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Best Management Practice Fact Sheet 9:

Bioretention

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This fact sheet is one of a 15-part series on urban stormwater management practices.

Please refer to definitions in the glossary at the end of this fact sheet.
Glossary terms are *italicized* on first mention in the text. For a comprehensive list, see "Urban Stormwater: Terms and Definitions," Virginia Cooperative Extension (VCE) publication 426-119.

What Is Bioretention?

A *bioretention cell*, or rain garden, is a *best management practice* (BMP) designed to treat *stormwater* runoff from roofs, driveways, walkways, or lawns. They are a shallow, landscaped depression that receives and treats polluted stormwater with the goal of discharging water of a quality and quantity similar to that of a forested *watershed* (figure 1).

Figure 1. A sample bioretention cell or rain garden.
Photo courtesy of WSSI Inc.

Where Can Bioretention Be Used?

Bioretention can be used in commercial areas, parking lots, and highways to treat roof and road runoff. Bioretention can also be used in residential landscapes or parks; however, steps should be taken to minimize *sediment*. Bioretention cells that receive sediment loading tend to clog and hold water rather than *infiltrate* it.

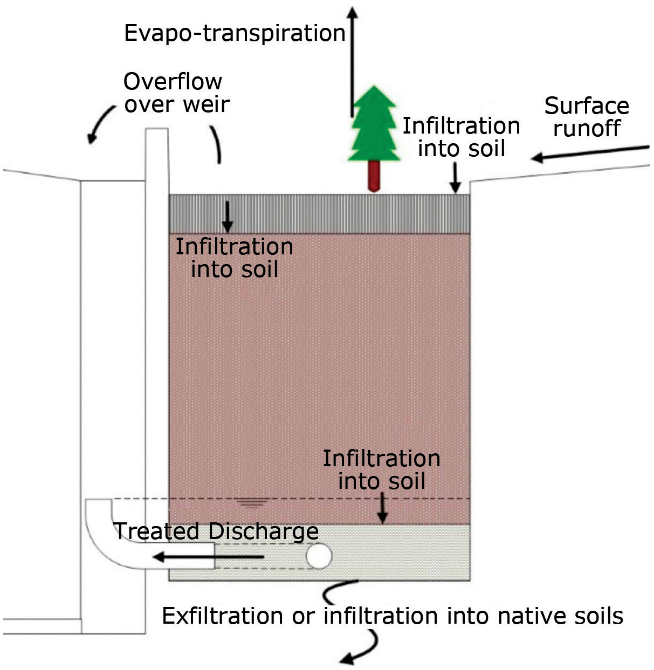

Figure 2. Note how the cell's vertical profile is exaggerated.

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What Does Bioretention Do?

The practice of bioretention was developed to reduce pollution within runoff from urban *impervious surfaces* during moderate storms. A typical bioretention cell consists of a depression with a vegetated layer, a *mulch* layer, several layers of sand, soil, an organic *media filter bed*, an overflow, and an optional *underdrain* (figure 2). A small pretreatment basin known as a *forebay* is created with river rock to trap sediment prior to entering the bioretention cell. Within a cell, runoff is treated by a variety of physical, chemical, and biological processes.

Bioretention provides both quantity and quality control benefits. It enhances *biodiversity* by providing natural *habitat* and can be a beautiful addition to the urban landscape.

How Does Bioretention Work?

Stormwater storage is provided when water ponds in the *cell*. The collected stormwater is filtered through different layers of mulch, media, and *compost* inside the cell. Media, plants, and microorganisms in the soil treat the pollutants carried by the runoff through physical processes like *filtration*, infiltration, or *adsorption* and biological processes like *biological uptake* or *microbial decomposition*.

An underdrain consists of perforated pipe in a gravel layer installed along the bottom of the media *filter bed*. An upturned *outlet* promotes periodic *anaerobic* conditions within a fluctuating water table and facilitates removal of nitrogen. In soils with high infiltration rates, the underdrain can be omitted, thus increasing runoff reduction. Bioretention cells without underdrains should be avoided in commercial and industrial areas to prevent *groundwater contamination*.

