow to another BMP, such as a grass swale or rain garden.
- Install the cistern's pump system to transfer water from the cistern to the indoor plumbing fixtures. This can be either a submersible pump or a booster/jet pump. Install the pressure tank and switch that will activate the pump. Install a float switch to keep the pump from



Level 2 BMP

BMP cost:



Installation:



Maintenance:



Water quality:



Water quantity:



Call Miss Utility (811)...

...to have underground utilities marked and to avoid damage to utilities during construction or by the weight of the full, heavy tank.

Contact the City's Department of Planning, Building and Development at 540-853-1090 early in your planning to know what permits and inspections are required.

Note:

Rainwater should be tested for pH if the system will use metal pipes. The pH of rainfall in Virginia is usually acidic, between 4.4 and 4.9. The EPA recommends a water pH level above 6.5 for systems with metal plumbing. Use a home test kit to sample the water from your rainwater system, and consider treating the water if the pH is below 6.5. Concrete cisterns often raise the pH of water due to limestone in the concrete.

operating when the cistern is low on water. A floating suction hose with a filter will ensure water is not drawn from the bottom where sediment and pollutants may be more concentrated.

- Install a 5 micron sediment filter to remove remaining small particles and contaminants that were not caught in the first flush diverter or did not settle in the tank.

The resources listed at the end of this sheet offer detailed information on calculating the size of a cistern tank, selecting an appropriate pump system and filters, and selecting components of a cistern.

Tips for Maintenance

Homeowners should inspect their cisterns and its components two to four times per year:

- Clean leaves and debris from gutters and downspouts and remove overhanging vegetation. Consider installing gutter filters or a self-cleaning downspout screen to make maintenance easier.
- Clean pre-screening devices and first flush diverters.
- Clean and inspect storage tank lids and the inflow/outflow vents and screens.
- Inspect the overflow outlet and the area where the overflow drains (for evidence of erosion)

A qualified inspector should be contracted every three years to inspect and clean tank buildup, check the backflow preventer, inspect the integrity of the tank, pump, pipe and electrical system, and replace any damaged parts.

The following provide a range of resources on designing and installing cisterns:

DCR guidance, including detailed guidance on calculations for proper sizing of the cistern:
vwrrc.vt.edu/swc/

Virginia Department of Health Rainwater Harvesting and Use Guidelines:
www.vdh.state.va.us/EnvironmentalHealth

Virginia Rainwater Harvesting Manual, by the Cabell Brand Center:
www.cabellbrandcenter.org/Downloads/RWH_Manual2009.pdf



What is a green roof?

A green roof is a specialized roof designed to accommodate plants and capture rainfall, thereby reducing runoff from the typically impervious surface. They are also known as “vegetated roofs” or “living roofs.”

A green roof has several advantages, including:

- reduction in heating and cooling costs/energy conservation
- visual appeal
- durability
- stormwater quality and quantity improvements
- noise reduction

Existing buildings can be retrofitted for a green roof through structural reinforcement to support the weight of plants and soil. Flat and sloped roofs can be adapted for green roof installation. With limited seasonal maintenance (weeding, trimming and watering, especially in the first year), a green roof will last years longer than a traditional shingle roof.

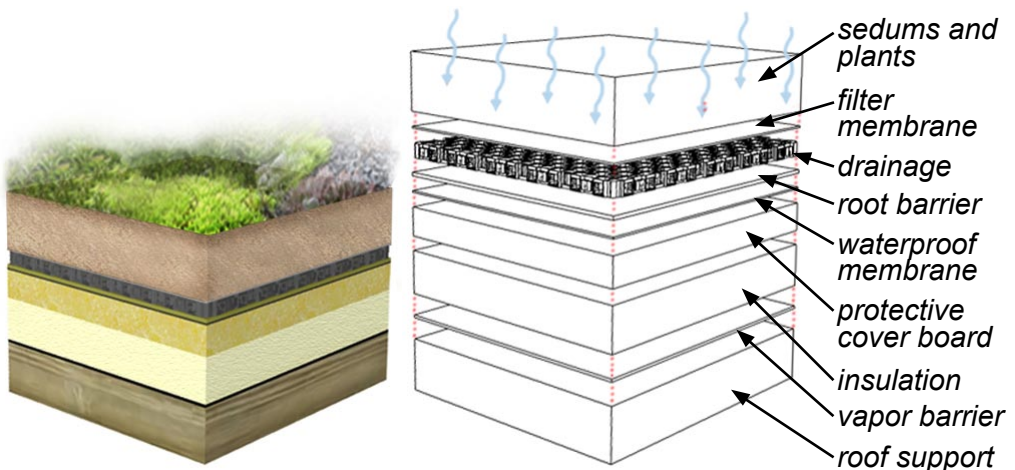
How do I design and install it?

There are two types of green roofs: the simpler extensive green roof and a more robust and complex intensive green roof. An extensive green roof is more appropriate for single-family applications. Extensive green roofs are designed to be lightweight, with a layer of growing medium 6” or less, and planted with drought-resistant plants (sedum varieties are a common choice). A green roof can be either a modular interlocking grid system or a custom integrated system where the parts of the green roof are installed directly on the roof surface.

Designing and installing an extensive green roof requires technical expertise; it is not a do-it-yourself project. Homeowners should have a licensed architect or engineer determine if their structure can support a green roof. Design and installation should be carried out by a landscape architect, engineer, or certified and experienced green roof contractor.

The typical layers of a green roof system include:

- *Plant layer* with perennials, particularly succulents, that are hardy, shallow rooted, low growing, easily maintained, fire resistant, and tolerant of extreme conditions.
- *Engineered growing soil* that is lightweight, with a mix of organic and inorganic materials for plant nourishment and water retention.
- *Filter fabric* that captures fine particles in draining water.
- *Drainage layer* to permit flow of excess water to the roof drain.
- *Root barrier* to protect the waterproofing layer from root penetration.
- *Waterproof membrane* to protect the structure from water infiltration.
- *Protection layer* that provides protection and support for the waterproofing layer.
- *Insulation* to reinforce the thermal insulation provided by the moisture content of the growing medium.
- *Vapor barrier* as a plastic or foil sheet to repel moisture infiltration.
- *Roof support* to reinforce the roof structure to hold the weight of the saturated growing medium and plants.



Level 2 BMP

BMP cost:



Installation:



Maintenance:



Water quality:



Water quantity:



Want to see a green roof?

The City of Roanoke installed a green roof on a portion of the City Hall. Planted with varieties of sedums, the roof is visible at the Church Avenue entrance.



Not ready to try a green roof on your house?

Consider a smaller-scale green roof project on your shed, gazebo, or garage.

Some considerations about a green roof:

- Can your home or building structurally support a green roof? How much reinforcing is needed?
- Do you have a qualified, experienced contractor?
- Can you handle the maintenance or contract with a specialist? Do you have adequate access to the roof to carry out maintenance?
- What limitations are there for structures in historic or preservation districts? At a minimum, a green roof should not be visible from the street or cover important historic features on structures in these areas.
- Are slope, orientation of the roof, and wind resistance properly factored into the design?
- Are design/installation costs and long-term savings properly factored?

Tips for Maintenance

Most green roofs require little maintenance after the first season of establishment. Irrigation is required until plants are established and during lengthy dry spells. Periodic weeding is needed, particularly during the first growing season. Some degree of replanting will be necessary over the course of the lifetime of the roof.

When contracting to have a green roof installed, find out if the contractor offers a warranty/maintenance period.

The following provide a range of resources on designing and installing green roofs:

Secretary of the Interior's Standards for Rehabilitation Technical Guide for installing a green roof on historic buildings: www.nps.gov/tps/standards/applying-rehabilitation

National Institute of Building Sciences Design Guide for Extensive Vegetative Roofs has detailed information on green roof materials and installations: www.wbdg.org/resources/greenroofs.php

Green Roofs for Healthy Cities is a green roof industry not-for-profit with educational information and a list of accredited professionals: www.greenroofs.org/

North Carolina State University's BAE Green Roof research site: www.bae.ncsu.edu/greenroofs