Limitations

- Adequate sunlight and irrigation may be required.
- Because of the potential of bioretention cells to clog from sediment, installation of bioretention should always wait until upstream areas are stabilized.
- Typically limited to 5 percent of a small drainage area (2 acres). For example, for an 18,000-square-foot lot, a 900-square-foot bioretention cell is likely needed.
- Minimum media depth of 1.5 feet is required; however, increasing to up to 3 feet improves performance.
- At least 2 to 4 feet of elevation drop from the top of the cell to groundwater and/or the outlet should be available.
- Plants must tolerate dry periods and potential submerged roots for as long as 24 hours. Specific plant lists are available from the Virginia Department of Conservation and Recreation (VA-DCR; 2011) and Virginia Cooperative Extension (VCE; Andmczyk, Swanson, Fox, et al. 2009).

Maintenance

- Maintenance is similar to garden work.
- Inspect the forebay and mulch/media surfaces in the treatment area to avoid clogging and repair if necessary.
- Replace dead plants and replenish mulch layer — recommended annually.

Performance

Bioretention can be very effective at reducing runoff and removing pollutants such as excess nutrients from incoming water flow. A typical bioretention cell has a media depth of 1.5 to 2 feet. An annual reduction of 25 percent for total phosphorus, 40 percent for total nitrogen, and 40 percent for runoff can be expected. Improving the media and its depth to 2 to 3 feet and providing a gravel underdrain and other enhancements can improve the estimated annual reductions to 50 percent for total phosphorus, 60 percent for total nitrogen, and 80 percent for runoff (VA-DCR 2011).

Expected Cost

The installation cost of a bioretention cell is approximately $10,000 for a 900-square-foot cell. The annual maintenance cost is approximately $600 — $350 for mulch and debris removal and $250 for vegetation replacement (Low Impact Development Center 2005).

Additional Information

The Virginia departments of Conservation and Recreation (VA-DCR) and Environmental Quality (VA-DEQ) are the two state agencies that address nonpoint source pollution. The VA-DCR oversees agricultural conservation; VA-DEQ regulates stormwater through the Virginia Stormwater Management Program.

Additional information on best management practices can be found at the Virginia Stormwater BMP Clearinghouse website at http://vwrrc.vt.edu/swc. The BMP Clearinghouse is jointly administered by the VA-DEQ and the Virginia Water Resources Research Center, which has an oversight committee called the Virginia Stormwater BMP Clearinghouse Committee. Committee members represent various stakeholder groups involved with stormwater management.

Online Resources

Chesapeake Stormwater Network – http://chesapeakestormwater.net/all-things-stormwater/bioretention-design-specification.html

King County (Washington) Road Services – http://kingcounty.gov/transportation/kcdot/Roads/Environment/LowImpactDevelopment_MilitaryRd/BioRetentionFacilityRainGarden.aspx

Low Impact Development Center – http://lid-stormwater.net/index.html and http://lowimpactdevelopment.org/ffxcty/1-1_bioretentionbasin_draft.pdf

North Carolina State University, Department of Biological and Agricultural Engineering, Stormwater Group – http://bae.ncsu.edu/topic/bioretention/design.html

Pennsylvania Department of Environmental Protection – http://dep.state.pa.us/dep/DEPUTATE/Watermgt/wsm/WSM_TAO/reuse/V-B-2-Zeigler/Rain_Garden.html

Prince George's County (Maryland) – http://princegeorgescountymd.gov/der/esg/bioretention/bioretention.asp

U.S. Environmental Protection Agency – http://epa.gov/owm/mtb/biortn.pdf and http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=72

Virginia Stormwater BMP Clearinghouse – http://vwrrc.vt.edu/swc/

Companion Virginia Cooperative Extension Publications

Andruczyk, M., L. Swanson, L. Fox, S. French, and T. Gilland. 2009. *Urban Water Quality Management: Rain Garden Plants*. VCE Publication 426-043.

Daniels, W., G. Evanylo, L. Fox, K. Haering, S. Hodges, R. Maguire, D. Sample, et al. 2011. *Urban Nutrient Management Handbook*. Edited by J. M. Goatley. VCE Publication 430-350.

Gilland, T., Fox, L., Andruczyk, M., French, S., and Swanson, L. 2009. *Urban Water Quality Management: What Is a Watershed?* VCE Publication 426-041.

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References

Andruczyk, M., L. Swanson, L. Fox, S. French, and T. Gilland. 2009. *Urban Water Quality Management: Rain Garden Plants*. VCE Publication 426-043. http://pubs.ext.vt.edu/426/426-043/426-043.html.

Low Impact Development Center. 2005. LID BMP Fact Sheet: Fairfax County (Virginia) Bioretention Basins. http://lid-stormwater.net/index.html; http://lowimpactdevelopment.org/ffxcty/1-1_bioretentionbasin_draft.pdf.

Virginia Department of Conservation and Recreation (VA-DCR). 2011. *Virginia DCR Stormwater Design Specification No. 9: Bioretention*, Version 1.9. http://vwrrc.vt.edu/swc/nonPBMPSpecsMarch11/DCR%20BMP%20Spec%20No%209_BIORETENTION_FinalDraft_v1-9_03012011.pdf

Virginia Department of Forestry. 2008. *Rain Gardens Technical Guide: A Landscape Tool to Improve Water Quality*. http://dof.virginia.gov/mgt/resources/pub-Rain-Garden-Tech-Guide_2008-05.pdf.

Glossary of Terms

Adsorption – A process by which dissolved compounds separate from the liquid phase and become physically or chemically bound to solid materials and are removed via treatment.

Anaerobic – Chemical reactions that proceed without the presence of oxygen.

Baseflow – The portion of flow in a stream that continues even during extended dry periods.

Best management practice – Any treatment practice for urban lands that reduces pollution from stormwater. A BMP can be either a physical structure or a management practice. A similar but different set of BMPs is used to mitigate agricultural runoff.

Biodiversity – The number of different species and a measure of the health of the observed system.

Biological uptake – The process by which plants absorb *nutrients* for nourishment and growth.

Bioretention, bioretention cells – A best management practice that is a shallow, landscaped depression that receives and treats stormwater with the goal of discharging water of a quality and quantity similar to that of a forested watershed. Bioretention cells typically consist of vegetation, soils, an optional underdrain, and an outlet.

Compost – Vegetative or organic matter that has been allowed to fully decompose, leaving a rich, organic medium that can be mixed with soils.

Erosion – the movement of soils and rock through weathering from water and wind

Filtration – A process by which solids are separated from fluids by use of media.

Forebay – A small basin within a best management practice that removes sediment by settling prior to other treatment processes, thus protecting those processes from excess sediment and potential clogging.

Groundwater contamination – The presence of unwanted chemical compounds in groundwater. In this case, we would normally be referring to dissolved nitrogen compounds, such as nitrates.

Habitat – The environment where organisms, like plants, normally live.

Impervious surface – A hard surface that does not allow infiltration of rainfall into it; not *pervious*.

Infiltration – The process by which water (surface water, rainfall, or runoff) enters the soil.

Media, media filter bed, filter bed – The topsoil that supports plant growth. Bioretention media typically has a high sand and low clay content and a low phosphorus content.

Microbial decomposition – The breakdown of compounds or organic matters into smaller one with the aid of microorganisms.

Mulch – An organic material applied on the surface above the media to protect vegetation and underlying media.

Nutrients – Substances that are required for growth of all biological organisms. When considering water quality, the nutrients of most concern in stormwater are nitrogen and phosphorus. Excessive amounts of these substances are pollution and can cause algal blooms and dead zones to occur in streams and estuaries.

Outlet – The point of exit of water from a downspout or other BMP.

Pervious – A ground surface that is porous and allows infiltration.

Sediment – Soil, rock, or biological material particles that are formed by weathering, decomposition, and erosion. In water environments, sediment is transported across a watershed via streams.

Stormwater – Water that originates from *impervious surfaces* during rain events, often associated with urban areas; also called "runoff."

Stormwater treatment practice – A type of best management practice that is structural and reduces pollution in the water that runs through it.

Underdrain – A perforated pipe in the bottom of a bioretention cell designed to collect water that does not infiltrate native soils.

Watershed – A unit of land that drains to a single "pour point." Boundaries are determined by water flowing from higher elevations to the pour point. A pour point is the point of exit from the watershed, or where the water would flow out of the watershed if it were turned on end.